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Arkansas Technical Reference Manual

Version 7.0

Approved in Docket
10-100-R

EVALUATION, MEASUREMENT & VERIFICATION PROTOCOLS

TRM Version 7.0 Volume 1: EM&V Protocols

Applicable for Program Year 2018

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on behalf of the

Parties Working Collaboratively

FINAL

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Section I: Introduction/Overview

In September 2007, the Arkansas Public Service Commission (Commission) ordered each of the investor-owned, regulated utilities within the state to offer its customers energy savings programs. Now that Demand Side Management (DSM) programs are operating throughout Arkansas, it is important to periodically evaluate success factors and the level of market penetration for the programs to determine how effectively programs have been designed and implemented, estimate energy and demand savings attributable to the programs, and provide feedback and recommendations as programs mature. Program evaluation is not an afterthought; it is a vital part of successful program implementation and development. This document provides guidance and insight regarding some of the important Evaluation, Measurement & Verification (EM&V) methods and recommends best approaches to use specifically with the Arkansas DSM Program Portfolio.

This document is divided into two sections:

- Section I – Provides an overview of EM&V terms, methods, and approaches
- Section II – Provides the EM&V Protocols

The protocols presented in this Volume 1 of the TRM are based on a review of the current industry literature on a broad range of topics including:

- Master Plan and Project Management;
- Program Tracking and Database Development and Management;
- Protocols for Post-Implementation Verification;
- Process Evaluation Guidance;
- “Level of Effort” or “Rigor” Protocols;
- Protocols for the addition of new measures and deemed savings values as well as the Verification and Ongoing Modification of Deemed Savings Values;
- Protocols for the Determination of Accurate Net Program Impacts (including net-to-gross estimates and non-energy benefits); and
- Provisions for Large Customers.

This review also draws heavily from the leading industry references used to guide EM&V activities for DSM Programs throughout the United States. This document also contains a complete bibliography of materials referenced to develop these EM&V Protocols for Arkansas, and are cited as appropriate. A Glossary of common EM&V terms is also included.

A. PURPOSE OF EM&V PROTOCOLS

The purpose of these EM&V Protocols is to provide a common framework and set of reference points for conducting cost-effective DSM Program evaluations. These protocols describe the ***types*** of information that must be collected to conduct a comprehensive examination of a program's overall effectiveness, the recommended ***frequency*** for conducting these program evaluations, and the key ***metrics*** that must be reported during these evaluation activities.

These protocols provide additional guidance regarding the role of EM&V for DSM programs, as well as key definitions, recommendations regarding data capture and EM&V reporting formats. The EM&V plans developed for each organization or utility will describe the specific EM&V activities that will be completed during the evaluation cycle.

This document is not designed to address all of the key topics in the EM&V field. Rather, it is designed to address the specific topic areas in the Order 10-100-R.

Topics covered include:

- Evaluation Definitions
- Evaluation Planning
- The Value of Baseline Assessments
- The Role of Process Evaluations
- The Role of Impact Evaluations
- Specific Evaluation Protocols for the following topics:
  - Program Tracking and Database Development and Management;
  - Protocols for Post-Implementation Verification;
  - Process Evaluation Guidance;
  - "Level of Effort" Protocols;
  - Protocols for Verification and Ongoing Modification of Deemed Savings Values;
  - Protocols for the Determination of Accurate Net Program Impacts (including net-to-gross estimates and non-energy benefits); and
  - Provisions for Large Customers

This document does not attempt to address the entire range of issues facing the current EM&V community. Therefore, these protocols will not address the following EM&V topics:

- Program Logic Models
- Market Transformation Studies
- Documenting Market Effects
- The Role of Economic Cost/Benefit Tests

The goal of these EM&V Protocols is to provide the underlying evaluation framework for EM&V activities. The Arkansas Commission and the EM&V Parties Working Collaboratively (PWC) can then build on this framework to address additional EM&V issues as the energy efficiency market evolves and matures throughout the State. This document includes protocols on process evaluation and behavior-based energy efficiency programs. Subsequent revisions of this document should include protocols on a variety of other important energy efficiency topics as they reflect advances in the market. This will include the results of further analysis by the PWC regarding the inclusion of non-utility resources and other non-energy benefits (NEBs) that can be attributed to energy efficiency programs in the calculation of program cost-effectiveness.

B. BASICS TO GOOD EVALUATION PRACTICES

EM&V is the embodiment of the old adage "*Begin with the end in mind.*" Ideally, program evaluation is built into the fabric of every program design so when the time comes for an evaluation, the baseline data and measure data will be readily available and the evaluation activity will be a seamless, integrated process. However, the ideal is rarely the reality in program evaluations. Oftentimes, evaluators who are called upon to review program operations must rely on less-than-perfect data. The goal of these EM&V Protocols is to move the Arkansas EM&V activities closer to the ideal evaluation process by providing a clear description of what is needed and required.

The first step is a proper understanding of what evaluation means and entails. If a DSM program worked successfully, less energy will have been consumed by end-users during a specific time period. Evaluation is not measuring an event that happened; rather, it attempts to measure *"what did not happen. It is an estimate"* (Schiller Consulting 2010).

It is critical to understand that even the best evaluation practices are based on highly refined estimates, and do not provide absolute findings. The energy savings from a program cannot be determined directly from available energy use data but must be measured against what ***would have happened if the program did not exist***. Therefore, the goal of a good EM&V protocol is to identify the best approaches for determining reasonable and defensible estimates – largely based on surveys with program participants, non-participants and other market actors – about events that would have happened in the absence of the programs. With any evaluation, there is a level of ***risk*** that the estimations are inaccurate, and there are different points for an acceptable margin of error (or levels of confidence). These protocols manage the risk of inaccuracy, and minimize the margin of error, by specifying the information and data points required to properly document savings and provide the best possible estimates of energy savings.

A second major issue regarding good EM&V practices relates to the level of effort required to obtain meaningful results, while managing evaluation costs. It is important to weigh the costs associated with obtaining additional, incremental information (or developing more precise estimates of program impacts, i.e., higher certainty), with the incremental costs associated with gathering and studying additional information.

Therefore, EM&V methodologies involve a series of tradeoffs guided by answering two questions:

Q1. "What is the comparison point?
Q2. "How good is good enough?"

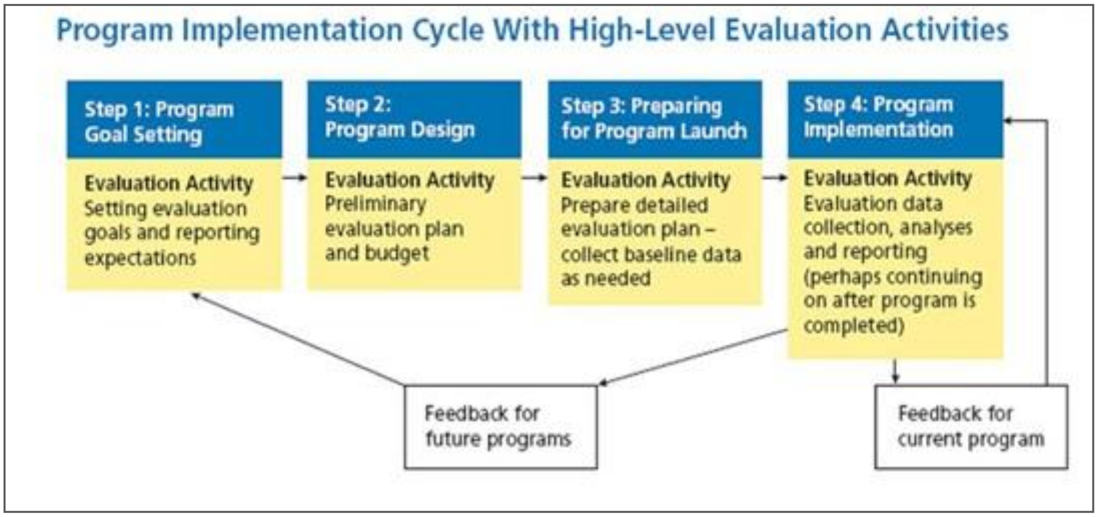
The answers to these questions are based on the size, scale, and scope of the overall program portfolio as it relates to the ultimate energy savings goals and objectives.

C. ROLE OF EVALUATION

The role of a Program Evaluation is to:

- **Quantify Results:** Document, measure and estimate the energy and demand savings of a program in order to determine how well it has achieved its goals and managed its budget.
- **Gain Understanding:** Determine why certain program effects occurred (or didn't occur) and identify ways to improve and refine current and future programs; also to help select future programs (NAPEE 2007).

The National Action Plan for Energy Efficiency (2007), which is heavily referenced in these protocols, provides an excellent visual representation of the role of program evaluation activities during the life cycle of a typical DSM program.



(Source: NAPEE 2007)

Figure 1: Program Implementation Cycle With High-Level Evaluation Activities

As Figure 1 shows, program evaluation is viewed as an ongoing process that provides information regarding changes in program direction and adjustments to program goals and objectives over time.

D. DEFINITIONS OF PROCESS AND IMPACT EVALUATIONS

The American Evaluation Association defines evaluation as "*assessing the strengths and weaknesses of programs, policies, personnel, products and organizations to improve their effectiveness.*"

- **Process Evaluation** describes and assesses overall program structure, materials and activities.
- **Impact Evaluation** examines the long-term effects from a specific program, including unintended effects.
- **Process and Impact Evaluations** *work together* to provide a complete picture; activities related to these separate evaluation efforts often overlap.

According to the U.S. Department of Energy, program evaluations are used to make future decisions regarding program operations. The key questions that program evaluations answer include (EERE 2006):

- Should the program continue?
- How should the program be changed? Should it be expanded, consolidated, or replicated?
- Do program funds need to be reallocated?
- How can program operations be streamlined, refined or redesigned to better meet program objectives?
- What elements of the program can or should be discontinued?
- Is it time for this program to be discontinued?

The first step in a program evaluation is to specify the evaluation objectives. The two most common types of objectives are: 1) studies that guide decisions about future program implementation and 2) estimates of quantified savings and insight regarding a program's overall performance. Table 1 compares these two types of evaluation activities.

Table 1: Comparison of Program Evaluation Objectives

Informational Needs	Evaluation Type
Efficiency of program implementation processes, e.g., to document the effectiveness of specific activities, what works and what does not work, where additional resources could be leveraged, participant satisfaction.	**Process**
Quantified outcomes that can be attributed to the program's activities, i.e., what are the results or outcomes that would not have occurred without the influence of the program. This is also called "net impacts."	**Impact**

(Source: Modified from EERE 2006)

Examples of common program evaluation objectives are:

- Assess the impact of the program on customer awareness and knowledge of energy efficiency actions.
- Measure customer response to "follow-up" program elements designed to encourage audit participants to implement recommendations.
- Examine program awareness, delivery channels, factors that influenced participation, program effects and customer satisfaction levels.

- Document energy efficiency actions taken by program participants compared to actions taken by non-participants.
- Estimate energy savings accruing from participation in the program over time; verify the reported energy savings as results of the program.
- Determine if there have been any changes in the building characteristics of program participants between program years.
- Evaluate the effectiveness of program modifications made in a specific fiscal year.
- Complete a customer segmentation analysis of the primary target population.
- Explore barriers to participation in program activities and develop recommendations for improving the promotion and targeting of existing services, as well as new program knowledge and services (Source: Expanded and modified from EERE 2006).

Process Evaluations are effective management tools that focus on improving both the design and delivery of energy efficiency programs. They are most commonly used to document program operations for new programs or those in a pilot or test mode. Since process evaluations examine program operations, they can identify ways to make program enhancements and improvements that reduce overall program costs, expedite program delivery, improve customer satisfaction, and fine-tune program objectives. These evaluations can also be used to assess the effectiveness of various incentive programs and rebated technologies. Process evaluations rely on a variety of qualitative and quantitative research methods, beginning with a review of program materials and records, conducting in-depth interviews with program staff and implementers, and surveys with key customer and trade ally groups. Process evaluations can also provide feedback on ways to streamline and enhance data collection strategies for program operations (NAPEE 2007).

Impact Evaluations measure the change in energy usage and demand (kWh, kW, and therms) attributable to a program. They are based on a variety of approaches to quantify (estimate) energy savings, including statistical comparisons, engineering estimation, and modeling, metering, and billing analysis. The impact evaluation approach selected is primarily a function of the available budget, the technologies or energy end-use measures (EUMs) targeted in the program, the level of certainty of original program estimates, and the overall level of estimated savings attributable to the program (NAPEE 2007).

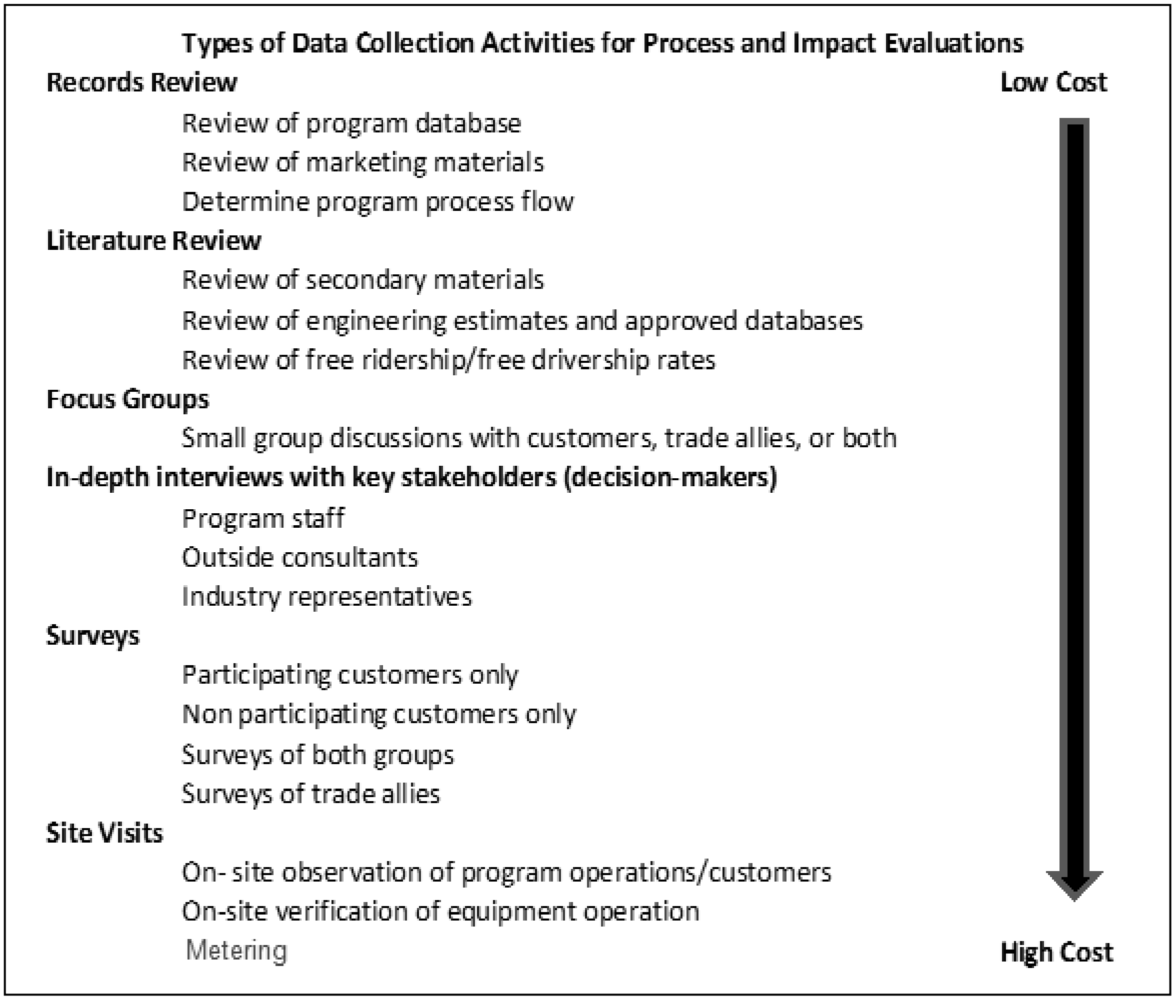
There are many decisions that affect the design of an impact evaluation. However, each impact evaluation should address the following seven major issues before the budget and evaluation plan are prepared:

1. Define evaluation goals and scale (relative magnitude or comprehensiveness);
2. Set a time frame for evaluation and reporting expectations;
3. Set a spatial boundary for evaluation;
4. Define a program baseline, baseline adjustments, and data collection requirements;
5. Establish a budget in the context of information quality goals (level of acceptable margin of error and risk management);
6. Select impact evaluation approaches to estimate gross and net savings calculations; and
7. Select who (or which type of organization) will conduct the evaluation (NAPEE 2007).

NAPEE 2007 summarizes what it considers to be the *"Best Practices in Evaluation"*. These EM&V best practices are summarized below to provide further guidance for evaluation activities conducted in Arkansas.

- Incorporate an overall evaluation plan and budget into the program plan at the beginning of program planning;
- Adopt a more in-depth evaluation plan each program year;
- Prioritize evaluation resources where the risks are highest. This includes focusing impact evaluation activities on the most uncertain outcomes and highest potential savings. New and pilot programs have the most uncertain outcomes, as do newer technologies;
- Allow evaluation criteria to vary across program types to allow for education, outreach, and innovation;
- Conduct ongoing verification as part of the program process;
- Establish a program tracking system that includes necessary information for evaluation;
- Match evaluation techniques to the situation with regard to the evaluation costs, the level of precision required, and feasibility;
- Maintain separate staff for evaluation and for program implementation. Rely on an outside review of evaluations (e.g., state utility commission), especially if the program is implemented by internal utility staff. It is important that the program evaluation is an activity conducted independently of program operations; and
- Evaluate regularly to refine programs as needed to meet changing market conditions.

Process and impact evaluations require data collection from a variety of sources. The timing, mix, and types of data collection activities must be specified in the EM&V plans for each program. Figure 2 presents the types of data collection activities for process and impact evaluations.



Types of Data Collection Activities for Process and Impact Evaluations

Records Review
- Review of program database
- Review of marketing materials
- Determine program process flow

Literature Review
- Review of secondary materials
- Review of engineering estimates and approved databases
- Review of free ridership/free drivership rates

Focus Groups
- Small group discussions with customers, trade allies, or both

In-depth interviews with key stakeholders (decision-makers)
- Program staff
- Outside consultants
- Industry representatives

Surveys
- Participating customers only
- Non participating customers only
- Surveys of both groups
- Surveys of trade allies

Site Visits
- On- site observation of program operations/customers
- On-site verification of equipment operation
- Metering

(Source: Reynolds, Johnson & Cullen 2008)

Figure 2: Types of Data Collection Activities for Process and Impact Evaluations

It is important to note that not every process or impact evaluation will require the complete set of data collection activities. Rather, the evaluation plan specifies the data collection strategies that will be used in each phase of the program evaluation as well as the anticipated budget expenditures for each data collection activity.

E. EVALUATION TIMING

All dates are approximate and subject to change based on commission rules and orders.

The decision regarding the appropriate evaluation time frame has two components:

1. **When and over what period of time the evaluation effort will take place.** A standard evaluation would begin before program implementation begins in order to collect important baseline data, and then continue for some time after the program is completed to analyze persistence of savings and other program elements. However, the actual timing of the evaluation is influenced by several factors, including:

- What will be the time period of analyses (i.e., how many years)?
- Will persistence of savings be determined, and if so, how?
- What is the timing for policy decisions and evaluation planning?
- What is the need for early feedback for program implementers?
- Where is the program in its life cycle?
- What are the evaluation data collection time lags?
- What are the other regulatory and/or management oversight requirements to be addressed in this evaluation?
- What information or data are needed to update specific energy and demand savings from the measure, and to quantify life estimates?
- What is the timing and format required for the reporting process? Is a single, final program report needed, or are more frequent reports required?

In general, program evaluations are conducted with a three-year plan. Process evaluations are usually conducted at the end of the first year of program operations and at the conclusion of the program period. Impact evaluations may be conducted annually or at the conclusion of Program Years 2 and 3, and generally free ridership and spillover no more frequently than once every three years provided there are sufficient data to determine energy savings estimates and adjustments and no significant changes in a program design. The timing for the EM&V activities must be specified in the EM&V plans.

2. **What is the level of detail or "granularity" required for the evaluation analyses?** This relates to whether 15-minute, hourly, monthly, seasonal, or annual data collection and savings reporting are necessary. The granularity decision is based how the information will be used from the evaluation. Annual savings data provide an overview of program benefits. More detailed data are usually required for both cost-effectiveness analyses and resource planning purposes.

   If demand savings are to be calculated, the choice of definition (e.g., annual average, peak summer, coincident peak, etc.) is related to time granularity. When evaluating energy or demand savings, it is important to properly define the project boundaries (i.e., what equipment, systems, or facilities will be included in the analyses). Ideally, all primary effects (the intended savings) and secondary effects (unintended positive or negative effects), and all direct (at the project site) and indirect (at other sites) will be captured in the evaluation. The decision concerns whether savings will be evaluated for specific pieces of equipment. For example, the "boundary" may include motor savings or light bulb savings estimates, the end-use system (e.g., the HVAC system or the lighting system), the entire facility, or the entire energy supply and distribution system (Modified NAPEE 2007).

Therefore, the EM&V plans filed for each program portfolio will stipulate the sampling strategy, the confidence and precision levels necessary to provide for a robust EM&V analysis of the savings estimates. Although the sampling strategy will vary by program and across the program portfolio, it must be fully described in each EM&V plan.

F. DEFINING PROGRAM BASELINE, BASELINE ADJUSTMENTS, AND DATA COLLECTION REQUIREMENTS

A major impact evaluation decision is defining the ***baseline conditions.*** The baseline reflects the conditions, including energy consumption, that were occurring before the launch of the program. Baseline definitions consist of site-specific issues and broader, policy-oriented considerations.

Site-specific issues include the characteristics of equipment in place before an efficiency measure is implemented as well as how and when the affected equipment or systems are operated. When defining the baseline, it is also important to consider where in the life cycle of the existing equipment or systems the new equipment was installed. The options are:

- *Early replacement* of equipment that had not reached the end of its useful life;
- *Failed equipment replacement,* with new energy efficient equipment installed; or
- *New construction.*

For each of these options, the two generic approaches to defining baselines are the *project-specific* and the *performance standard* procedure, described below.

Project-Specific Baseline

Under the project-specific procedure (used with all or a sample of the projects in a program), the baseline is defined by a specific technology or practice that would have been pursued, at the site of individual projects, if the program had not been implemented. For energy efficiency programs, the baseline is established by:

1. Assessing the existing equipment's energy consumption rate, based on measurements or historical data;
2. Completing an inventory of pre-retrofit equipment; or
3. Comparing to a control group's energy equipment (used where no standard exists or when the project is an "early replacement," i.e., implemented prior to equipment failure).

The most widely accepted method, and recommended for these EM&V Protocols is to define the baseline by determining what technologies the new equipment actually replaces; that is the baseline is related to actual historical base year energy consumption or demand, and carried forward to future years (NAPEE 2007).

Performance Standard Baseline

The Performance Standard Baseline approach avoids project-specific determinations of quantified energy and demand savings and instead develops a performance standard, which provides an estimate of baseline energy and demand for all the projects in a program. The assumption is that any project activity will produce *additional* savings if it has a “lower” baseline than the performance standard baseline. Performance standards are sometimes referred to as “multi-project baselines” because they can be used to estimate baseline savings for multiple project activities of the same type.

Under the performance standard procedure, baseline energy and demand are estimated by calculating an average (or better-than-average) consumption rate (or efficiency) for a blend of alternative technologies or practices. These standards are used in large-scale retrofit (early replacement) programs when the range of equipment being replaced and how it is operated cannot be individually determined. This would be the case, for example, in a residential compact fluorescent lamp (CFL) incentive program, where the types of lamps being replaced and the number of hours they operate cannot be determined for each home. Instead, studies are used to determine typical conditions. Another common use of performance standards is to define a baseline as the minimum efficiency standard for a piece of equipment as defined by a law, code, or standard industry practice. This is commonly used for new construction or equipment that replaces failed equipment (NAPEE 2007).

This approach is especially important when it is difficult to determine baselines, such as in new construction programs since no comparison period exists. However, the concepts of project and performance standard baseline definitions can still be used in these circumstances. The industry-accepted methods of defining new construction baselines are based on:

- The specifications of buildings that would have been built or equipment installed, without the influence of the program, at the specific site of each construction project. This might be evaluated by standard practice evaluation or building plans and specifications that were prepared prior to the program being launched;
- Existing building codes and/or equipment standards; and
- The performance of equipment, buildings, etc., in a comparison group of similar program non-participants.

G. DEFINING ADJUSTMENT FACTORS

A number of factors, or independent variables, affect energy and demand levels at the customer site and need to be considered when evaluating a DSM program. By accounting for these factors that are beyond the control of the program implementer or end-user, the adjustments bring energy use in the two time periods (before program launch and after or during program delivery) to the same set of conditions. Common adjustment examples are:

- Weather corrections;
- Changes in occupancy levels and hours;
- Production levels;
- Economic conditions;

- Energy prices;
- Changing codes/standards and common practice/changes to the baseline;
- Interactions with other programs; and
- Changes in household or building characteristics.

These factors all affect total energy used and energy demand levels. There are a few methods for isolating the impacts of these factors in order to accurately attribute energy and demand reductions to the program being evaluated.

The decision to calculate gross energy savings or net energy savings depends on the program objectives and available evaluation resources. Gross savings are calculated when all that is needed is an estimate of the savings for each project participating in a program. The most common example of this is a project involving a contractor completing energy efficiency measures in a facility for the sole purpose of achieving energy savings (e.g., performance contracts). Net savings (which account for the range of independent variables discussed previously) are calculated when one wants to know the level of savings that occurred as a result of the program's influence on program participants and non-participants (Schiller Consulting 2010). The methods to adjust gross and net savings are summarized below:

Estimates of Gross Savings

Gross energy or demand savings are the expected change in energy consumption or demand that results directly from program-promoted actions (e.g., installing energy efficient lighting) taken by program participants under pre-defined assumed conditions.

Estimates of Net Savings

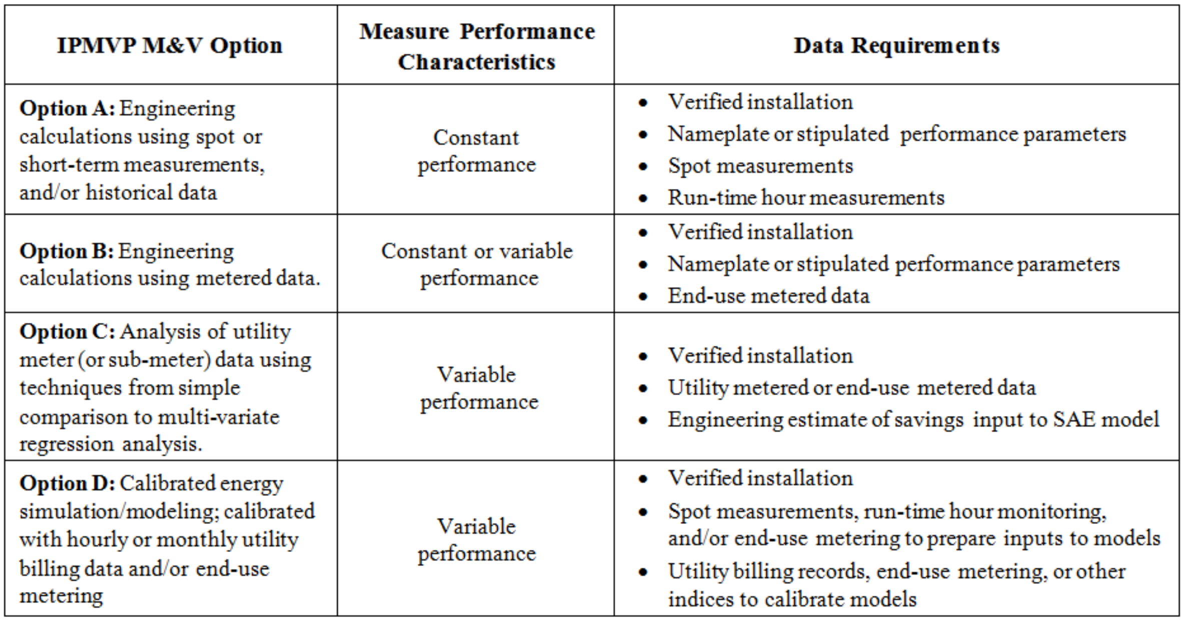
Net energy or demand savings refer to the portion of gross savings that is directly attributable to the influence of the program. This involves separating out the impacts that are a result of other influences, such as weather, energy prices, or even consumer self-motivation.

Most program evaluations seek estimates for both gross and net energy/demand savings. They require a net-to-gross estimate. Net-to-gross estimates refer to the ratio of total (gross) savings that are program-influenced (net savings). For example, a program's overall impact is determined by calculating the actual savings less the anticipated or projected estimates and then adjusted for free ridership and spillover.

$$\textbf{Impact = Actual post – Projected}_{\textbf{pre}} \pm \textbf{Adjustments}$$

The level of effort necessary to complete an evaluation is driven by the equipment type and data collection needs. The International Performance Measurement and Verification Protocol (IPMVP) is an important and widely used guidance document for determining the level of effort required to conduct EM&V studies. It provides guidelines about the "level of effort" required to document energy efficiency savings. The IPMVP presents various M&V options, summarized in Table 2, that help guide savings verification methods and levels of effort.

Table 2: Summary of IPMVP Protocols



IPMVP M&V Option	Measure Performance Characteristics	Data Requirements
Option A: Engineering calculations using spot or short-term measurements, and/or historical data	Constant performance	• Verified installation • Nameplate or stipulated performance parameters • Spot measurements • Run-time hour measurements
Option B: Engineering calculations using metered data.	Constant or variable performance	• Verified installation • Nameplate or stipulated performance parameters • End-use metered data
Option C: Analysis of utility meter (or sub-meter) data using techniques from simple comparison to multi-variate regression analysis.	Variable performance	• Verified installation • Utility metered or end-use metered data • Engineering estimate of savings input to SAE model
Option D: Calibrated energy simulation/modeling; calibrated with hourly or monthly utility billing data and/or end-use metering	Variable performance	• Verified installation • Spot measurements, run-time hour monitoring, and/or end-use metering to prepare inputs to models • Utility billing records, end-use metering, or other indices to calibrate models

(Source: IPMVP Protocols 2010)

Budget Considerations

Establishing a budget (i.e., funding level) for an evaluation requires consideration of all aspects of the evaluation process. The costs for high levels of confidence in the calculations must be balanced against the risks (and costs) associated with the value of savings being allocated to projects and programs. In this sense, evaluation processes involve some risk management decisions. Low-risk projects require less evaluation confidence and precision; high-risk projects require more confidence and precision. The acceptable level of uncertainty is often a subjective judgment based on the value of the energy and demand savings, the risk to the program associated with over- or underestimated savings, and a balance between encouraging efficiency actions and high levels of certainty. An important aspect of evaluation planning is deciding what level of risk is acceptable and thus determining the requirements for accuracy and a corresponding budget.

The level of acceptable risk is usually related to:

- The overall amount of savings expected from the program;
- Whether the program is expected to grow or shrink in the future;
- The uncertainty about expected savings and the risk the program poses in the context of achieving portfolio savings goals;
- The length of time since the last evaluation was conducted and the degree to which the program has changed in the interim; and
- The requirements of the regulatory commission or oversight authority, and/or the requirements of the program administrator.

On a practical level, the evaluation budget reflects a number of factors. At the portfolio level, for example, evaluation budgets may be established in regulatory proceedings. However, evaluation needs and costs require scrutiny at the program level to ensure proper funding levels. At the program level, budgets are often influenced by factors that affect the level of quality associated with evaluation results. For example, budgets may increase to accommodate follow-up studies aimed at assessing and reducing measurement error, or to pay for additional short-term metering, training of staff, or testing of questionnaires and recording forms to reduce data collection errors. Additional resources might be required to ensure that "hard-to-reach" portions of the population are included in the sampling frame (reducing non-coverage error) or devoted to follow-up aimed at increasing the number of sample members for whom data are obtained (reducing non-response bias).

The determination of the appropriate sample size also affects the evaluation budget. Procedures such as a statistical power analysis help researchers determine the sample size needed to achieve the desired level of precision and confidence for key outcomes. In this way, researchers are assured of a statistically significant sample size.

The National Action Plan for Energy Efficiency (2007) suggests that a reasonable spending range for evaluation is 3 to 6 percent of program budgets. In general, on a unit-of-saved-energy basis, costs are inversely proportional to the magnitude of the savings (i.e., larger projects have lower per-unit evaluation costs) and directly proportional to uncertainty of predicted savings (i.e., projects with greater uncertainty in the predicted savings warrant higher EM&V costs) (NAPEE 2007).

Cost-Effective Strategies for Program Evaluation

One effective way to minimize the EM&V evaluation costs – while maximizing the overall effectiveness of the final program evaluations – is to encourage (PWC) parties working collaboratively on EM&V activities where possible.

In particular, larger utilities should be encouraged to include smaller utilities in EM&V planning and research.[1] The potential cost savings from PWC on evaluation projects can be significant, especially for utilities with relatively small programs. Other advantages include a consistent methodological approach and a consistent reporting format. Similarly, market assessments and baseline studies naturally lend themselves to a regional approach because markets do not conform to service-territory boundaries.

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[1] Although not mandatory, collaboration is a potentially cost-effective option that should be given consideration.

Specific types of evaluation activities may be appropriate for collaboration:

1. Baseline Studies
2. Market Assessment Studies
3. Incremental Cost Studies
4. Process or Impact Evaluations where programs are substantially similar
5. DSM Potential Studies

If programs meet the following criteria, then conducting EM&V activities collectively via the PWC is strongly encouraged:

- **The programs delivered across multiple utility territories are very similar.** If the programs target the same customer class and offer the same measure mix, then there are significant cost savings to be gained by conducting a joint evaluation across the utility service territories. The most common DSM programs that encourage this PWC effort include residential CFL programs, residential weatherization programs, and energy audit programs.
- **The finding should be reported consistently across utility service territories where appropriate**. This PWC effort will only work if the participating utilities are tracking the customer data in the same manner across the joint programs. The individual utilities can report their EM&V activities separately but share the EM&V costs associated with executing these activities (Reynolds et al., 2009).

The Importance of Independence

EM&V requires third-party verification and reporting. Therefore, the organization selected to conduct any EM&V activities should be independent of the organizations involved in the program design, management, and implementation efforts. The evaluations should be conducted at an “arms-length distance,” such that the verification professionals have no financial stake in the program or program components being evaluated beyond the contracted evaluation efforts.

Section II: EM&V Protocols

This section describes the recommended EM&V Protocols that should be incorporated in process and impact evaluations of the DSM programs pursuant to Docket No. 10-100-R.

PROTOCOL A: PROGRAM TRACKING AND DATABASE DEVELOPMENT

Protocol Scope: This protocol provides guidance to develop an effective DSM program tracking, evaluation and project database. It lists the key data elements that must be tracked, the key measure characteristics, key customer demographics and other data fields.

Customer Classes: All except self-directing customers

All tracking systems should capture all of the variables required to determine the energy savings. Please refer to the most recent version of the Deemed Savings estimates developed for the Arkansas Technical Reference Manual (TRM) as specified in the Deemed Savings No. 07-152-TF[2].

Table 3: Recommended Data Fields and Description

Recommended Data Fields	Description
Participating Customer Information • Unique customer identifier, such as account number • Customer contact information – name, mailing address, telephone number • Date/s of major customer milestone/s such as rebate application date, approval date, rebate processing date, etc.	Information used to readily identify customers for follow-up contact
Measure-Specific Information • Measure Group (Equipment Type) • Equipment Fuel/Energy Source • Equipment size • Equipment quantity • Efficiency level	Information that documents the details of the equipment installed and equipment replaced under the program

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[2] http://www.apscservices.info/EEInfo/TRM.pdf

Recommended Data Fields	Description
Measure-Specific Information • Estimated savings • Estimated incremental measure cost, if applicable • Equipment Useful Life • Measure Name - Text Description • Measure Code - Numerical Code* • Serial Number (where applicable) • Reported age of equipment replaced (if available) • Reported measure type of equipment replaced (if available) • Other inputs necessary for the use and compliance with the TRM	***Measure Codes**: Ideally, all data should be captured in numeric format to facilitate data tracking and analysis. Therefore, a data legend should identify each measure type and contractor type. This data legend should also be clearly labeled in the program database's supporting materials.
Vendor-Specific Information • Name and Contact Information for Contractor • Contractor Type • Date of Installation • Cost of the installed equipment (if available) • Efficiency level of the installed equipment	To be collected when the measure is installed by a third-party vendor. This information can be determined from the supporting documentation provided to qualify for the program incentive.
Program Tracking Information • Date of the initial program contact/rebate information • Date of rebate/incentive paid • Incentive amount paid to date • Incentive amounts remaining • Application Status (i.e., number of applications approved, pending or denied) • Reason and Reason code for application denial	Information to determine program cost effectiveness and timing for rebate applications and processing
Program Costs • Overall program budgets • Program expenditures to date • Incentive Costs • Administrative Costs • Marketing/Outreach Costs • Evaluation Costs	This information is directly related to program expenses. This information may be tracked in a separate worksheet from measure costs; however, the totals should be reported annually.
Marketing and Outreach Activities • Advertising and marketing spending levels • Media schedules • Summary of number of community events/outreach activities • Other media activities – estimated impressions via mailings, television/radio, print ads	The program implementers should be able to provide separate documentation regarding the type, number, and estimated impressions made for each marketing or outreach activity.

Table 4: Example of Data Legend for Database Tracking and Evaluation Purposes

Example Measure Category	Example Measure Code
Air Source Heat Pump	1
Room Air Conditioner	2
Central Air Conditioner	3
Natural Gas Furnace	4
Storage Water Heater (Gas)	5
Tankless Water Heater (Gas)	6
Storage Water Heater (Electric)	7
Heat Pump Water Heater	8
Attic Insulation	9
Wall Insulation	10

Similarly, the contractor type could also be identified by a category and a numeric code to facilitate analysis and tracking. Ideally, the program database and tracking system would be linked to the utility's or energy provider's current Customer Information System so that it can be updated regularly to verify eligibility.

Table 5: Example of Contractor Codes

Example Contractor Type	Example Contractor Code
Architect	11
Engineer	22
Plumber	33
HVAC	44
Insulation Installer	55
Home Builder (Production)	66
Home Builder (Custom)	67
Specialty	90

"Best practices" regarding database tracking and development also suggest capturing additional types of information during data collection to facilitate EM&V. Examples are provided below in Table 6.

Table 6: Suggested Data Collection Fields

Suggested Data Collection Fields	Description
Premise Characteristics • Housing Type • Number of Occupants • Estimated/Actual Square Footage	This information includes descriptions of the housing type and similar data points asked of participants during the measure installation.
Measure Characteristics • Efficiency level of equipment removed (retrofit only) • Model level for equipment removed (retrofit only)	This information is commonly captured by the contractor or recorded from the invoice and could be tracked in the program database.

PROTOCOL B: PROTOCOLS FOR THE POST-IMPLEMENTATION VERIFICATION OF ENERGY EFFICIENCY PROGRAM MEASURE INSTALLATIONS AND ESTIMATION OF ENERGY AND DEMAND SAVINGS

Protocol Scope: This protocol specifies the types and categories of measures that require post-implementation verification, the recommended timing for these activities, and the key data to capture during on-site inspections. For more detailed information regarding the data collection requirements for on-site inspections refer to the IPMVP listed on www.evo-world.org and the requirements listed in the Deemed Savings Docket 07-152-TF.

Customer Classes: All except self-directing customers

Calculating Energy and Demand Savings: For efficiency programs, determining energy savings is the most common goal of impact evaluations. Energy usage and savings are expressed in terms of consumption over a set time period and defined in well understood terms (e.g., therms of natural gas consumed per month, megawatt hours [MWh] of electricity consumed over a year, season, or month). Energy savings results may also be reported by costing period, which break the year into several periods coinciding with a utility rate schedule.

Special cases of savings by period include demand savings for peak and off-peak periods or summer and winter periods.

Examples of demand savings definitions are:

> **Annual average demand (MW) savings** – Total annual energy (MWh) savings divided by the hours in the year (8,760).
>
> **Peak demand reductions** – The maximum amount of demand reduction achieved during a period of time. This time period should be clearly defined, whether it is annual, seasonal, or during a specific period of time, such as summer weekday afternoons or winter peak billing hours.
>
> **Coincident peak demand reduction** – The demand savings that occur when the servicing utility is at its peak demand from all (or segments) of its customers. This indicates what portion of a utility's system peak demand is reduced during the highest periods of electricity consumption. Calculating coincident peak demand requires knowing when the utility has its peak (which is not known until the peak season is over).

PROTOCOL B1: RECOMMENDED PROTOCOLS FOR GROSS ENERGY EVALUATION
1. A Simple Engineering Model (SEM) with M&V equal to IPMVP Option A and meeting all requirements for this M&V Protocol is recommended. Other approaches and options should be considered as evaluation requirements or studies dictate.
2. Normalized Annual Consumption (NAC) using pre- and post-program participation consumption from utility bills from the appropriate meters related to the measures installed, weather-normalized, using the identified weather data to normalize for heating and/or cooling as appropriate. Twelve or more months' pre-retrofit and twelve months' post-retrofit consumption data is recommended.

(Source: CA Evaluators' Protocols 2006)

PROTOCOL B2: RECOMMENDED PROTOCOLS FOR GROSS DEMAND EVALUATION

1. Requires using secondary data to estimate demand impacts as a function of energy savings. End-use savings load shapes or end-use load shapes will be used to estimate demand impacts as available:
    a. End-use savings load shapes, end-use load shapes or allocation factors from simulations conducted for Arkansas TRM as available.
    b. Allocation factors from forecasting models or utility forecasting models through the evaluation plan review process such as econometric, end-use, load forecast and other models as appropriate.
    c. Allocation based on end-use savings load shapes or end-use load shapes from other studies for related programs/similar markets with approval through the evaluation review process as applicable.

(Source: Modified from the CA Evaluators' Protocols 2006)

PROTOCOL B3: RECOMMENDED PROTOCOLS FOR PARTICIPANT NET IMPACT EVALUATION

1. Analysis of utility consumption data that addresses the issue of self-selection bias for both participants and non-participants.
2. Enhanced self-report method using other data sources relevant to the decision to install/adopt. These could include: a record/business policy and paper review, examination of similar decisions, interviews with multiple actors at end-user site including participants and non-participants, interviews with mid-stream and upstream market actors, reviews of standard buildings and equipment installation practices by builders and/or stocking practices.

(Source: Modified from the CA Evaluators' Protocols 2006)

PROTOCOL B4: SAMPLING AND UNCERTAINTY PROTOCOL

Level Gross Impact Options:

Simplified Engineering Models (SEM): The sampling unit is the premise or site where the measure was installed. The sample size selected must be justified in the evaluation plan and approved as part of the evaluation planning process.

Protocols for Estimating Net Impacts:

If the method used for estimating net energy and demand impacts and net-to-gross ratios (NTGR) is regression-based; there are no relative precision targets. For both impacts and NTGR calculation, evaluators are expected to conduct, at a minimum, a statistical power analysis as a way of initially estimating the required sample size. Other information can be taken into account such as professional judgment and prior evaluations of similar programs or similar measures.

Normalized Annual Consumption (NAC) Models:

If NAC models are used, there are no targets for relative precision. This is due to the fact that NAC models are typically estimated for all participants for whom there is an adequate amount of pre- and post-billing data. Thus, there is no sampling error. However, if sampling is conducted, either a power analysis or justification based upon prior evaluations of similar programs must be used to determine sample sizes. The sample size selected should be justified in the evaluation plan and approved as part of the evaluation planning process.

(Source: Modified from the CA Evaluators' Protocols 2006)

PROTOCOL B5: SAVINGS FOR PROJECTS SPANNING TWO PROGRAM YEARS

There are instances where large custom projects are implemented during one program year, but sufficient data is not available to complete final M&V until the following program year. In these cases, it would be appropriate, but not required, to split the savings across program years.

Appropriate Savings Split

Utilities are allowed to split projects across program years using percentages that range between 40% and 60%. The exact percentage can change depending on the project and the utilities' specific risk appetite. However, the first year savings should be at least 40% and never exceed 60%, while the savings claimed the following year would be the balance.

Evaluation of Split Projects

The evaluation of projects split will also be split across the program years. The initial evaluation will assess the project based on the information that is available at the time of the evaluation, and any necessary corrections will be made. The remaining percentage of savings will be evaluated the following program year when sufficient data is available. This second evaluation will be used as a true up to ensure the appropriate savings are claimed for the project as a whole. Therefore, it is possible that if savings were significantly overstated during the previous program year, the evaluated savings during the second year could be negative.

For example, a custom project is initially estimated to save 100,000 kWh of electricity. Since the project was completed in December, the utility decides to claim 60% during the current year, or 60,000 kWh. The remaining 40,000 kWh will be claimed the following year. The evaluator uses the information available at the time to validate that the initial claim of 60,000 kWh is reasonable. However, during the evaluation the following year, the evaluator determined the customer made significant operational changes to the project and it is only expected to save 50,000 kWh total. The evaluator would therefore report -10,000 kWh (negative savings) during the second year to true up the project as a whole.

PROTOCOL C: PROCESS EVALUATION GUIDANCE

Protocol Scope: This protocol provides guidance regarding the timing and scope for process evaluations of the Arkansas utility programs. Process evaluations focus on determining the overall effectiveness of program delivery, identifying opportunities for program improvements and assessing key program metrics, including participation rates, market barriers, and overall program operations.

PROTOCOL C1: PROCESS EVALUATION STRUCTURE AND TIMING

Protocol Scope: This protocol section provides additional guidance on how to best structure process evaluations at the state, portfolio, program, service, and market sector level. Process evaluations need to be structured to meet the specific goals and objectives at a particular point in time.

Customer Classes: All except self-directing customers

Program Types: All

Approach: The process evaluation decision-maker, either the utility or third-party administrator, should determine if a process evaluation is needed based on any of the criteria described in Protocols C1 and C2, which summarize the two major criteria for determining if a process evaluation is necessary. The first criterion is to determine if it is time for a process evaluation; the second criterion is to determine if there is a need for a process evaluation. Figures 3 and 4 illustrate this decision-making process.

Keywords: "timing; portfolio level evaluations; process evaluation structure; diagnostic process evaluations; under-performing programs; programs not meeting targets"

PROTOCOL C1: DETERMINING APPROPRIATE TIMING TO CONDUCT A PROCESS EVALUATION

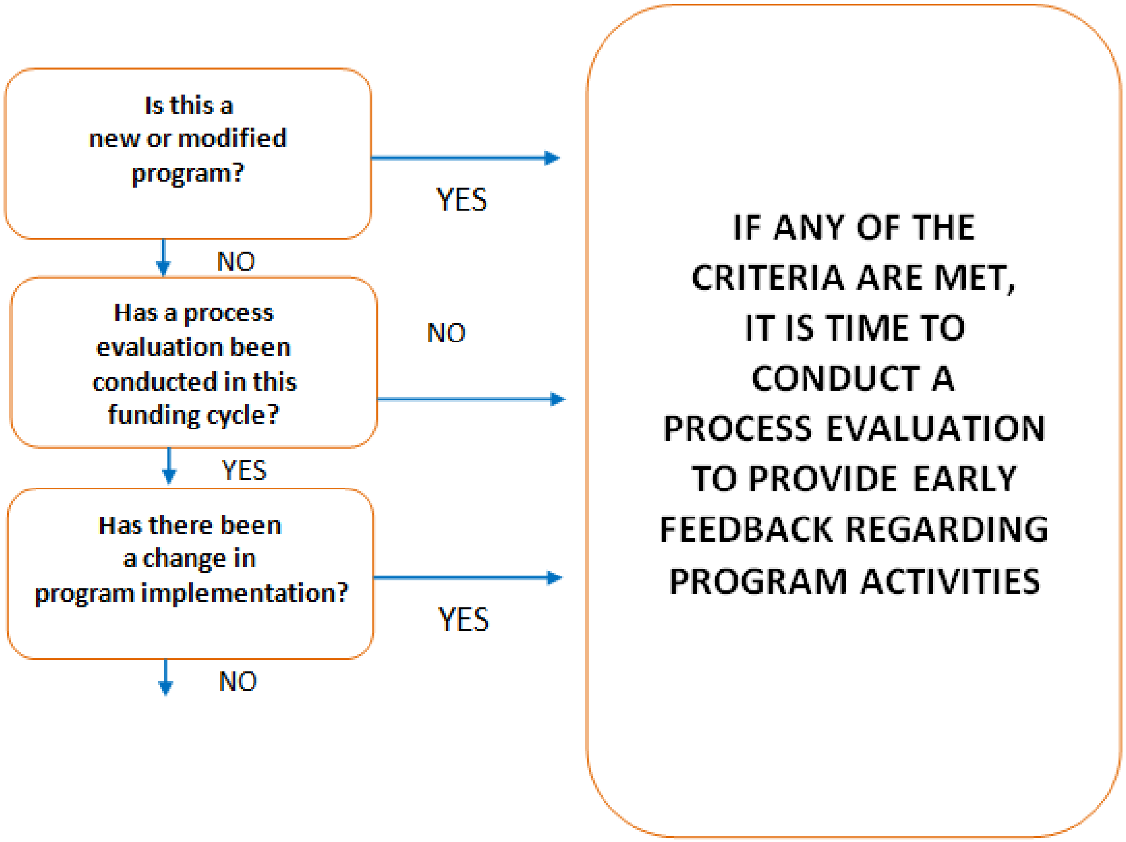
1. **New and Innovative Components:** If the program has new or innovative components that have not been evaluated previously, then a process evaluation needs to be included in the overall evaluation plan for assessing their level of success in the current program and their applicability for use in other programs.
2. **No Previous Process Evaluation:** If the program has not had a comprehensive process evaluation during the previous funding cycle, then the Program Administrator should consider including a process evaluation in the evaluation plan.
3. **New Vendor or Contractor**: If the program is a continuing or ongoing program, but is now being implemented, in whole or in part, by a different vendor than in the previous program cycle, then the administrator should consider including a process evaluation in the evaluation plan to determine if the new vendor is effectively implementing the program.

If any of these criteria are met, it is time to conduct a process evaluation.

If none of these criteria are met, then the evaluation decision-maker should proceed to Step 2 in the Process Evaluation Decision Map.

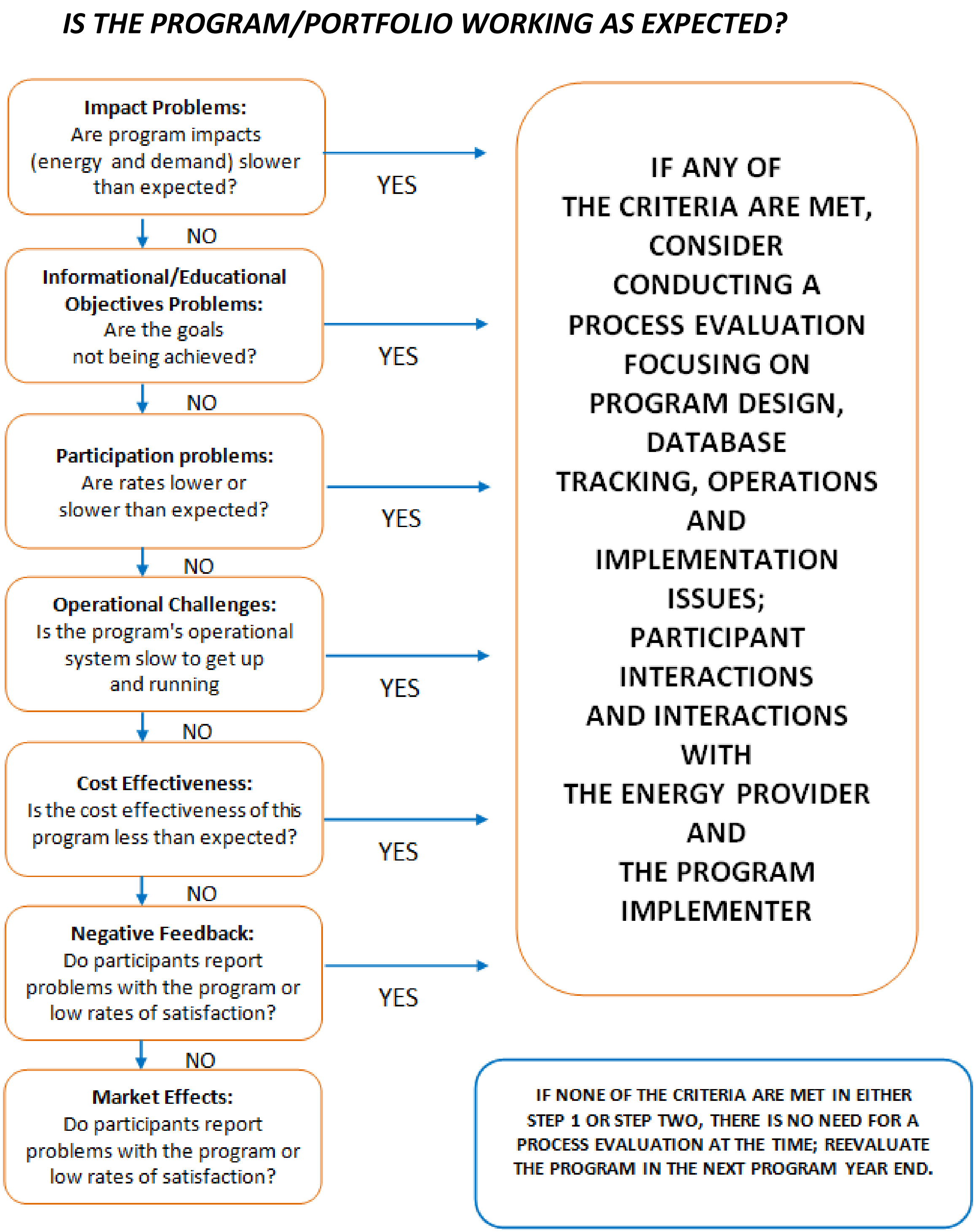
PROTOCOL C1: DETERMINING APPROPRIATE CONDITIONS TO CONDUCT A PROCESS EVALUATION
Process evaluations may also be needed to diagnose areas where the program is not performing as expected. These conditions may include the following:
1. Impact Problems: Are program impacts lower or slower than expected?
2. Informational/Educational Objectives: Are the educational or informational goals not meeting program goals?
3. Participation Problems: Are the participation rates lower or slower than expected?
4. Operational Challenges: Are the program's operational or management structure slow to get up and running or not meeting program administrative needs?
5. Cost-Effectiveness: Is the program's cost-effectiveness less than expected?
6. Negative Feedback: Do participants report problems with the program or low rates of satisfaction?
7. Market Effects: Is the program producing the intended market effects?
If any of the criteria is met, a process evaluation is needed to identify ways to address and correct these operational issues. **If none of these criteria is met in either Step 1 or Step 2, then a process evaluation is not needed at this time.** **Re-evaluate the need for a process evaluation at the end of the program year.**

IS IT TIME FOR A PROCESS EVALUATION?



(Source: Johnson & Eisenberg 2011, p. 21.)

Figure 3: Determining Timing for a Process Evaluation



(Source: Modified from Johnson & Eisenberg 2011, p. 22)

Figure 4: Determining Need to Conduct a Process Evaluation

Additional Guidance for Conducting Limited/Focused Process Evaluations

In all cases, the evaluator should conduct a limited or focused process evaluation consisting of a review of the program database and staff interviews to determine each program's progress throughout the evaluation cycle. The findings from these activities will serve to:

- Provide a progress report for each recommendation for program improvement made in previously conducted evaluations. For each evaluation recommendation, the report should indicate whether the recommendation has been accepted and implemented, rejected, or is still under consideration. If the recommendation is rejected, an explanation of the reason for rejection should be provided. If a recommendation is still under consideration, then an explanation should be provided for the steps underway to reach an implementation decision for that recommendation;
- Identify the progress made towards achieving the objectives as described in the Commission Checklist;
- Interview at least one member of the program staff and clearly label these findings for each program; and
- Identify any issues that may need to be explored more fully in future program evaluations.

Process evaluation guidance for the Consistent Weatherization Approach

Given the importance of monitoring the progress of the Commission-ordered Consistent Weatherization Approach, it is important to note in all process evaluations (i.e., either full or limited) the status of this program as it is currently being implemented by each IOU. Specifically, the process evaluation activity should report out, in a separate section, the following information annually:

- The program name;
- Description of how the Consistent Weatherization Approach is being implemented the utility;
- The number of audits conducted during the Program Year;
- The number of participants (i.e., projects submitted to program);
- The conversion rates (i.e., audit to project ratio) for eligible customers;
- The average number of measures installed per project;
- The average program cost per participant;
- Percentage of pre-approved contractors actively promoting the program (i.e., submitting projects); and
- Additional information that may inform program design or operations.

PROTOCOL C2: PROCESS EVALUATION PLANNING

Protocol Scope: This protocol provides guidance on the key issues that should be addressed in process evaluations. It is especially important to focus on the aspects of program operations to address any deficiencies identified in the Process Evaluation Decision Map, Figure 4.

Customer Classes: All

Program Types: All

Approach: The process evaluation plan should use the following outline to identify the key researchable issues that must be addressed in the process evaluation. This outline applies to process evaluations conducted at the program, portfolio, and state level.

Keywords: "process evaluation planning; EM&V plan process evaluation timing; portfolio level process evaluations; process evaluation structure; process evaluation components; process evaluation scope"

PROTOCOL C2: RECOMMENDED ELEMENTS OF A PROCESS EVALUATION PLAN
Introduction: Description of the program or portfolio under investigation; specific characteristics of the energy organization providing the program including current marketing, educational or outreach activities and delivery channels
Process Evaluation Methodology: Process evaluation objectives, researchable issues, and a description of how specific evaluation tactics will address the key researchable issues including the proposed sampling methodology for program/third-party staff, key stakeholders, trade allies/vendors, and customers. The sampling methodology should be clearly explained with specific targets of completed surveys or interviews clearly described in the EM&V Plan.
Timeline: Summarized by key tasks identifying the length of the process evaluation and key dates for completion of major milestones
Budget: Costs of conducting the process evaluation by specific tasks and deliverables

(Source: Modified and Expanded from the California Evaluators' Protocols - TecMarket Works 2006).

While Protocol C2 provides a general outline of the key elements that should be included in a process evaluation plan, Protocol C3 provides more detailed information regarding the key areas for investigation that need to be addressed in a process evaluation. Protocol C3 also identifies those areas that are most applicable to new programs or pilot programs, those areas that should be investigated when the program is experiencing specific operational issues or challenges, and those topic areas that should be covered in all process evaluations.

PROTOCOL C3: RECOMMENDED AREAS OF INVESTIGATION IN A PROCESS EVALUATION	
Program Design	**Additional Guidance**
Program design and design characteristics, and program design process	This area is especially important to address in first-year evaluations and evaluations of pilot programs.
The program mission, vision and goal setting and goal setting process	
Assessment or development of program and market operations theories	
Use of new or best practices	
Program Administration	**Additional Guidance**
The program management process	This area should be covered in all process evaluations, but it is especially important to address in those evaluations where operational or administrative deficiencies exist.
Program staffing allocation and requirements	
Management and staff skill and training needs	
Program tracking information and information support systems	
Reporting and the relationship between effective tracking and management, including operational and financial management	
Program Implementation and Delivery	**Additional Guidance**
Description and assessment of the program implementation and delivery process	This is critical to gathering the information necessary to assess the program's operational flow.
Program marketing, outreaching, and targeting activities	These are areas that should be addressed if the program is not meeting its participation goals or if the program is under-performing.
Quality control methods or operational issues	
Program management and management's operational practices	
Program delivery systems, components and implementation practices	
Program targeting, marketing, and outreach efforts	The process evaluator should request copies of all marketing and outreach materials and include an assessment as part of the document review task.
Program goal attainment and goal-associated implementation processes and results	These areas should be addressed in all process evaluations, but are especially important if the program is under-performing regarding savings or participation rates.
Program timing, timelines and time sensitive accomplishments	
Quality control procedures and processes	

PROTOCOL C3: RECOMMENDED AREAS OF INVESTIGATION IN A PROCESS EVALUATION	
Documentation of program tracking methods and reporting formats	This is a key element of the review of the program database and the evaluator should request copies of the program records or extracts along with the data dictionary.
Customer interaction and satisfaction (both overall satisfaction and satisfaction with key program components, including satisfaction with key customer-product-provider relationships and support services)	These topics should be investigated in the customer surveys and should be a priority if the program is experiencing negative feedback or lower than expected participation rates or energy savings.
Customer or participant’s energy efficiency or load reduction needs and the ability of the program to deliver on those needs	
Market allies’ interaction and satisfaction with the program	
Reasons for a low level of market effects and spillover	
Intended or unanticipated market effects	

The process evaluation report should include the following reporting requirements:

1. **Detailed Program Description**. The process evaluation report should present a detailed operational description of the program that focuses on the program components being evaluated. The use of a program flow model is highly recommended. The report should provide sufficient detail so that readers are able to understand program operations and the likely results of the recommended program changes.

2. **Program Theory**. The process evaluation should include a presentation of the program theory. If the program theory is not available, or cannot be provided in time for the evaluation report due date, the evaluator should include a summary program theory built from the evaluation team's program knowledge. It should be complete enough for the reader to understand the context for program recommendations, but does not need to be a finely detailed program theory or logic model.

3. **Support for Recommended Program Changes**. All recommendations need to be adequately supported. Each recommendation should be included in the Executive Summary and then presented in the Findings text along with the analysis conducted and the theoretical basis for making the recommendation. The Findings section should also include a description of how the recommendation is expected to help the program, including the expected effect that implementing the change will have on the operations of the program.

4. **Detailed Presentation of Findings**. A detailed presentation of the findings from the study is essential. The presentation should convey the conditions of the program being evaluated and should provide enough detail so that any reader can understand the findings and the implications of the overall operations of the program and its cost-effectiveness (Modified from the CA Evaluators' Protocols 2006).

PROTOCOL D: "LEVEL OF EFFORT" PROTOCOLS

Protocol Scope: This section addresses appropriate levels of effort for program evaluation activities based on measure type. This protocol specifies the following: 1) which measures are best suited to relying on deemed savings estimates; 2) which measures are best served through simplified EM&V activities such as on-site inspections or an engineering review; and 3) which measures require full EM&V activities, as defined by the IPMVP. These determinations are based on the measure characteristics, usage patterns, and program types. They are often conducted jointly with a desk review of all related measure-supporting documents, such as invoices, technical studies, and energy audits. In many cases, lower levels of effort are sufficient for estimating measure impact, which may help increase the overall cost-effectiveness of EM&V activities.

Customer Classes: All except self-directing customers

Protocol D1 specifically refers to those measures that have been defined in the Arkansas TRM as "deemed savings measures." Relying on agreed upon energy savings using the appropriately updated deemed savings values described in the Arkansas TRM is a valid approach for prescriptive and direct-install measures used in a traditional manner including, but not limited to: water heaters, furnaces, boilers, food service equipment, low-flow showerheads and faucet aerators. Please consult this document for the most up-to-date listing of applicable measures filed in Deemed Savings Docket 07-152-TF. This document includes the appropriate deemed savings measures for electric and gas measures in the residential, commercial and industrial (C&I) markets.

Measure Lives and Failure Rates

Measure lives listed in this TRM should be used, unless a reason is given for deviating from a measure life, along with support for the deviation.

- "Failure" is defined as an instance where an implementation contractor reports that a measure has been installed, but a subsequent inspection finds that the equipment is non-operational and/or not properly installed and that difference has not been accounted for elsewhere.
- "Failure rate" should be defined as the percent of inspected installation sites where any equipment fails inspection (i.e., the equipment is either not installed or not operating) and that possibility has not been otherwise accounted for.

Note, the definition of failure is intended to not count issues related to persistence or normal measure lives.

PROTOCOL D1: USING DEEMED SAVINGS VALUES

Deemed savings approaches are most commonly used for measures that involve simple new construction or retrofit energy efficiency measures with well-defined applications[3]. The deemed savings approach is most applicable when most of the following conditions are true:

a. There are limited evaluation resources;
b. The projects involve simple energy efficiency measures with well understood savings mechanisms, and are not subject to significant variation in savings due to changes in independent variables;
c. The uncertainty associated with savings estimates is low and/or the risk of under- or over-estimating savings is low;
d. Documented per-measure stipulated values are available and applicable to the measure installation circumstances; and
e. The primary goal of the evaluation is to conduct field inspections for all or a sample of projects to make sure measures are properly installed and have the potential to generate savings rather than having rigorously determined energy savings.

Deemed values should be based on reliable, traceable, and documented sources of information, with an emphasis on rigorous evaluations of similar measures or programs in other jurisdictions. Other appropriate secondary sources of deemed parameters may include:

a. Standard tables or algorithms from recognized sources that indicate power consumption (wattage) of certain pieces of equipment that are being replaced or installed as part of a project (e.g., lighting fixture wattage tables);
b. Manufacturer's specifications;
c. Building occupancy schedules; and
d. Maintenance logs.

Deemed saving values may vary depending on whether the measure was removed prior to the end of its expected useful life or replaced on burnout. In the case of replacement prior to the expected useful life, extra care should be taken that the savings are not over estimated.

(Source: Modified and Expanded from the CA Evaluators' Protocols 2006)

PROTOCOL D2: M&V PROTOCOLS

The IPMVP protocols require two elements of measurement and verification (M&V).

1. Verification that the measure or project has the potential to perform (is installed and operating correctly); and
2. Verification that energy savings is occurring.

   An M&V approach should be pursued only if the value of the reduction in uncertainty it yields exceeds its cost. Uncertainty in a savings estimate is partly a function of the variability in the energy use from one application to the next. To address this, IPMVP classifies projects as having high or low *energy variation* and high or low *value*. Consult the full IPMVP M&V Plan requirements to ensure that the EM&V activities conform to the specific data collection requirements. The four options presented in the IPMVP for savings estimation are listed next.

(Source: Schiller Consulting 2010 and IPMVP Protocol)

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[3] Examples include T-8 lighting retrofits in office buildings or compact CFL giveaways for residential utility customers. In each example, an assumption is made about the average wattage savings and the average hours of operation combined with the effort of verifying that the T-8s were installed and the CFLs were actually provided to residents.

The following set of measure-specific protocols has been adapted and modified from the Northeast Energy Efficiency Partnerships (NEEP) EM&V Protocols (2010), which have combined current "best practices" for determining program estimates with both a recommended approach and an alternative approach consistent with the IPMVP approach. These protocols have been modified to reflect characteristics of the current Arkansas DSM programs. These protocols are measure-specific, but are not meant to be exhaustive or exclusive. Please consult the full list of all deemed measures in the Arkansas TRM for a full listing of appropriate deemed measures.

Option A – Retrofit Isolation: Key Parameter Measurement
Typical Application: Lighting retrofit where power draw is key performance parameter. This is measured on a constant and periodic basis.
Savings Determined by: Estimating lighting operating hours based on building schedules and occupant behavior.
Option B – Retrofit Isolation: All Parameter Measurement
Typical Application: Variable-speed drive and controls installed on a motor to adjust pump flow; there are variable/differing operating characteristics.
Savings Determined by: *Spot Metering or collection of interval data.* An example is measuring electric power with a kW meter installed on electrical supply to the motor, which reads power at specified intervals. In baseline period this metering may be in place for a period of time, as appropriate to verify motor loading levels. The meter is in place throughout reporting period to track variations in power use.
Option C – Whole Facility Energy Bill Analysis
Typical Application: Multi-faceted energy management program affecting many systems in a facility.
Savings Determined by: Measuring energy use with the gas and electric utility meters for a 12-month baseline period and throughout the reporting period.
Option D – Whole Facility Calibrated Simulation
Typical Applications: Multifaceted energy management program affecting many systems in a facility but where no meter existed in the baseline period – such as new construction.
Savings Determined by: Energy use measurements, after installation of gas and electric meters that are used to calibrate a simulation. Baseline energy use, determined using calibrated simulation, is compared to either a simulation of reporting period energy use or actual meter data.

RESIDENTIAL MEASURES

Residential measures covered here include:

- Residential Lighting
- Residential Central Air Conditioning
- Residential Comprehensive Multi-Measure Retrofit
- Residential Natural Gas Boilers and Furnaces

RESIDENTIAL LIGHTING

Recommended EM&V Methods

This category is limited to single-family residential lighting exclusive of specialty hard-to-reach and multifamily programs. These measures include new construction, retrofit, direct install, and retail lighting programs.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross energy and demand savings, initial net impacts as applicable. • Baseline quantity and wattage, installed quantity and wattage, location (as available), hours of use, in-service rate, HVAC interaction.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. The tracking needs to conform with the requirements specified in Protocol A.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete "socket counts" by room and fixture type provide key data for impact evaluations, baseline studies, and hours-of-use studies. Questions on purchasing habits and "shelf" stock inform in-service rate research. Site visits with time-of-use lighting loggers are the most defensible approach to residential lighting programs. Collection of basic heating and cooling system information can be helpful in assessing interactive savings effects.	Time-of-use lighting loggers on a sample of lamps and fixtures, typically by room type.
Acceptable Alternative M&V Methods	Alternatively, the Verification component can rely upon customer telephone surveys to obtain information such as socket counts, hours of use, and purchasing habits. These findings can be supplemented with literature reviews of other lighting studies to determine best estimates. This type of verification is an acceptable degree for rigor for these types of program installations.	The details regarding the alternative M&V approach must be documented in the Evaluation Plan submitted to the PSC. The EM&V for residential lighting may also address the issue of changing baselines due to the EISA phase out of standard incandescent lamps.

(Source: Modified from the NEEP EM&V Protocols 2010)

RESIDENTIAL CENTRAL AIR CONDITIONING

Summary of Recommended EM&V Methods

This category is limited to central air conditioning (CAC) installed as a stand-alone measure and excludes CAC installed through comprehensive new construction programs. This category does not include ENERGY STAR room air conditioners or other "space cooling" measures.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross energy and demand savings, as well as initial net impacts as applicable. • Number of installed units, unit capacity, baseline and installed efficiency, and full load cooling hours.	Additional parameters useful for quality control and also for evaluation design as specified in an EM&V plan.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering offers the most defensible approach to residential CAC programs.	Metering methods may include time-of-use loggers and spot power measurements. Logging load and energy draw data are recommended
Alternative M&V Methods	On-site inspections with metering that fully isolates the entire CAC system (Option B) is an acceptable alternative approach.	Metering would be interval kW measurements on both the outdoor compressor and indoor fan units.
	Billing analysis (Option C) is a reasonable energy evaluation method for residential CAC at lower cost.	Billing analysis alone generally cannot quantify demand impacts.
	Calibrated simulation modeling (Option D) is a viable alternative and can be effective at capturing measure interaction. CAC simulation modeling may be appropriate for evaluating comprehensive cooling measures.	Metering can be used to calibrate the model. Such metering may include whole premise interval kW recorders with some end-use metering.

(Source: Modified from the NEEP EM&V Protocols 2010)

RESIDENTIAL COMPREHENSIVE MULTI-MEASURE RETROFIT

Summary of Recommended EM&V Methods

This category encompasses comprehensive multi-measure retrofit installations in residential homes. Sometimes called "deep retrofits" or "home energy services," these measures are characterized by a whole-home approach that typically involves an audit followed by efficiency recommendations for multiple end-uses and technologies. The comprehensive residential approach tends to be electric-centric but may also span fuel measures such as water heating, boilers or furnaces.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial estimates of gross energy and demand savings, as well as initial net impacts as applicable. • Detail on individual measures, such as: air conditioner, heat pump, boiler/furnace, water heater quantities and sizes; baseline and installed equipment efficiencies; home square footage; insulation and weatherization actions.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling as specified in the EM&V plan.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with visual inspections, quality of installation assessments, interviews, and short-term metering for selected electric measures. Simple engineering models of savings impacts.	Metering is limited to time-of-use loggers on lighting and HVAC equipment supported by spot power measurements.
Alternative M&V Methods	For measures that save both natural gas and electricity, an option is to pair the Option A approach with a billing analysis (Option C) to determine gas impacts. Diagnostic testing of HVAC equipment, blower door, and duct blaster tests adds rigor and reduces uncertainty to savings estimates for envelope measures.	Evaluators should design an evaluation plan to achieve the identified objectives of the EM&V activities.
	Calibrated simulation modeling (Option D) is a viable alternative and it is capable of capturing measure interaction. This approach may be most appropriate for comprehensive multi-measures.	Metering can be used to document HVAC system and whole premise interval kW and recorders with some temperature measurements.

(Source: Modified from the NEEP EM&V Protocols 2010)

RESIDENTIAL NATURAL GAS BOILERS AND FURNACES

Summary of Recommended EM&V Methods

This category is limited to residential natural gas boilers and furnaces and excludes: space heating equipment such as portable or room space heaters; electric or oil space heating equipment; and associated controls such as boiler reset controls. This category addresses stand-alone heating equipment and excludes natural gas boilers/furnaces installed through comprehensive new construction programs.

Characteristic	Approach	Additional Comments
Program Tracking	Initial gross energy and demand savings, initial net impacts as applicable. Number of installed units, unit capacity, baseline and installed efficiency and full load heating hours.	Any additional parameters that could be useful for quality control or for evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys or on-site inspections. Telephone surveys supplemented by rebate forms can confirm installation and gather data on household demographics and other operational characteristics to support the billing analysis.	Validity of billing analysis depends on whether the baseline and post-installation operation is similar, and/or appropriate corrections are made.
Alternative M&V Methods	Adding on-site inspections enhances overall confidence in household characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) may be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT Loggers and spot power measurements.
	Calibrated simulation modeling (Option D) is a viable approach and is well suited for evaluating measures in a comprehensive package.	Natural gas sub-meters may be installed to isolate the heating equipment from other end-uses. Collecting both electric and gas usage can be helpful in calibrating and validating building energy models.

(Source: Modified from the NEEP EM&V Protocols 2010)

COMMERCIAL MEASURES

Commercial measures covered here include:

- C&I Comprehensive Multi-Measure New Construction
- C&I Custom Measures
- C&I Natural Gas Boilers and Furnaces
- C&I HVAC: Prescriptive Chillers
- C&I HVAC: Unitary/Split
- C&I HVAC: Other Measures
- C&I Lighting (New Construction)
- C&I Lighting (Retrofit)
- C&I Motors
- C&I Variable Speed Drives

C&I COMPREHENSIVE MULTI-MEASURE NEW CONSTRUCTION

Summary of Recommended EM&V Methods

This category is limited to the installation of commercial and industrial comprehensive multi-measure new construction projects.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial estimates of gross energy and demand savings, initial net impacts as applicable. • Savings by measure component; description of individual measures with, as applicable, unit quantities, sizes/capacities, baseline and installed efficiencies, and operating hours.	Any additional parameters that could be useful for quality control or for evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	Calibrated simulation modeling (Option D) which is effective at capturing measure interaction. On-site data collection and review of construction documents would gather parameters, specifications, and operational characteristics to inform the model. Data collected from building Energy Management Systems (EMS) can also provide cost-effective information and should be included in EM&V plans if available.	Metering should include whole premise interval kW recorders with some end-use metering.
Alternative M&V Methods	An alternative would be to conduct on-site inspections with metering that encompasses the entire set of measures (Option B). A detailed engineering spreadsheet model can be used to capture the dynamics and interactions on an hourly basis. Less rigorous metering (Option A) could be performed but may come at the cost of reduced accuracy and validity.	Metering can be used to calibrate the model. Such metering may include whole premise interval kW recorders with some end-use metering.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I CUSTOM MEASURES

Summary of Recommended EM&V Methods

This category is limited to the installation of Commercial and Industrial (C&I) custom measures in both retrofit and new construction situations. The custom category includes measures that either do not comply with or benefit from examination beyond a prescriptive calculation approach. In general, these are more complex measures that require site-specific information and detailed calculations to estimate energy and demand savings. In this context, custom measures may entail any end-use or technology.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross estimates of energy and demand savings and initial net impacts as applicable. • Measure description with, as applicable, unit quantities, sizes/ capacities, baseline and installed efficiencies, and operating hours.	Any additional parameters that could be useful for quality control or for evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	On-site inspections with partial (Option A) or complete (Option B) measurements on a census or sample of program participants. Site visits with short-term metering is the most appropriate approach for C&I Custom measures. A detailed engineering spreadsheet model can be used to capture the dynamics and interactions on an hourly basis. Data collected from Energy Management Systems (EMS) may also provide cost-effective information and should be included in EM&V plans if available.	Metering methods often include time-of-use loggers, interval kW recorders, and spot power measurements.
Alternative M&V Method	If the Custom measure involves significant HVAC equipment and/or controls, calibrated simulation modeling (Option D) offers a viable alternative for capturing measure dynamics and interaction.	Metering can be used to calibrate the model. Such metering may include whole premise interval kW recorders with some end-use metering.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I NATURAL GAS BOILERS AND FURNACES

Summary of Recommended EM&V Methods

This category is limited to commercial natural gas boilers and furnaces.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross energy and demand savings and initial net impacts as applicable. • Number of installed units, unit capacity, baseline and installed efficiency, and full load heating hours.	Any additional parameters that could be useful for quality control or for evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys and supplemented by rebate forms and/or on-site inspections. Telephone surveys may be used to confirm installation and gather data on facility size and operating hours to support the billing analysis. Data collected from building Energy Management Systems (EMS) can also provide cost-effective information and should be included in EM&V plans if available.	Billing analysis is only valid when the pre-existing (gas bills from the pre-retrofit period) is the appropriate baseline to be used in impact analysis.
Alternative M&V Methods	Adding on-site inspections to the basic method above improves confidence in building characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) may be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT Loggers and spot power measurements.
	Calibrated simulation modeling (Option D) is a viable alternative that maybe useful if Option C is inadequate or for measures that are part of a comprehensive package.	Natural gas sub-meters can be installed to isolate the heating equipment from other end-uses.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I HVAC: PRESCRIPTIVE CHILLERS

Summary of Recommended EM&V Methods

This category is limited to air-cooled and water-cooled chiller installations in commercial and industrial facilities as a prescriptive measure. Custom chiller installations are covered under C&I Custom Measures.

Characteristic	Approach	Additional Comments
Program Tracking	• Estimates of initial gross energy and demand savings and initial net impacts as applicable. • Number of installed units, chiller capacity, baseline and installed efficiency, and full load cooling hours.	Any additional parameters that could be useful for quality control or evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering offer the most cost-effective approach to prescriptive chiller projects. Data collected from building EMS may also provide cost-effective information and could be included in EM&V plans if available. Other factors that should be examined for cooling towers include the cleanliness of the cooling tower and the water temperature.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power measurements.
Alternative M&V Methods	An enhanced alternative is to conduct on-site inspections with metering that fully captures the entire chiller water system including supporting pumps and tower fans (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Additional parameters of value include supply and return water temperature and water flow expressed in gallons/minute.
	Calibrated simulation modeling (Option D) is a viable alternative that is especially effective at capturing measure interaction. Simulation modeling is particularly good at temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model.	Metering can be used to calibrate the model. Such metering may include whole premise interval kW recorders with some end-use metering.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I HVAC: UNITARY/SPLIT

Summary of Recommended EM&V Methods

This category is limited to unitary HVAC installations in commercial and industrial facilities as a prescriptive measure. Unitary equipment covers split system AC, packaged systems, air-source heat pumps, and water source heat pumps. Custom unitary air conditioning applications are covered under C&I Custom Measures.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross energy and demand savings, initial net impacts as applicable. • Number of installed units, HVAC unit capacity, baseline and installed efficiency, and full-load cooling *and heating* hours.	Any additional parameters that could be useful for quality control or evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most cost-effective approach to prescriptive unitary/split projects. Data collected from building Energy Management Systems (EMS) can also provide cost-effective information and should be included in EM&V plans if available.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power, flow and temperature measurements.
Alternative M&V Methods	An enhanced alternative is to conduct on-site inspections with metering that fully surround the measurement boundary (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Interval kW metering on whole-package units or both indoor/outdoor components of a split system.
	Calibrated simulation modeling (Option D) is a viable alternative that is effective at capturing measure interaction. Simulation modeling is particularly useful for assessing temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model. This is a viable option for buildings with many HVAC units, zones, or solar coupling effects.	Metering would conform Option D inputs and outputs and may include the whole-premise interval kW with some space temperatures.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I HVAC: OTHER MEASURES

Summary of Recommended EM&V Methods

This focuses on the Other HVAC category to HVAC control measures such as thermostats, economizers, and dual enthalpy controls. This category is limited to prescriptive installations in commercial and industrial facilities. Custom HVAC applications are covered under C&I Custom Measures.

Characteristic	Approach	Additional Comments
Program Tracking	• Initial gross energy and demand savings and initial net impacts as applicable. • Number of installed units, unit capacity and efficiency, full load cooling hours, free cooling/setback hours.	Any additional parameters that could be useful for quality control or evaluation design, such as sampling that are described in the EM&V plan.
Recommended M&V Method	On-site inspections with limited measurements on a sample of program participants (Option A). Site visits for HVAC control measures focus upon accurately inspecting and verifying operation of the controls. Data collected from building Energy Management Systems (EMS) can also provide cost-effective information and should be included in EM&V plans if available.	Metering methods may include strategically-placed time-of-use loggers to verify controls.
Alternative M&V Methods	An enhanced alternative would be an on-site inspection with metering that fully captures the impacts of the control (Option B). An hourly impact analysis would isolate the control impacts from the monitored data stream and assess across a Typical Meteorological Year (TMY) dataset.	Metering would be interval kW measurements on the affected HVAC units. Advanced metering can include enthalpy readings and damper position.
	Calibrated simulation modeling (Option D) is a viable alternative that is effective at capturing measure interaction and also control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. This is a viable option for buildings with many HVAC units and complex controls.	Metering would conform to Option B and include whole premise interval kW recording with some space temperatures.

(Source: Modified from the NEEP EM&V Protocols 2010)

<table>
<tr><th colspan="3">C&I LIGHTING (NEW CONSTRUCTION)
Summary of Recommended EM&V Methods</th></tr>
<tr><td colspan="3">This category encompasses C&I lighting in new construction programs.</td></tr>
<tr><th>Characteristic</th><th>Approach</th><th>Additional Comments</th></tr>
<tr><td>Program Tracking</td><td>• Initial gross energy and demand savings and initial net impacts as applicable.
• Installed quantity and wattage, corresponding baseline, fixture location, annual operating hours, in-service rate, HVAC interaction factor.</td><td>Any additional parameters that could be useful for quality control or for evaluation design, such as sampling that are described in the EM&V plan. Fixture location is critical for evaluation.</td></tr>
<tr><td>Recommended M&V Method</td><td>On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models. Data collected from building Energy Management Systems (EMS) can also provide cost-effective information and should be included in EM&V plans if available.</td><td>Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and or operating schedule.</td></tr>
<tr><td>Alternative M&V Methods</td><td>Some C&I Lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/ diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters are useful for recording lighting loads on circuits with many, individual occupancy sensors or dimming controls. Additional analysis with simple engineering models or 8,760 hour spreadsheets for rigorous assessment of coincident impacts could also be used.</td><td>More liberal use of lighting loggers. Alternatively, many commercial buildings isolate lighting systems in 277V power panels that can offer an excellent opportunity for interval metering on large amounts of lighting.</td></tr>
</table>

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I LIGHTING (RETROFIT) **Summary of Recommended EM&V Methods**		
This category encompasses C&I lighting in retrofit programs.		
Characteristic	**Approach**	**Additional Comments**
Program Tracking	Initial gross energy and demand savings estimates and initial net impacts as applicable. Installed quantity and wattage, corresponding Baseline, fixture Location, annual operating hours, in-service rate, HVAC interaction factor.	Any additional parameters useful for quality control such as sampling. Fixture location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models. Data collected from building EMS may also provide cost-effective information and should be included in EM&V plans if available.	Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and/or operating schedule.
Alternative M&V Methods	Some C&I lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters have proven useful for recording load on lighting circuits with many, individual occupancy sensors or dimming controls. Analysis with simple engineering models or 8,760 hour spreadsheets for rigorous assessment of coincident impacts could also be used.	More liberal use of lighting loggers. Alternatively, many commercial buildings isolate lighting systems in 277V power panels that offer a prime opportunity for interval metering on large amounts of lighting.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I MOTORS **Summary of Recommended EM&V Methods**		
This category is limited to the installation of premium efficient motors in C&I facilities as a prescriptive measure.		
Characteristic	**Approach**	**Additional Comments**
Program Tracking	• Initial gross energy and demand savings and initial net impacts as applicable. • Number of installed units, motor horsepower, ends Use and application (e.g. HVAC supply fan), Location, baseline and installed efficiency, Loading factor, and annual operating hours.	Any additional parameters useful for quality control and also for evaluation design such as sampling. Motor location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Basic site visits with time-of-use metering offers the most defensible and cost-effective approach to constant-speed, prescriptive motors. Data collected from building EMS may also provide cost-effective information and should be included in EM&V plans if available.	Metering methods include time-of-use CT or “magnetic field” loggers and spot power measurements.
Alternative M&V Methods	An enhanced alternative is to conduct on-site inspections with interval kW metering that track the electrical performance of the motor throughout its load range (Option B). This added rigor captures part-load efficiency effects that tend to be neglected in a Time-of Use (TOU) metered approach with SEMs.	Metering would be interval kW measurements for a reasonable duration to span a variety of motor loading situations.

(Source: Modified from the NEEP EM&V Protocols 2010)

C&I VARIABLE SPEED DRIVES **Summary of Recommended EM&V Methods**		
This category is limited to Variable Speed Drives (VSD) installations in C&I facilities as a prescriptive measure. Custom VSD applications are covered under C&I Custom Measures.		
Characteristic	**Approach**	**Additional Comments**
Program Tracking	• Initial gross energy and demand savings and initial net impacts as applicable. • Number of installed units, motor horsepower, end-use and application (e.g. HVAC supply fan), Location, savings factors, and annual operating hours.	Any additional parameters useful for quality control and also for evaluation design such as sampling. VSD location is critical for evaluation.
Recommended M&V Method	On-site inspections with interval kW metering that tracks the electrical performance of the motor/VSD combination throughout its load range (Option B). Lesser rigor would not capture the variability intrinsic to a VSD application.	Metering would be interval kW measurements for a reasonable duration to span a variety of loading situations.
Alternative M&V Methods	Calibrated simulation modeling (Option D) is an alternative that is effective at measure interaction and control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. This is a viable option for facilities with many VSDs on HVAC systems units.	Metering can be used to calibrate and validate the model. Such metering would mirror Option B perhaps with whole premise interval kW recording and some space temperatures.

(Source: Modified from the NEEP EM&V Protocols 2010)

PROTOCOL E: PROTOCOLS FOR VERIFICATION AND ONGOING MODIFICATION OF DEEMED SAVINGS VALUES

Protocol Scope: These protocols include the recommended timing for updating deemed savings values, especially for those technologies in which significant energy efficiency improvements occur on a periodic basis, such as lighting. These protocols also provide sources to consider when reviewing and modifying deemed savings, based on the findings from the literature review.

Customer Classes: All except self-directing customers

PROTOCOL E1: REVISING AND UPDATING DEEMED SAVINGS VALUES

1. Each deemed measure or measure set in the Arkansas Technical Reference Manual (TRM) is subject to a review to establish a "Sunset Date" at a minimum of every three (3) years or sooner if sooner conditions warrant. High Impact Measures will be reviewed annually. A High Impact Measure (HIM) is an energy efficiency measure that accounts for at least 5% of total portfolio gross kilowatt hour, kilowatt, and/or therm savings in one or more of the utility's energy efficiency programs.

2. Upon reviewing a Deemed Measure, the parties participating in the parties working collaboratively process may recommend that the Commission:
   a. Extend the "Sunset Date" for the measure with its cost and savings unchanged;
   b. Adopt revised cost and savings assumptions for the measure;
   c. Re-instate the Deemed Measure, contingent on the outcome of future evaluations, M&V, engineering work, and/or market research;
   d. Sunset the Deemed Measure and recommend that
      - A Simplified M&V Protocol will be developed for it;
      - It will be treated as a Custom M&V Measure; or
      - It will be eliminated.

PROTOCOL E2: IMPLEMENTATION OF CODE CHANGES

Codes and standards that affect equipment and systems sold and installed in Arkansas may be periodically updated. These codes and standards may include, but are not limited to, those listed below:

1. The International Energy Conservation Code, IECC
2. ASHRAE 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings
3. Arkansas Energy Code
4. The National Appliance Energy Conservation Act (NAECA)
5. EISA – the Energy Independence and Security Act of 2007

The purpose of these code and standards updates is to increase energy efficiency by codifying minimum equipment performance or baselines. This is in contrast to DSM programs, which are intended to motivate participants to install systems and equipment that exceed prevailing codes or standards.

These code and standard changes affect and change the baseline efficiency or performance used in calculating savings for; (1) replace on burnout and (2) new construction projects as well as (3) ‘outyear’ baselines on dual-baseline early retirement projects.

It is recognized that there is a lag between the time when a code or standard comes into force and when the industry has made a substantial transition to the new code or standard. In recognition of this lag time, TRM 7.0 makes provides a lag time to allow for the industry to adjust. Specifically, the TRM adoption date for a code or standard update is the beginning of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the beginning of the following program year.

PROTOCOL F: PROTOCOLS FOR THE DETERMINATION OF NET PROGRAM IMPACTS

Protocol Scope: These protocols, commonly used to determine net-to-gross ratio ("NTGR"), isolate free ridership and spillover rates. This protocol is designed to clarify the steps necessary to complete a "true-up" of program savings estimates ex post to determine the Lost Contribution to Fixed Costs (LCFC).

Customer Classes: All except self-directing customers

There are five approaches for determining NTGR:

- **Self-Reporting Surveys:** From participants and non-participants without independent verification;
- **Enhanced Self-Reporting Surveys:** Self-reporting surveys are combined with interviews and independent documentation review and analysis. They may also include analysis of market-based sales data;
- **Econometric Methods:** Statistical models are used to compare participant and non-participant energy and demand patterns. These models often include survey inputs and other non-program-related factors such as weather and energy costs (rates);
- **Deemed Net-to-Gross Ratios:** An NTGR is estimated using information available from evaluation of similar programs; and
- **Stipulation of Net-to-Gross Ratios:** The stipulation of a net-to-gross ratio is periodically used when the expense of the NTGR analysis and the uncertainty of the results are considered significant barriers (NAPEE 2007). This protocol does not support the usage of stipulated values if they yield results that are uncertain and/or costly; instead, the protocol would support the usage of literature reviews.

Recommended Net-to-Gross Analysis

Net-to-Gross (NTG) analysis is an important component of program evaluation because it helps to quantify estimated savings attributable to a program. NTG estimation involves triangulating data from multiple sources and therefore is incorporated into both the process and impact evaluation tasks. Relevant data sources include: surveys or in-depth interviews with customers, trade allies, and other key program stakeholders; data collection during on-site field inspections; billing records; and demand elasticity modeling using participating retailer sales data. In addition, NTG estimates may be further validated through a comparison of results from similar energy efficiency programs operating in other jurisdictions or examining a range of market data sources such as surveys, conference proceedings, and market assessments.

Estimating the impacts that are attributable to a program poses many challenges. First, the participants may not be able to accurately answer the necessary hypothetical question: *"What measures would you have installed anyway if you had not participated in the program?"* However, attribution is estimated not only for energy efficiency programs but also for other public policy initiatives/investments. While this is difficult and subject to some judgments and assumptions, NTG analyses can be performed on energy efficiency programs in such a way that reasonable information can be provided to policy makers that will assist them in making good decisions about these programs. While this is not an exact science, the attribution methods proposed herein are meant to achieve that objective (i.e., provide information in context that will inform policymakers and assist in assessing historic and future investments in energy efficiency).

Methodology

This section presents general definitions and methods that will be employed as part of a sound NTG analysis. The discussion is purposefully kept at a relatively high-level; additional details regarding the question sets and methods used to conduct the NTG analysis will be provided by the EM&V contractor. The NTG calculation will be applied retrospectively to the gross savings achieved during the program year being evaluated.

Derivation and Definition of Attribution

The methodology for assessing the energy savings attributable to a program is based on a NTGR that has two main components: free ridership and spillover.

Free ridership refers to program participants who received an incentive but would have installed the same efficiency measure on their own had the program not been offered. This includes partial free riders, defined as customers who, at some point, would have installed the measure anyway, but the program persuaded them to install it *sooner* or customers who would have installed the measure anyway but the program persuaded them to install more efficient equipment and/or more equipment. For the purposes of EM&V activities, participants who would have installed the equipment within one year will be considered full free riders; participants who would have installed the equipment later than one year will not be considered to be free riders (thus no partial free riders will be allowed).

Free ridership is the share of gross program savings that is generally the savings accounted for in program records and then adjusted for the naturally occurring adoption; the free ridership rate is based on actions participants "would have taken anyway" (i.e., actions that were not induced by the program). Each energy efficiency program covers a range of energy efficiency measures and is designed to move the overall market for energy efficiency forward. However, it is likely that some participants would have wanted to install some high efficiency measures (possibly a subset of those installed under the program) even if they had not participated in the program or been influenced by the program in any way.

Spillover refers to energy savings that are due to the influence of a program but are not counted in program records. For example, a customer installs a set of efficiency measures in one of his/her buildings. These measures were promoted (and incented) under a DSM program. The customer then decides to install the same measures at another site, where there is no program incentive. In this case, the program had an influence on the market beyond the energy savings in this customer's first building. Spillover can be broken out in three categories:

- **Participant Internal Spillover** represents energy savings from additional measures implemented by participants at participating sites not included in the program but directly attributable to the influence of the program.
- **Participant External Spillover** represents energy savings from measures taken by participants at non-participating sites not included in the program but directly attributable to the influence of the program.
- **Non-Participant Spillover** represents energy savings from measures that were taken by non-participating customers but are directly attributable to the influence of the program.

Spillover adds to a program's measured savings by incorporating indirect (i.e., not incented) savings and effects that the program has had on the market above and beyond the directly incented or directly induced program measures.

Total spillover is a combination of several factors that may influence non-reported actions to be taken at the project site itself (inside spillover) or at other sites by the participating customer (outside spillover). Each type of spillover is meant to capture a different aspect of the energy savings caused by the program, but not included in program records. Because a primary goal of most DSM programs is to transform markets through a variety of strategies – including education, promotion, and increasing awareness of the benefits of energy efficiency – one would expect spillover to occur to some extent in the market.

The overall NTGR is meant to account for both the net savings at participating projects and spillover savings that result from the program (but are not included in program records). When the gross program savings multiplies the NTG ratio, the result is an estimate of energy savings that are attributable to the program (i.e., savings that would not have occurred without the program). The basic equation is:

$$NTG = 1 - \text{Free ridership} + \text{Spillover}$$

The underlying concept inherent in the application of the NTG formula is that only savings caused by the program should be included in the final net program savings estimate, but this estimate should include all savings caused by the program (i.e., the net program savings should account for free ridership and include spillover).

Estimating Free Ridership: Survey Techniques

Data to assess free ridership should be gathered through a series of survey questions asked of end-use customers and trade allies who participated in the program. Free ridership can be evaluated by asking direct questions, aimed at obtaining respondent estimates of the appropriate free ridership rate that should be applied to them, and by supporting, or influencing questions used to verify whether the direct responses are consistent with participants' views of the program's influence.

The direct free ridership questions ask respondents to estimate the share of measures that would have been incorporated at high efficiency if not for the technical and financial assistance of the program. The questions also ask respondents to estimate the likelihood that they would have incorporated measures "of the same high level of efficiency" if not for the technical and financial assistance of the program. This flexibility in how respondents conceptualize and convey their views on free ridership will allow respondents to provide their most informed response, thus improving the accuracy of the free-ridership estimates.

The "program influence" questions clarify the role that program interventions (e.g., financial incentives and technical assistance) played in decision-making and provide supporting information on free ridership. Responses to these questions are analyzed for each respondent and used to identify whether the direct responses on free ridership are consistent with how each respondent rated the "influence" of the program.

These results will then be compared to free ridership estimates based on on-site inspections/audits, and/or estimates derived from similar surveys completed in other jurisdictions.

Estimating Spillover: Survey Techniques

The basic method for assessing participant (inside and outside) spillover employs a three-step approach to determine the following:

1. **Whether spillover exists at all**. These are yes/no questions that ask, for example, whether the respondent incorporated energy efficiency measures or designs that were not recorded in program records. Questions relate to extra measures installed at the project site (inside spillover) and to measures installed in non-program projects (outside spillover).

2. **The extent of the spillover.** These questions request information about the number or share of projects/jobs/facilities into which additional measures or technologies are installed (these questions are not asked for inside spillover because the value is simply the one project on which the interviewee focuses).

3. **The amount of savings per spillover project.** These questions ask respondents to estimate the energy savings associated with the non-recorded measures relative to the savings from the participating project itself.

The outcome of these inquiries is an estimate of the share of those non-recorded savings that can be attributed to the influence of the program.

Timing of Data Collection for Free Ridership vs. Spillover

The evaluation team should, where possible, use a staggered data collection approach to collect information in support of the NTG analysis. The rationale for this approach is that free ridership and spillover data are best collected at different points in time. Free ridership data are considered to be most accurate when collected as closely as possible to the point in time when the participation decision is made. Doing so helps to ensure accurate participant recall of motivating factors and relative program influence while also producing other benefits, including near-term feedback for program staff regarding program influence effects. Conversely, spillover data are considered most accurate when collected sometime after the participating project has been completed. Allowing a reasonable amount of time to pass before asking participants about spillover effects ensures that participants have sufficient time to: a) install the incented equipment, b) experience its operating parameters and costs, and c) then decide whether or not to install additional energy efficiency measures at the project site or some other location independent of any program support or financial incentive (Johnson et al., 2010).

Hierarchical Approaches for Determining When to Update NTG Values

One of the primary goals of this protocol is to provide a common framework with respect to the updating of NTG. It is critical that all utilities and their evaluators adopt this protocol to ensure a more thorough and consistent approach to net savings estimation and application, plus to direct evaluation resources to the areas of highest uncertainty. Note that the intent of this protocol is *not* to dictate the specifics (e.g., survey batteries or algorithms, market based approaches, etc.) with which NTG is estimated, but rather to help determine when an updated NTG estimate is needed and to ensure the evaluators provide clear rationale for determining which NTG approach was used in their reporting.

A several step decision tree should be used to help steer the timing for updating attribution analysis, which in the future should help evaluators determine when to collect current primary data, and when prior research or Arkansas specific secondary data might be reliable, with the final option being to rely on literature reviews. The framework is straightforward, whereby the updating of net savings follows the hierarchical approach (presented visually in Figure 5):

1. **Has NTG research been conducted on the same program in a prior year?** The first step to determining whether primary NTG research should be conducted in a given program year is to assess whether primary data – collected for the same program – are available from a prior year.[4] If prior data are available, the evaluation contractor should determine whether the prior values are applicable in the current year. There are at least two

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[4] Note that the prior data do not necessarily need to be from the prior year, nor do they need to necessarily be from a single year (e.g., two years of data may also be used if both years are determined to meet these criteria and it is believed the additional data would provide more robust results).

overarching components of this decision, both of which could have significant impacts on the NTG ratio.[5]

a. First, determine if the current program is similar to the program in which the primary data was collected: Is the mix of measures the same? Is the contribution to savings for each measure similar? Are the incentive levels comparable? Is (are) the delivery method(s) similar?

b. Second, determine if the market conditions are similar to the time period in which the prior data were collected: Has there been a substantial change in incremental cost for the efficient measures? Has there been a substantial change in the supply or availability of the efficient measures? Has there been a substantial change in the market share of efficient measures (i.e., the ratio of efficient measures sold to total comparable standard and efficiency measures)? Are the local or federal codes and standards the same as when the prior NTG values were estimated?

If the program and market conditions are comparable to the time period(s) in which the prior primary NTG research was conducted, these prior values can be considered applicable to the current program year.

2. **If prior year primary data are not available or are determined not to be applicable due to changes to either program or market conditions.** The evaluator should then determine whether or not the estimated savings from the program support primary research. In general, programs that represent at least 5-10 percent of the portfolio estimated savings in any given year should use NTG ratios that are estimated via primary data research for that specific program.[6]

3. **If prior year data for the program are not available or applicable, and the program savings does not support primary data collection.** The evaluation should then consider if NTG values derived from Arkansas-based comparable programs are available. A comparable program is defined as one that is similar in terms of program maturity, incentive levels, delivery mechanism, and measure types. Ideally, NTG values derived in the same program year would be used, but values from prior years may also be used if the comparability conditions are met.

4. For existing and new programs that do not meet any of the above specifications, then a literature review may be undertaken to locate a similar program (or programs) that has (or have) an established NTG value(s). This approach requires that the research be well documented, ***and the selected NTG value be reviewed and agreed to as reasonable by the IEM***. A program may be identified as similar if it meets the following conditions:

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[5] Note the questions presented here are examples of questions to ask to assess comparability, but are not meant to be exhaustive of the types of questions that should be addressed.

[6] The IEM understands that smaller portfolios have limited budgets to support any primary research, these thresholds are estimates and may vary based on the overall portfolio budget. As discussed, final decisions regarding the use of primary vs. secondary data for NTG research should be made in consultation with the IEM as part of the evaluation planning process.

i. **Program Similarity**: maturity, incentive levels, delivery mechanism, and measure types are similar; and

ii. **Market Similarity:** demographic, household, and business characteristics are similar (or as similar as possible) to Arkansas.

The IEM believes this hierarchical approach maximizes the use of valuable evaluation resources towards programs that could most benefit from primary research, and thus avoids unnecessarily repeating NTG research every year for the same programs. However, to prevent NTG values from being repeated too many years and becoming potentially “stale”, NTG values for programs that meet the contribution to savings threshold (#2 above) should be updated at least via primary research at least once during every three-year program cycle.

The IEM also understands that these decisions are open to some amount of interpretation and subjectivity (e.g., determining exactly what constitutes a substantial change in incremental cost, availability, or market share), so the steps along this decision tree should be clearly presented and discussed as part of the annual evaluation plans, and thus decision can be made in consultation with the IEM. The EM&V planning process has typically occurred in the summer months for the current program year. The IEM, however, is also available to discuss and agree upon final evaluation NTG approaches earlier in each program year.

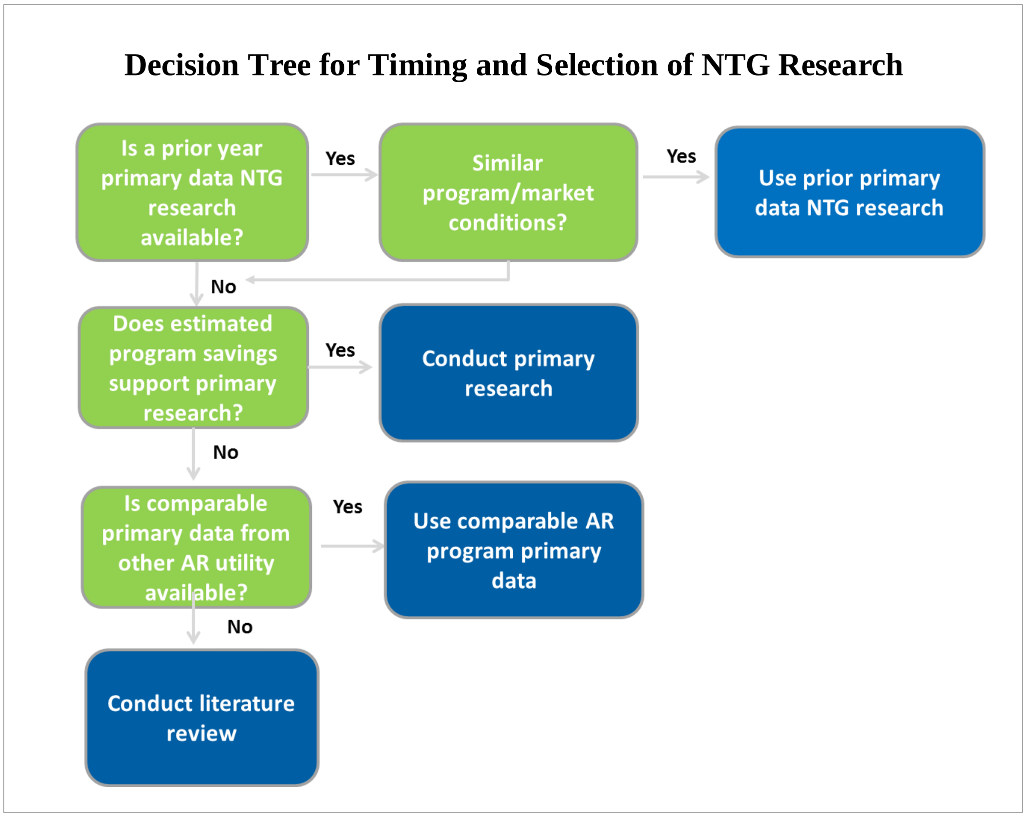

Figure 5: Decision Tree for Timing and Selection of NTG Research

Reporting Requirements

As noted above, while the intent of this protocol is *not* to dictate the specifics of all aspects of updating NTG estimates, the IEM believes this protocol can benefit evaluators and stakeholders alike by offering guidance to ensure the annual EM&V reports include robust reporting related to NTG research, methods, and findings. The goal is to ensure a degree of consistency and transparency in reporting. To help ensure consistency and transparency in reporting, the TRM recommends evaluators use the following minimum reporting protocol in their annual EM&V reports:

1. **Provide summary of each programs NTG source:** A simple table would suffice to allow readers a clear understanding of which programs received updated research versus those that relied on previous values, deemed values, or secondary research.
2. **Provide clear rationale for use of previous estimate or literature review:** EM&V Reports should cite evidence that the delivery, incentives, measures, and program design were unchanged.
3. **If unique NTG values are assigned to distinct program components, then each component should be reported with gross and net savings contributions.** Where different program components (e.g., measures) have different NTG values, evaluators should include each program component savings along with the respective NTG values in the EM&V reports.

To avoid redundancy in reporting while providing sufficient methodological details, this protocol also recommends evaluators follow a general approach to NTG methods in their reports, including:

4. **Provide high-level approach in methods section.** A methods section should detail the overarching NTG approach across programs, especially if the same algorithms and logic are used across multiple programs. The goal of this is to avoid redundancy and duplicative reporting across the individual program sections.
5. **Provide program-specific logic in each section.** If individual program NTG research includes customized logic that is distinct from the overall approach included in the methods section, then the differences in approach should be reported within each individual program section.
6. **Extensive detailed logic (questions, full battery of survey question) should be included in an appendix.** Complete survey battery logic, flow-charts, and comprehensive details of the program NTG approach should be included in an appendix.

Application of Trade Ally Input

As noted in the PY2013 IEM Report, the PY2013 evaluations included a number of NTG estimates that – according to the program evaluation plan – were going to leverage trade ally input, yet did not include trade ally responses or values (IEM PY2013 Annual Report, pg. xiii). In addition, a number of programs did utilize trade ally input, yet the research provided limited evidence that the responses were representative of the programs for which the values were utilized.

It is imperative that the evaluations adhere to the approved work plans, and where they diverge note the reasons for doing so and provide strong argument as to why they were not followed (e.g., inadequate sample, poor response rates, etc.). This is particularly true for NTG methods, which can provide widely different estimates depending on the method and the respondent type.

Evaluators should include specific details regarding their planned integration of trade ally responses with customer survey responses for overall program attribution within their work plans. Evaluations using trade ally responses should be collected for programs where the trade allies play a key role in the installation decision[7], and the work plans should present a discussion of the representation from the trade ally respondents. This protocol is not requiring evaluators to follow a specific algorithm to integrate trade ally responses, but the viability and consistency of approaches will be addressed by the IEM during the work plan review.

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[7] The importance of the trade ally on the decision to install an energy efficient measure can be assessed through participant surveys.

PROTOCOL G: PROVISIONS FOR LARGE CUSTOMERS

Protocol Scope: This protocol provides more detailed information regarding projects installed by industrial and commercial customers, and the challenges associated with establishing a streamlined process for measurement and verification. These protocols rely on the established "best practices" for ensuring that large custom-project directors will maintain the necessary building records and measure data to provide for robust EM&V activities and accurate measurement of energy savings. Often these projects involve highly technical, on-site engineering analysis and verification, which should be performed efficiently and cost-effectively, with as little impact on the customer site as possible. It is important to note that these types of EM&V protocols address custom measures for which deemed savings values do not exist and for prescriptive/direct-install measures that are being used in a non-traditional manner.

For specific guidance on the Opt-Out/Self-Direct Option, please consult Section 11 of Conservation & Energy Efficiency (C&EE) Rules filed in Docket 10-101-R.

Customer Classes: Large C&I customers except self-directing customers

The objectives of measure installation verification are to confirm that the:

- Measures were actually installed,
- Installation meets reasonable quality standards, and
- Measures are operating correctly, have the potential to generate the predicted savings.

The M&V should also verify and quantify actual savings at the site.

Installation verification should be conducted at all sites claiming energy or peak demand impacts where M&V is conducted. Installation verification activities may also be specified by the process or market effects protocols. Data collected from the building's EMS may provide cost-effective information and should be included in EM&V plans if available.

M&V projects conducted under this protocol shall adhere to the International Performance Measurement and Verification Protocol (IPMVP).

Development of Site-Specific M&V Plan: This protocol requires submittal of an M&V plan for each field measurement project that documents the project procedures and rationale in such a way that the results can be audited for accuracy and repeatability. Within the guidelines established by the IPMVP and these protocols, there is considerable latitude for the practitioner in developing a site-specific M&V plan and implementing the plan in the field. The M&V contractor shall evaluate the uncertainty in the desired data product, and develop a site-specific M&V plan that manages the uncertainty in the most cost-effective manner.

Initial estimates of engineering parameter uncertainties should be used to provide an estimate of the overall uncertainty in the savings calculations. Assumptions used to create initial estimates of parameter uncertainty values should be documented. The contribution of specific engineering parameters to the overall uncertainty in the savings calculations should be identified and used to guide the development of the M&V plan. The components of the M&V plan should:

1. **Identify Goals and Objectives.** The goals and objectives of the M&V project should be stated explicitly in the M&V plan.
2. **Specify Site Characteristics**. Site characteristics should be documented in the plan to help future users of the data understand the context of the monitored data. Depending on the nature of the measure, the site characteristics description should include:
    a. General building configuration and envelope characteristics, such as building floor area, conditioned floor area, number of building floors, opaque wall area and U-value; window area, U-value and solar heat gain coefficient;
    b. Building occupant information, such as number of occupants, occupancy schedule, building activities;
    c. Internal loads, such as lighting power density, appliances, plug and process loads;
    d. Type and quantity and nominal efficiency of heating and cooling systems;
    e. Important HVAC system control set points;
    f. Changes in building occupancy or operation during the monitoring period that may affect results; and
    g. Description of the energy conservation measures at the site and their respective projected savings.
3. **Specify Data Products and Project Output**. The planned output and results of the M&V activity should be specified. These data products should be referenced to the goals and objectives of the project, and include a specification of the data formats and engineering units.
4. **Specify an M&V Option.** The M&V option chosen for the project should be specified according to the IPMVP, consistent with the M&V protocol.
5. **Specify Data Analysis Procedures and Algorithms.** Engineering equations and stipulated values, as applicable, shall be identified and referenced within the M&V plan. Documentation supporting baseline assumptions shall be provided.
6. **Specify Field Monitoring Data Points.** The actual field measurements planned should be specified, including the sensor type, location, and engineering units.
7. **Estimate Data Product Accuracy.** All measurement systems have error, expressed in terms of the accuracy of the sensor and the recording device. The combined errors should be estimated using a propagation of error analysis, and the final data product should be accurately described.
8. **Specify Verification and Quality Assurance Procedures**. Data analysis procedures to identify invalid data and treatment of missing data and/or outliers must be provided.
9. **Specify Recording and Data Exchange Formats**. Data formats compliant with the data reporting protocol should be described.

(Modified and Expanded from CA Evaluators' Protocols 2006).

Additional Guidance for the IPMVP Protocols for Custom Projects
1. **Measure existence** should be verified through on-site inspections of facilities; measure make and model number data shall be collected and compared to participant program records as applicable. Sampling may be employed at large facilities with numerous measures installed. As-built construction documents may be used to verify measures such as wall insulation where access is difficult or impossible. Spot measurements may be used to supplement visual inspections, such as solar transmission measurements and low-e coating detection instruments to verify the optical properties of windows and glazing systems.
2. Quality of Installations: Measure installation inspections shall note the quality of measure installation, including the level of workmanship employed by the installing contractor toward the measure installation and repairs to existing infrastructure affected by measure installation, and physical appearance and attractiveness of the measure in its installed condition. Installation quality guidelines developed by the program implementer shall be used to assess installation quality. If such guidelines are not available, then the guidelines shall be developed by the M&V contractor and approved by the Commission prior to conducting any verification activities. Installation quality shall be determined from the perspective of the customer.

(Source: Modified from CA Evaluators' Protocols 2006)

PROTOCOL H: TECHNICAL REFERENCE MANUAL (TRM)

Protocol Scope: To provide a clear and effective method for updating the Arkansas TRM

The Arkansas TRM is designed to be a dynamic document which will benefit from periodic updates developed by the PWC through an objective and thoughtful process. Defining a process that coordinates with the needs of users, evaluators, and the APSC is critical. It is critical to maintain a current TRM and consider any necessary updates to the document at least annually, at the same time recognizing the need for the users of the TRM and others to have some degree of certainty as to the TRM values upon which they can rely. Accordingly, this protocol describes the process for updating the TRM and coordinating this process with other critical activities. The annual update process set forth herein is the preferred course of action for updating the TRM.

TRM Update Process

The PWC should work cooperatively to identify any necessary revisions and to present any revisions to the Commission by August 31 each year. Examples of events that may precipitate the need to consider changes to the TRM, may include but are not limited to:

- **New measure additions.** As new technologies become cost-effective, they will need to be characterized and evaluated for addition to the manual. In addition, new program delivery design may result in the need for new measure characterization.
- **Existing measure updates.** Updates may be required for a number of reasons. Examples include: the federal standard for efficiency of a measure has changed; the qualification criteria are altered; the measure cost falls; or a new evaluation provides a better value of an assumption for a variable. In addition, as programs mature, characterizations need to be updated, where changes in the market support changes in calculation assumptions. In such cases, these changes must be identified and appropriate changes to the TRM evaluated.
- **Retiring existing measures.** When the economics of a measure become such that it is no longer cost-effective, or the free rider rate is so high that it is not worth supporting the measure, or if the market has changed, then the measure should be evaluated for retirement.
- **High Impact Measure (HIM) reprioritization.** The prioritization of measures in terms of the HIM Tier classification is subject to change over time depending on the relative magnitude of reported energy savings resulting from actual program measure installations.

The flowchart in Figure 6 outlines the steps for regular TRM updates. The PWC will work cooperatively to identify any necessary revisions to the TRM. To ensure there is a clear differentiation between policy and technical matters, the PWC should establish regular meetings devoted to policy issues and resolving technical issues in which the PWC can discuss these matters and determine the any necessary revisions to the TRM for recommendations to the Commission for approval.

The process outlined in Figure 6 requires a number of different roles to ensure effectiveness, sufficient review, and independence. The following is a list of key roles and responsibilities for this process. The list of roles and responsibilities is not comprehensive.

- **Arkansas Public Service Commission (Commission)**

  - Approves or denies any changes to the TRM, as well as this TRM process.
- **Independent Evaluation Monitor (IEM)**
  - Assures compliance with national Evaluation, Measurement, and Verification ("EM&V") "best practices," and Commission-approved protocols and the Arkansas TRM.
  - Manages timely updates and/or expansion of deemed savings and the TRM are pursued.
  - Oversees and coordinates the activities of the TRM Technical Manager.
  - Gives feedback on draft measure characterizations from other parties
  - Coordinates with Staff on recommendation for TRM revision to the Commission.
  - Manages and updates TRM manuals (after Commission approval of changes).
  - Ensures proper use of TRM in annual savings verification process.
- **Program Administrators / Utilities / Program Implementers**
  - Identify need for new or revised measure characterization (usually due to program changes or program/market feedback).
  - Communicates need for new or revised measure to IEM.
  - Give feedback on draft measure characterizations from other parties.
  - Participate in formal discussion and dispute resolution.
- **TRM Technical Manager**
  - Identifies need for revised measure characterization (usually based on knowledge of local or other relevant evaluation studies).
  - Reviews, researches and/or develops draft measure characterizations identified either by itself, EM&V Contractor, Utility, IEM or other party.
  - Incorporates revisions to draft and final TRM documents.
- **EM&V Contractors**
  - Identify need for revised measure characterization (usually based on local evaluation studies it has conducted or managed).
  - Research and/or prepare draft measure characterization for PWC consideration.
  - Provide input/feedback on draft measure characterizations developed by other parties.
  - Perform program evaluation - includes statewide market assessment and baseline studies, savings impact studies (to measure the change in energy and /or demand use attributed to energy efficiency), and other energy efficiency program evaluation activities.
  - Verify annual energy and capacity savings claims of each program and portfolio.

- **Staff**
  - Works with the PWC and IEM to identify any necessary changes to TRM.
  - Annually, by August 31, submits recommended revisions to the TRM to the Commission for its approval.
  - Provides supporting testimony for any recommended revisions.

- **Other Parties to the Docket/ Interveners**
    - Identify need for new or revised measure characterization (usually based on knowledge of local or other relevant evaluation studies).
    - Give feedback on draft measure characterizations from other parties.
    - Provide input and assist in identifying necessary revisions to the TRM.
    - Provide testimony as needed addressing recommended revisions to the TRM.

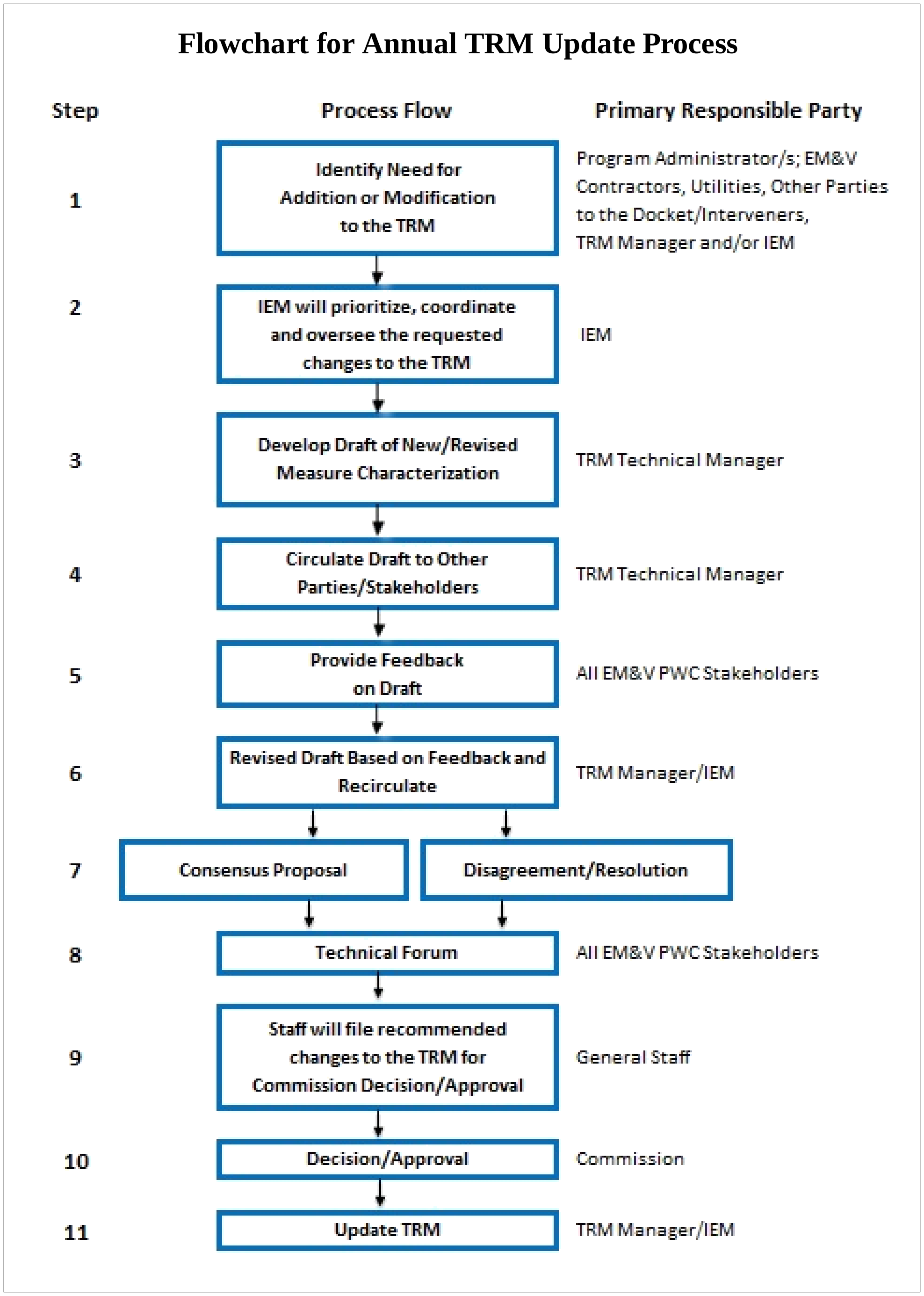


Figure 6: Flowchart for Annual TRM Update Process

This process includes several potential stages of discussion and feedback on draft modifications to the TRM. The IEM will convene a Technical Forum for the PWC and other key stakeholders. This forum will identify the changes made to the annual TRM update, and highlight the findings in the Annual TRM update. It will also provide an opportunity for the Parties to ask questions and provide more detailed information regarding the scope of these changes.

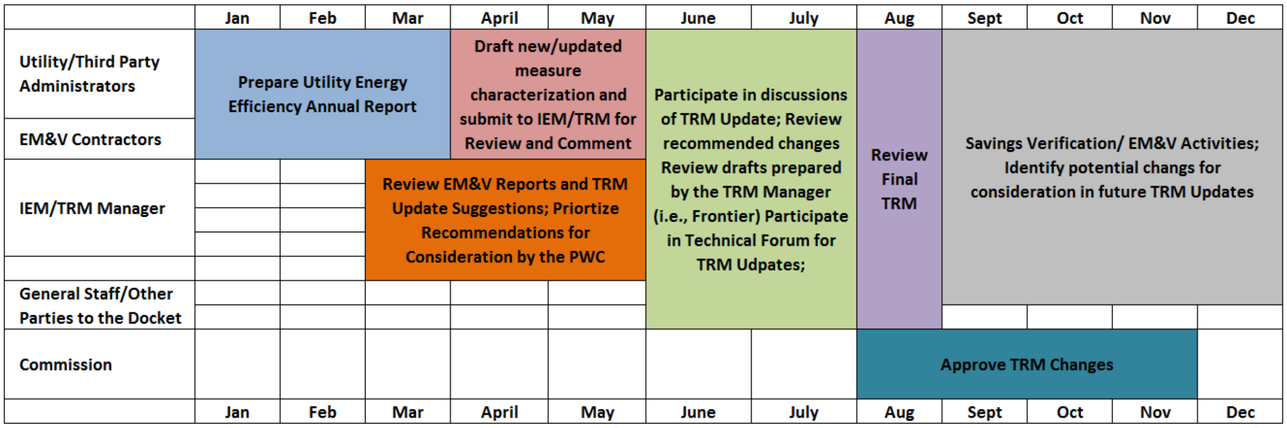
Items included in the Technical Forum include:

- Present what changes were made to the TRM, and the reasons for the changes including a detailed discussion of the assumptions made and the basis for these findings;
- Review the timing for incorporating the changes;
- Discuss the implications of the changes on current and future programs;
- Identify other potential energy efficient technologies that should be considered for future TRM updates, based on our experiences in other jurisdictions; and
- Attempted resolution of any disagreements.

The Technical Forum may take the form of a one-day workshop, and will include presentations from the EM&V contractors and the PWC in addition to the appropriate members of the IEM team.

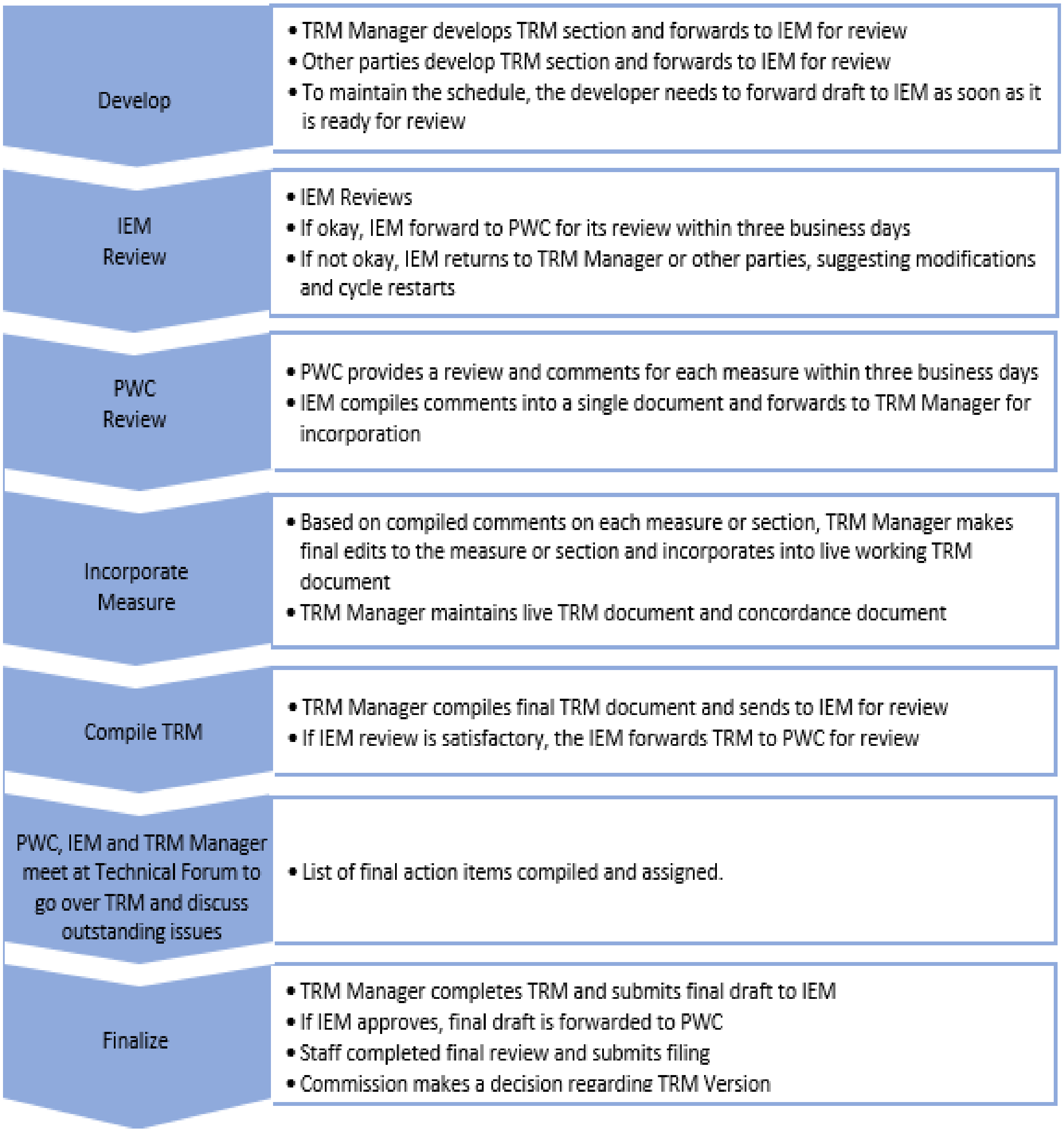
Table 7 provides a recommended timeline for a coordinated process in line with the Commission deadlines.

Table 7: Annual Verification and TRM Update Timeline



	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Utility/Third Party Administrators	**Prepare Utility Energy Efficiency Annual Report**			**Draft new/updated measure characterization and submit to IEM/TRM for Review and Comment**		**Participate in discussions of TRM Update; Review recommended changes Review drafts prepared by the TRM Manager (i.e., Frontier) Participate in Technical Forum for TRM Udpates;**		**Review Final TRM**	**Savings Verification/ EM&V Activities; Identify potential changs for consideration in future TRM Updates**			
EM&V Contractors												
IEM/TRM Manager			**Review EM&V Reports and TRM Update Suggestions; Priortize Recommendations for Consideration by the PWC**									
General Staff/Other Parties to the Docket												
Commission								**Approve TRM Changes**				
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

Detailed Process for Updating TRM



Develop

- TRM Manager develops TRM section and forwards to IEM for review
- Other parties develop TRM section and forwards to IEM for review
- To maintain the schedule, the developer needs to forward draft to IEM as soon as it is ready for review

IEM Review

- IEM Reviews
- If okay, IEM forward to PWC for its review within three business days
- If not okay, IEM returns to TRM Manager or other parties, suggesting modifications and cycle restarts

PWC Review

- PWC provides a review and comments for each measure within three business days
- IEM compiles comments into a single document and forwards to TRM Manager for incorporation

Incorporate Measure

- Based on compiled comments on each measure or section, TRM Manager makes final edits to the measure or section and incorporates into live working TRM document
- TRM Manager maintains live TRM document and concordance document

Compile TRM

- TRM Manager compiles final TRM document and sends to IEM for review
- If IEM review is satisfactory, the IEM forwards TRM to PWC for review

PWC, IEM and TRM Manager meet at Technical Forum to go over TRM and discuss outstanding issues

- List of final action items compiled and assigned.

Finalize

- TRM Manager completes TRM and submits final draft to IEM
- If IEM approves, final draft is forwarded to PWC
- Staff completed final review and submits filing
- Commission makes a decision regarding TRM Version

Figure 7: Detailed Process for Updating TRM

PROTOCOL I: ROLE AND RESPONSIBILITIES OF THE INDEPENDENT EM&V MONITOR

The Commission's Order, dated December 10, 2010, establishing the Parties Working Collaboratively (PWC) to develop an EM&V protocol required that Staff file with the Commission, on or before June 1, 2011, suggested EM&V rule changes requiring the implementation of EM&V in accordance with National Action Plan for Energy Efficiency (NAPEE) "best practices." Commission-ordered Task (2)(i) on page 16 calls for the "establishment of an ongoing, annual process for a single, Independent EM&V Monitor (IEM) jointly funded by EE utilities, to report to the Commission regarding the validity of utility EM&V programs and annual filings and to suggest ongoing improvements to EM&V activities."

Staff, after reviewing input from the utilities and other stakeholders, will be responsible for selection of the IEM. The Commission may ultimately resolve any disputes as to the selection and retention of the IEM. The IEM's fees and expenses shall be paid by the utilities, and these costs will be included in EM&V budgets and cost-effectiveness calculations, and recovered through its EECR rider. Each utility shall pay its share of the costs based on a ratio of its number of customers to the total of customers for all utilities combined.

The fundamental role of the IEM is to be advisory in nature. In this role, the IEM is tasked with providing technical consultation services to participating Arkansas utilities, staff and interveners regarding strategies that will result in program compliance with EM&V rules or protocols approved by the Commission. In the interest of regulatory economy, the IEM will work with staff, utilities and other parties to each utility's EE docket to ensure that any EM&V advisory input reflects the informed consideration of all parties.

To ensure fully independent evaluations, the IEM will be engaged throughout the ongoing process of prioritizing evaluation activities and budgets, defining evaluation objectives and methodologies, reviewing evaluation results, and a range of other continuing and related EM&V activities. At the conclusion of such an annual a process, the IEM will have the responsibility of issuing a report to the Commission regarding the integrity of utility EM&V programs and activities, and to suggest ongoing improvements to EM&V activities. After the issuance of the report and a reasonable comment period, the Commission may use the report as a basis to issue orders to the utilities.

The IEM will provide advisory assistance to the utilities, Staff and the interveners, including but not limited to the following broad categories. This list is intended to be illustrative.

- Assure of compliance with national EM&V "best practices," Commission-approved protocols and the TRM;
- Verify credentials, performance and independence of EM&V contractors and vendors.
- Assure adequacy of individual utility EM&V program budgets and the timing and prioritization of evaluation projects;
- Review utility energy efficiency program evaluation projects and EM&V methodologies, including PWC administered multi-utility evaluations;
- Recommend improvements to EM&V processes and procedures, including those related to custom program projects;
- Recommend improvements to the overall EM&V decision-making process and each utility's program design(s) and program implementation as it relates to EM&V;
- Assure timely updates and/or expansion of deemed savings and the TRM;

- Recommend updates to DSM potential and baseline studies as well as recommend appropriate multi-utility PWC EM&V efforts; and
- Recommend additional financial (or other) resources that may be necessary for the effective functioning of the IEM or EM&V stakeholder process.

PROTOCOL J: RESIDENTIAL BEHAVIOR-BASED PROGRAM EVALUATION PROTOCOL

This protocol was developed to reflect the evolving nature of energy efficiency programs now offered by utilities and third-party administrators in Arkansas. This protocol specifically addresses the prescribed approach to conducting evaluations for residential behavior-based programs. This protocol was developed based upon the recommended best practices described in the State and Local Energy Efficiency (SEE) Action Network (published by Lawrence Berkeley National Laboratory (LBNL) report, "*Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*"[8] and updated guidance from The Uniform Methods Project (UMP): Residential Behavior Protocol, 2017.[9] This protocol cites the sections in which these specifications are referenced.

Behavior-based energy efficiency programs are those that use strategies intended to affect consumer energy use behaviors to achieve energy and/or peak demand savings. Program types typically include real-time or delayed feedback about their energy use; supplying energy efficiency education and tips; rewarding households for reducing their energy use; comparing households to their peers; and establishing games, tournaments, and competitions (UMP, 2017). Such programs may rely on changes to consumers' *habitual* behaviors (e.g., turning off lights) or *one-time* behaviors (e.g., changing thermostat settings). In addition, these programs may target purchasing behaviors (e.g., purchases of energy efficient products or services), often in combination with other programs (e.g., rebate programs or direct install programs) and often target multiple end-uses. Savings from behavior programs are usually a small percentage of energy use, typically less than five percent (UMP, 2017).

Key Definitions

Conducting evaluations of these programs first requires defining the following key terms. These definitions are cited from the SEE Action/LBNL Report 2012:

- **Treatment Group:** the group of households that are assigned to receive the treatment
- **Control Group:** the group of households that are assigned not to receive the program
- **Experimental Design:** a method of controlling the way that a program is designed and evaluated in order to observe outcomes and infer whether or not the outcomes are caused by the program
- **Randomized Controlled Trial (RCT):** a type of experimental design; a method of program evaluation in which households in a given population are randomly assigned into two groups — a treatment group and a control group — and the outcomes for these two groups are compared, resulting in unbiased program savings estimates
- **Quasi-Experimental Design:** a method of program evaluation in which a treatment group

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[8] State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*. Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory. http://behavioranalytics.lbl.gov.

[9] Department of Energy, Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Chapter 17: Residential Behavior Protocol. September, 2017. https://energy.gov/eere/about-us/ump-protocols

and a control group are defined but households are not randomly assigned to these two groups, resulting in program savings estimates that may be biased (LBNL Report 2012, p. 14).

The protocol begins with a detailed discussion regarding the recommended evaluation design, then continues with a discussion regarding model specification, and concludes with other evaluation issues. The protocol also includes models that are appropriate for evaluators to use when determining the likely effects pre- and post- of behavior-based programs.

EVALUATION DESIGN

Since behavior-based programs may not always specify or track particular actions that result in energy savings, the recommended approach to determine the effects of behavior-based efficiency programs is randomized controlled trial (RCT), which will result in the most robust, unbiased program savings impact estimates. As an alternative, the protocols also allow for two quasi-experimental designs.

The Randomized Controlled Trials (RCT) Method

In an RCT, first a *study population* is defined and then the study population is *randomly assigned* to either the treatment or control group. Energy use data must be collected for all households in the treatment and control group in order to estimate energy savings. The estimate of energy savings is then calculated by comparing the difference between the measured energy usage of the treatment households relative to the energy usage of the control households. Measured energy use typically comes from utility meter data, often in monthly increments.

Random assignment means that each household in the study population is randomly assigned to either the control group or the treatment group based on a random probability, as opposed to being assigned to one group or the other based on some characteristic of the household (e.g., location, energy use, or willingness to sign up for the program).

Randomization eliminates pre-existing differences that are both observable differences (e.g., energy use or floor area of households) as well as differences that are typically unobservable (e.g., attitudes regarding energy conservation, number of occupants, expected future energy use, and occupant age) unless surveyed. Thus, because of this random assignment, an RCT control group is an ideal comparison group: it is statistically identical to the treatment group in that there are no pre-existing differences between the two groups, which means that selection bias is eliminated (LBNL Report, p. 24).

RCTs also eliminates the free rider concern during the study period because the treatment and control groups each contain the same number of free riders through the process of random assignment to the treatment or control groups. When the two groups are compared, the energy savings from the free riders in the control group cancel out the energy savings from the free riders in the treatment group. Furthermore, *participant spillover* is also automatically captured by an RCT design for energy use that is measured within a household. The resulting estimate of program energy savings, therefore, is an unbiased estimate of the net savings caused by the program (the true program savings) (LBNL Report, p. 24).

There are three basic program enrollment options for behavior-based programs: opt-out enrollment, opt-in enrollment, and encouragement design, which does not restrict or withhold participation in the program to any household. Program designs with *any* of these enrollment options may use RCTs for evaluation and thus each enrollment option can yield unbiased savings estimates. With any of the enrollment options, the random assignment of households into treatment and control groups is the crucial step. All data from the randomization point forward should be analyzed to ensure internal validity.

When implementing RCTs with any of these three enrollment options, the first step is to define the target market and the eligible households that are included in the study population (i.e., the screening criteria). Often this screening process restricts the study population to specific geographies (zip codes or service areas), specific demographics (hard-to-reach, medical needs, elderly), specific customer characteristics (high energy users, dual fuel use, length of customer bill history), and specific data requirements (one year of historical energy data available, census information is available, smart meter installed). Another way to reduce the size of the study population is to randomly select households out of a larger population in order to form a smaller subset of households (LBNL Report 2012, p. 26).

Randomized Controlled Trials with Opt-Out Enrollment

In some cases, program administrators may want to enroll households using an opt-out method (see Figure 8). For this type of program, an RCT with an opt-out recruitment strategy determines that after households have been evaluated for program eligibility (i.e., *screened in* or *screened out*); the remaining households are placed in the study population and are randomly assigned to either the control group or the treatment group. The treatment group receives the program (but are allowed to opt-out), and the control group does not receive the program (and are not allowed to opt-in). Energy use data must be collected for all of the households in the control and treatment group, whether or not they opt-out, in order to estimate energy savings without bias.

Randomized Controlled Trial With Opt-Out Enrollment

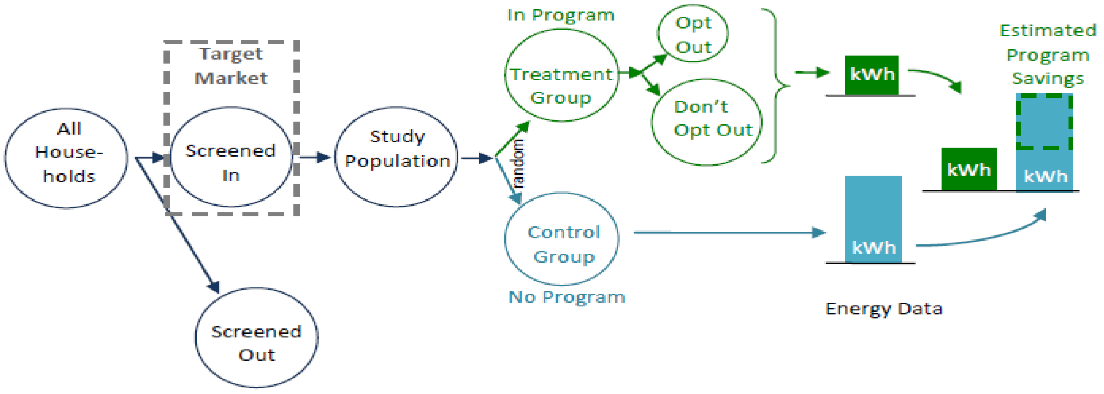

Figure 8: Randomized Controlled Trials with Opt-Out Enrollment[10]

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[10] SEE/LBNL, page 14.

Randomized Controlled Trials with Opt-In Enrollment

For some types of behavior-based efficiency programs, an opt-in enrollment method may be more desirable than an opt-out method. Using an RCT with an opt-in recruitment strategy, after households have been screened, the program is marketed to the remaining households. These households decide whether they want to opt-in to the program. The households that opt-in define the group of households in the study population, which are then randomly assigned to either the control group or the treatment group. It is important that a randomly selected group of opt-in households is placed in the control group in order to have unbiased results: if households that opt-in are compared with a control group of households that did not opt-in, then these two groups contain very different types of households, which can result in selection bias and potentially invalid results.

There are two methods for randomizing the opt-in households into a treatment and control group: *recruit-and-delay* and *recruit-and-deny*. In *recruit-and-delay (*also called *waitlist) design*, households that opt-in are told that the program is currently oversubscribed and some households may randomly be placed on a waitlist for a short time. In a *recruit-and-deny design*, households that opt-in are told that the program is oversubscribed and so some households will be randomly chosen to participate. Energy use data must be collected for all households in the treatment and control group in order to estimate energy savings.

Randomized Controlled Trials with Encouragement Design

Often, program implementers want to allow households to opt-in and do not want to deny or delay enrollment in the program. In this case, an *RCT with encouragement design* (sometimes called RED) yields an unbiased estimate and does not exclude *anyone* from participating in the program. However, an RED design typically involves a much larger sample size requirement to produce robust estimates of savings. An encouragement design is used after households have been screened by the utility; the households that meet the screening criteria define the study population and are randomly assigned to the control or treatment group. The treatment group is then encouraged to participate in the program. Some households may decide to opt-in to the program while others may not. Households in the control group are not encouraged to participate, although, because the program is open to anyone, some of these households may learn of the program and decide to opt-in. In order to have an unbiased estimate of energy savings, energy use data must be collected for all households in the treatment and control group for both the households that opted in to the program as well as those that did not.

Quasi-Experimental Methods

As discussed in the SEE/LBNL report, most quasi-experimental methods introduce potential bias into the savings estimates. For this reason, the Arkansas Behavior-Based Evaluation Protocol strongly recommends use of one of the RCT approaches wherever possible.

There are situations, however, where use of an RCT can be extremely difficult, and thus as a secondary approach these protocols do allow the use of quasi-experimental methods if necessary. The recommended approaches are identified in the SEE/LBNL report as the Regression Discontinuity Method and the Variation in Adoption (With a Test of Assumptions) methods.

Rather than recruit-and-delay or recruit-and-deny, which can be difficult to implement, both of these methods allow customers to opt-in at the time of interest.

Regression Discontinuity Method

Among the quasi-experimental methods, regression discontinuity typically yields the most unbiased estimate of energy savings. However, it is also the most complicated method; it requires knowledge of econometric models and often requires field conditions that allow the evaluator to utilize this analytic technique, and is therefore not always practical. This method works if the eligibility requirement for households to participate in a program is a cutoff value of a characteristic that varies within the population. For example, households at or above a cutoff energy consumption value of 900 kWh per month might be eligible to participate in a behavior-based efficiency program, while those below 900 kWh are ineligible. In this case, the households that are just below 900 kWh per month are probably very similar to those that are just above 900 kWh per month. Thus, the idea is to use a group of households right below the usage cutoff level as the control group and compare changes in their energy use to households right above the usage cutoff level as the treatment group. This method assumes that the program impact is constant over all ranges of the eligibility requirement variable that are used in the estimation (e.g., that the impact is the same for households at all levels of energy usage), although there are more complex methods that can be used if this assumption is not true.53 In addition, regression discontinuity relies on the eligibility requirement being strictly enforced.

Variation in Adoption (With a Test of Assumptions)

Under the Variation in Adoption method, also commonly referred to as a “rolling” control group design, the control group is made up of participants who sign up towards the end (or even following) the post-treatment period of interest.[11] The assumption is that the customers in the control group are similar to those in the treatment group, the primary difference being that they signed up at a slightly later period than the treatment group, thus their pre-participation period represents participant post-period usage in absence of the program (i.e., they serve as a control group up until the point that they enter the program, at which point they would be dropped from the treatment group).

As an example, assume that the year of interest for analysis is 2011, examining savings for all customers that signed up for the program (opted in) in 2011. The analysis would then need billing data for 2010-2012 to ensure that every participant has at least 12 months pre- and post- billing data. The control group, however, would be made up of customers that signed up in late 2012 (e.g., the last quarter) and early 2013 (e.g., the first and possibly second quarters). Any pre-program months for 2010-2012 for the control group can then be used in the billing analysis to represent the potential change from pre- to post-treatment of the participant group.

To implement this approach, the evaluation also needs to test the assumption that the only difference is the timing of enrollment, rather than any observable household characteristics. This

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[11] Note this approach has been used by evaluators for many years for identifying a control group for opt-in programs such as low-income or residential audit programs.

assumption can be tested through a duration analysis or propensity score matching, as discussed in the SEE/LBNL document.

Recommended Approach for Analysis Model Specification

This section presents a number of important issues regarding the specification of the model.

Length of Study and Baseline Period

Relatively longer treatment periods and pre-treatment data periods are likely to lead to greater precision of the estimated program impact. Although savings can be estimated using energy se data from the treatment period (UMP, 2017), it is important to collect at least one full year of historical energy use data in order to have baseline data for each month and season since patterns of household energy use often vary by season. Thus, it is strongly advised that at least one full year (the twelve continuous months immediately prior to the program start date) of historical energy use data be available for each customer — both for those in the treatment group and in the control group —so that the baseline energy use reflects seasonal effects. Energy use measurements should be collected directly from the utility, not from the program implementer (UMP, 2017).

Model Specification

Panel vs. aggregated data. Analysis models can either use energy data that are aggregated across time for both the pre- and post-program periods (e.g., average energy use for the period prior to and during the program year) or panel data (also called time series of cross-sectional data), which typically are data from multiple time points for pre- and post-program periods (e.g., monthly energy use for each month of the pre- and post-program periods). While the protocols allow for both, the panel data models are preferred because they result in a more precise estimate of energy savings, including seasonal variation of savings.

Comparison of energy usage vs. change in energy usage. Analysis models can be specified to estimate program savings by either comparing the energy saved by the treatment group (i.e., the change in energy use prior to and during the program) to the energy saved by the control group, or comparing the energy use of the treatment group to the control group during the program. The protocols recommend the difference between the change (i.e., the “difference of the differences”) because it will typically be more precise due to the fact that the amount that the change in energy usage varies between households often varies less than the amount that energy usage varies between households.

Equivalency Check

Because the degree to which a savings estimate is unbiased depends on how similar the control group is to the treatment group, an important part of the analysis is validating that the two groups are equivalent. The correct procedure is to determine if the households in the treatment group have characteristics that are statistically similar to those in the control group. At a minimum, the evaluators should compare the monthly or yearly pre-program energy use and the distribution of pre-program energy use between the treatment and control group. Other possible covariates, which may or may not be available, include geographic location, dwelling characteristics (e.g., square footage), demographic characteristics (e.g., age, income), and psychographic characteristics (e.g., opinions) and any other baseline covariates for which data is available. This should be done whether the program is designed as an RCT or a quasi-experiment.

Statistical Significance and Sample Sizes

Evaluations of behavioral programs in Arkansas should follow the SEE/LBNL report recommendation that a null hypothesis (i.e., a required threshold such as the level or percentage of energy savings needed for the benefits of the program to be considered cost-effective) should be established, and the program savings estimate should be considered acceptable (and the null hypothesis should be rejected) if the estimate is statistically significant at the 5% level or lower. This threshold, which is greater (more precise) than that typically used by energy program evaluation (which is usually a confidence/precision level of 90/10), is the acceptable standard in behavioral sciences research.

Consistent with UMP, 2017, the analysis sample should be large enough to detect the minimum hypothesized program effect with desired probability. UMP recommends using a statistical power analysis to determine the minimum number of subjects required and the number of subjects to be assigned to the treatment and control groups[12].

Note that evaluations of programs with smaller sample sizes (e.g., only hundreds of participants) should also attempt to assess savings at this significance level by using additional control variables as needed, but may report and claim savings at 90% significance.

Treatment of Households that Opt-Out or Close Accounts

Households that opt-out should never be excluded from the dataset; they should be included as part of the treatment group to avoid selection bias. In order to calculate an unbiased estimate of the effect of the program on those that did not opt-out, the program impact should be estimated including the opt-out households as part of the treatment group.

Households that close their accounts — including any changes in tenants at the same site — should be dropped entirely from the evaluation dataset (i.e., every data point for these households should be deleted) for both the control and treatment groups. However, there may be situations in which dropping households that closed accounts leads to biased estimates (e.g., younger and more mobile populations may be more responsive to behavior-based programs and may also be more likely to close accounts). In this case, if the analysis is done correctly with an indication that a specific sub-group of the population closed accounts, it may be better to include households that closed accounts.

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[12] See UMP Section 4.2 for more explanation.

Additional Evaluation Issues

Controlling for Double Counting

For programs in which efficiency measures can be tracked to a specific household (e.g., installation of insulation by a contractor), and sample sizes between the treatment and control group are equal, double-counted savings can be directly determined as the incremental participation in the non-behavior program (as shown in Figure 9 and in LBNL Report 2012, p.44). For cases where the sample sizes between the treatment and control group are not equal, the double counting should be quantified on the basis of the difference in per-participant savings from non-behavior programs.

Because the program and evaluation design of the behavior-based program utilizes a treatment and control group, we can infer that the double-counted savings were caused by the behavior-based program. While the SEE/LBNL report stops short of recommending how to handle the assignment of savings to program, the report does suggest that it is reasonable to assign at least half of the double-counted savings to the behavior-based efficiency program. The protocols agree with this assessment and approve of assigning half of the double-counted savings to each program. Note, however, that this also means appropriately dividing the program costs, as well as adjusting the lifetime savings for the measures that are being assigned to the behavioral program (i.e., greater than one year). Due to the potential complexity of dividing the incremental double-counted savings, however, the protocols also approve assigning all the incremental double counted savings to the other (non-behavioral) program, as has been the standard evaluation practice at the time of development of these protocols.

Example of Double-Counted Savings

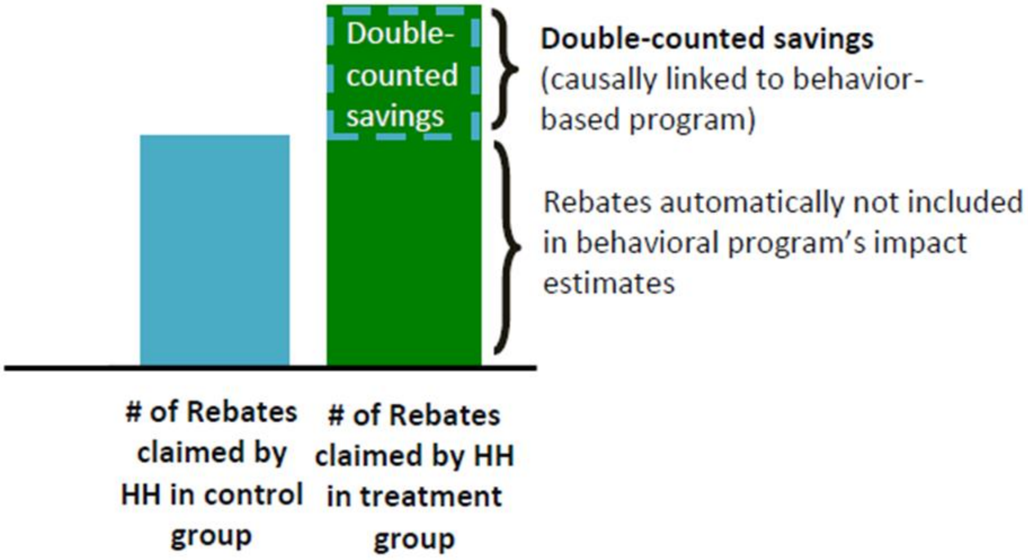

Figure 9: Example of Double-Counted Savings

Persistence of Program Savings

A control group should be maintained for every year in which program impacts are estimated, and the program is evaluated *ex post* every year initially and every few years after the program has been running for several years. UMP includes recommended methods to estimate savings after the behavioral program ends in order to understand whether the savings persist and for how long, as well as the rate of savings decay.

Applying Savings to a New Population of Participants in Future Years

The protocols do not allow for directly applying program savings impact estimates from an initial program to an expanded program with a new population in a future year. Consistent with the SEE/LBNL report, the IEM recommends creating and maintaining a new control and treatment group, and evaluating the expanded program using the similar methods described in those protocols.

Reporting Requirements

Consistent with UMP, evaluation reports should carefully document the research design, data collection and processing steps, analysis methods, and plan for calculating savings estimates. The evaluation reports of behavioral programs shall contain, at a minimum, the following:

- The program implementation and the hypothesized effects of the behavioral intervention
- The experimental design, including the procedures for randomly assigning subjects to the treatment or control group
- The sample design and sampling process, including relevant sample sizes of the treatment and control groups, and number of months (or alternative time periods) pre/post treatment period that were included;
- Results of the equivalency check between the treatment and control groups
- Processes for data collection and preparation for analysis, including all data cleaning steps;
- Analysis methods, including the application of statistical or econometric models and key assumptions used to identify savings, including tests of those key identification assumptions. Model specification should be clearly identified, including the name of the model consistent with UMP or SEE Action/LBNL (per section below);
- Results of savings estimate, including point estimates of savings and standard errors and full results of regressions used to estimate savings, including:
    - A 95% confidence interval for the monthly or annual savings
    - For each parameter, the estimated coefficient and standard error
    - Adjusted R^2
    - Tests of joint significance of the model (e.g., F Test)
    - Regression diagnostics (e.g., tests for multicollinearity, heteroscedasticity)
- Assessment of quantity and treatment of overlap with other rebate programs (i.e., double counting);
- Any surveys or other primary data collection that was conducted to assess how the savings were achieved.

Every detail does not have to be provided in the body of the report; many of the data collection and savings estimation details can be provided in a technical appendix.

Summary of Acceptable Model Specifications for Behavior-Based Programs

In the past several years, substantial evolution in model specification for residential behavior-based programs has occurred and this learning has been synthesized into the 2017 update of the residential behavioral UMP. Therefore, evaluators should review the section on Analysis Methods in detail and use a model consistent with UMP.

Generally, for RCT designs, UMP recommends using panel regression analysis to calculate savings, with the dependent variable as the energy use of the subject per unit of time. The primary independent variable is an indicator of whether the subject was in the treatment or control group and may be interacted with other independent variables. Fixed effects for subject characteristics or time may also be included. The models included in UMP are:

A) Simple Differences Regression Model of Energy Use. This model employs only data for the treatment period and includes an independent variable indicating whether the subject received treatment.

B) Simple Differences Regression Estimate of Heterogeneous Savings Impacts. This model expands on Model A, and obtains an estimate of savings from the treatment as a function of exogenous variables such as preprogram energy use, temperature, home floor space, or pretreatment efficiency program participation.

C) Simple Differences Regression Estimate of Savings During Each Time Period. This model also expands on Model A, and obtains an estimate of savings from the treatment during each period, by interacting the treatment indicator with indicator variables for the time periods.

D) Simple Differences Regression Model with Pre-Treatment Energy Consumption. This model builds on Model A but is conditional on a subject average pre-treatment energy consumption and uses time-period fixed effects. This is often referred to as “post-only”, as it includes pre-treatment energy consumption as an independent variable in the regression to account for differences between subjects in their post-treatment consumption. Variations on this model include indicator variables for each period, additional pre-treatment consumption control variables and other control variables.

E) Difference-in-Differences Regression Model of Energy Use. This model employs pre-treatment data in the regression model, and uses indicators for whether the time period is during treatment period and includes subject fixed effects.

F) D-in-D Estimate of Savings for Each Time Period. This is similar to Model D, but it includes time-period fixed effects.

Please see UMP, 2017 for models that may be used for RED designs and persistence designs. For quasi-experimental designs, please see SEE Action/LBNL Report 2012.

PROTOCOL K: LEAKAGE

Definition of Leakage

Cross-territory sales, or "leakage," occur when program-incented efficient products are installed outside of the funding utility's service territory. When this occurs, the energy and demand savings from the incentivized product are not being realized within the territory that paid for, and is claiming savings for, the unit. Upstream programs are particularly vulnerable to leakage as the rebate recipient is unknown and sales not restricted based on utility.[13]

While variations of leakage may occur in other forms (e.g., utility customers purchasing and installing a rebated product in a vacation home that sits outside the sponsoring service territory), these protocols are intended for upstream programs where the purchaser of the product is unknown. While the predominant upstream program is currently for efficient lighting, future upstream programs should also rely on these protocols. Other program types should handle cross-service territory installations through other means, such as telephone or on-site verification.

Program administrators should make concerted efforts to mitigate leakage. The most common effort is to limit participation of retail storefronts that are on the perimeter of the service territory.

Protocol K provides a brief synopsis regarding the Commission Orders regarding leakage and then focuses on the methodologies for determining leakage, as required by the Commission Orders in Docket No. 07-082-TF, Order No. 63, and Docket No. 07-085-TF, Order No. 85.[14]

Policy Regarding Leakage

The Commission determined that leaked energy efficiency measures do not generate Lost Contribution to Fixed Costs (LCFC), therefore limiting LCFC collection to proven lost fixed costs.

The Commission, therefore, determined that energy efficiency program leakage shall be incorporated into LCFC calculations as determined by the Orders, based upon a leakage calculation methodology that will be approved in the 2013 TRM update process after further refinement by the PWC, and implemented through the 2014 annual EECR adjustment.

With regard to net benefits and utility energy efficiency performance incentives, the Commission determined that the state, and ratepayers as a whole, benefit from energy saved and reduced demand. Also, sponsoring utility ratepayers have an interest in the continuation and refinement of a program to speed the implementation of emerging technologies such as LED lighting.

Based on aggregate ratepayer and statewide benefits, the need to address emerging lighting and other technologies, the need to promote efficient program administration, and the orderly implementation of Commission guidance, the Commission determined that leakage should not be

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[13] In upstream programs (also referred to as Point-of-Purchase Markdown Programs) the incentives go directly to the retailer or manufacturer rather than the customer.

[14] For more information on the policy implications of leakage see Arkansas Public Service Commission Docket No. 07-082-TF, Order No. 63, and Docket No. 07-085-TF, Order No. 85.

subtracted from energy efficiency goal achievement and net benefits calculations for PY 2012 or, absent a change in circumstances and further proceedings, for future years.

Research Recommendations to Address Leakage

Since retailers perceive customer contact information and sales data as highly confidential, estimating leakage is an inherently difficult task. Protocol K acknowledges this difficulty, with the understanding that any research approach will have at least some threats to validity. Protocol K therefore, recommends three research approaches, and further encourages evaluators to attempt as many of these as possible so as to minimize bias that may be introduced from any individual approach.[15]

However, if all three methods are not possible due to budget limitations, retailer refusal to participate, or other possible reasons, the methods are presented in order of preference from what is believed to be lowest to highest threats to validity. Combinations of approaches may also be used. For example, intercepts might be used only at the high volume stores to determine leakage, and geo-mapping could be used for the lower-volume retailers where conducting intercepts might be cost-prohibitive.

Research Method 1: Customer Intercept Surveys

Intercept surveys are the preferred data collection approach, as they gather primary data on specifically which customers purchase products at participating stores. Customer intercept surveys rely on in-store interviews with customers purchasing efficient products at participating stores. Likely leakage is then estimated by the number of products purchased for use outside of the service territory, divided by the total number of purchased products.

If using this approach, the evaluator needs to survey a geographically representative sample of participant retailers, and focus on retailers selling high volumes of incented bulbs. This ensures that the findings can be applied to the entirety of stores and distributed bulbs.

In recent years, retailers have been increasingly hesitant to allow evaluators to survey customers inside their stores. Many have restricted these types of activities entirely. Residential program implementers and utilities can add significant value by gaining permission for these surveys and should actively encourage participant retailers to permit third-party evaluators in their stores.

Potential bias from intercepts can occur in a number of ways. For example, retailer permission may be inconsistent; retailers may limit intercepts to certain days (e.g., during promotions); weekend vs. weekday customer traffic may differ. Protocol K therefore recommends that evaluators minimize this bias by attempting to include as many participating retailers as possible, not limiting the days of the intercepts to in-store promotions, and including a mix of weekend and weekdays.

One acknowledged challenge of intercepts is to include a mix of all retailer types, particularly for retailers that sell few program products, as it may not be cost-effective to have an in-store surveyor

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[15] The IEM acknowledges that the approaches presented here do not represent an exhaustive list of all options. Alternative methods, or modifications to these methods, are allowed under Protocol K with prior approval from the IEM team.

on-site conducting the interviews. Protocol K recommends two potential strategies to deal with potential retailer/distribution channel bias:

- ***Include sales of efficient and standard efficiency products.*** The evaluator may expand the survey to include a mix of efficient vs. standard efficiency products. For example, intercept surveys can include purchasers of program-incented products (e.g., CFLs), non-program high efficiency products, and standard efficiency products (e.g., incandescent or Energy Independence and Security Act (EISA) compliant halogen bulbs). All participants in the surveys can be asked about the intended location of the production installation, which can be used to derive the leakage estimate. This assumes that the leakage of non-program efficient products and standard efficiency products matches that of program-incented products. Because of this assumption, this method is only recommended for retailers where the purchase of inefficient products is so limited as to make the intercept approach cost-prohibitive.
- ***Weighting results to the population of retailers.*** Another approach, consistent with the recommendation from the Uniform Methods Project, is to weight the results from the sample population to the universe of participating retailers.[16] For those distribution channels that have not received intercept surveys, the evaluator should first assess how the leakage might differ and then apply extrapolated values.

As an example, if intercepts are only conducted at retailers that represent 75 percent of all program sales, the determined leakage rate should reflect the 75 percent of sales. For the remaining 25 percent of sales, the leakage rate can be adjusted based on factors such as proximity to the service territory border, distribution channel (e.g., groceries might have lower leakage rates than large home improvement stores), geo-mapping (as described below) and any other factors that can be determined from the actual in-store intercepts that were conducted.

Finally, in-store intercepts offer another important advantage because they can be used to determine the percentage of incented products that have been sold to commercial customers. Commercial customers typically use lighting products for more hours per day than do residential customers, and typically have higher peak coincidence factors, thus leading to higher savings. Savings from incented products sold to the sponsoring program administrator’s commercial customers can be claimed towards both program goals and cost-recovery.[17]

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[16] See http://www1.eere.energy.gov/wip/pdfs/53827-6.pdf for a final copy of the Uniform Methods Project Residential Lighting Evaluation Protocols.

[17] Note, however, that if sales to commercial customers are going to be determined, the survey should also probe for type of business, as hours of use can differ significantly between business types.

Research Method #2: Geo-Mapping and General Population Surveys

The evaluations of the 2012 upstream lighting programs relied on an approach of "geo-mapping", whereby each program storefront is assigned a leakage score based on the percentage of the sponsoring utilities customers (vs. other utility customers) that lie within a 60-minute drive time from that store. The 60-minute drive time radius, however, was adjusted for stores where an alternative storefront in the same distribution channel existed (i.e., with the assumption that customers will drive to the closest grocery, large home improvement, discount store, or any other store type within the same distribution channel).

The primary strength of this approach is that each storefront is assigned its own leakage score, and the overall estimate of leakage represents a weighted average of program storefronts. The primary limitation of this approach, however, is that the drive time/shopping estimates will all be based on evaluator judgment in the absence of any actual primary data collection.

Protocol K specifies that the geo-mapping approach will be supplemented with telephone surveys to test to the assumptions regarding drive time. The specific steps would include:[18]

1. ***Overlay utility service areas and population data from the U.S. Census Bureau***. This step matches the utility to all population points within its service area based on the census data in the highest publicly-available resolution.
2. ***Estimate the customer base for each retail store by calculating store territory based on drive time to the nearest store***. In this step, territories for each program storefront are developed, looking at various increments of drive time. The drive times between adjacent storefront distribution channels are split in the middle between the two stores. So if two grocery stores are located 30 minutes apart, the analysis should assume that customers drive to the closest grocery store (i.e., no more than 15 minutes for those customers that sit in between the two stores).
3. ***Conduct a telephone survey to identify customer-shopping patterns for incented products***. A randomized survey of residential customers in the sponsoring utility service territory, as well as the neighboring utility service territory/ies, should be conducted to test the drive-time assumptions in the leakage model. For example, the survey can identify customers that purchased an energy efficient product in the last year (program or non-program), and where they purchased the product from, as well as where they normally shop for the product. A survey such as this can leverage a general population survey for the sponsoring utility customers, supplementing the sample with a random digit dial (RDD) sample of neighboring utility customers.
4. ***Allocate subsidies for each store to the population within the store territory, using actual sales data***. Each store would then be assigned a leakage score, with some percentage of the incented product assigned to the sponsoring utility customers and some percentage assumed to have been sold to neighboring utility customers.
5. ***Calculate leakage by summarizing the subsidies received by the population in and out of the utility service areas for each store territory***. Combine all the stores to determine an

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[18] These steps align closely to the steps outlined in the Cadmus May 1, 2013 memo entitled "CFL Subsidy Leakage in Arkansas."

overall leakage rate for the sponsoring utility. This leakage rate should also include error bounds that account for potential error in the mapping of the census data to the service territory.

Research Method #3: Opt-In Surveys

Using "opt-in" surveys is also an option to determine leakage. This approach offers several advantages: it can to reach all participating storefronts and all customers purchasing incented products, it can be relatively inexpensive to implement, it can provide cross-customer class (commercial) sales, and it will provide a leakage estimate based on actual customer data. The limitation of this approach, however, is that as an "opt-in" survey response rates are typically extremely low, and thus may lead to significant non-response bias.

Should this method be implemented, the Protocol K specifies:

- ***The evaluation should try to include all incented products from all program storefronts***. Ideally, each product would have a label/note about how to participate in the study.
- ***Customers should receive an incentive for their participation in the study.*** This may include a combination of individual incentives (e.g., a $10 gift card for the next time they shop at that participating retailer) as well as entry into a drawing for a larger, higher profile prize.
- ***The survey provides a multimodal approach.*** These can include sending in a reply card, taking the survey on-line, or sending customer contact information via other means, such as texting (allowing a call back from the research firm).
- ***Derive stratified leakage rates that are then weighted to the population.*** Similar to the intercept and geo-mapping methods, the leakage estimate should attempt to differentiate leakage rates by distribution channel or storefront, then weighting the findings up to the total population.

Reporting Leakage

As a way to provide additional transparency for calculating leakage, the evaluator should include a leakage rate for each participant storefront, along with the method for used for determining the leakage rate. In addition, details regarding the assumptions should be included (e.g., if the geo-mapping method is used, the average drive time should be included).

Relationship of Leakage with Net-to-Gross

Each method presented here is specific to estimating leakage (i.e., the percentage of incented product sold to non-sponsoring utility customers). The survey questions, particularly in the intercept and opt-in surveys approaches, should be brief and focus on customer name, contact information, and expected location of installation (address, self-reported utility, customer sector, and – if applicable – business type). These questions are completely distinct from net-to-gross (NTG) analysis, where the survey questions are likely to examine customer intentions, price-elasticity, and other potential parameters to estimate the likelihood that the customer would have purchased the incented product in absence of the program rebate. The estimated leakage values and NTG values, therefore, should be incorporated as two separate adjustments to the savings estimates as required by the relevant Commission rules and Orders.

The IEM does acknowledge, however, that NTG approaches may provide an NTG estimate that includes sales to customers outside the sponsoring utility service territory. This is appropriate for calculation of energy savings for the assessment of energy efficiency goal achievement and net benefits calculations, as leakage is not deducted from these estimates, and therefore the net savings should be based on utility and non-utility customers.

For purposes of the LCFC, however, leakage is incorporated, and thus the NTG ratio should be based off of sponsoring-utility customers. This would require calculating two separate NTG ratios, one for sponsoring utility customers and one for non-sponsoring utility customers. While this is worthy of consideration, the calculation of dual NTG ratios will introduce additional uncertainty, and thus should be subject to budget and timeline considerations, as well as prior approval of the IEM Team. In absence of a sponsoring-utility specific NTG ratio, the overall NTG ratio (i.e., that which incorporates all purchasers) should be used for both the energy efficiency goal achievement and the LCFC calculations.

PROTOCOL L: NON-ENERGY BENEFITS

After reviewing the guidance from the Parties Working Collaboratively, the Arkansas Public Service Commission (Commission) issued Order No. 30 on December 10, 2015, which provides further direction and guidance regarding the inclusion of Non-Energy Benefits ("NEBs") in the Technical Reference Forum (p. 21 of 21):

> *"The Commission therefore directs that the IEM be requested to recommend an approach for quantification of deferred equipment replacement NEBs in individual instances when they are material and quantifiable. Approval of deferred customer equipment NEBs, however, is conditioned as follows: The Commission directs that each recommended approach for customer deferred equipment replacement NEB quantification shall be included within the annual TRM update filing, and that its reasonableness shall be addressed in testimony by the IEM and/or Staff, and may be addressed by other parties, so that the Commission may approve or disapprove such proposed NEB quantifications.*
>
> *The Commission therefore orders and directs that the following three categories of NEBs be consistently and transparently accounted for in all applications of the TRC test, as it is applied to measures, programs, and portfolios:*
>
> - *benefits of electricity, natural gas, and liquid propane energy savings (i.e., other fuels);*
> - *benefits of public water and wastewater savings; and*
> - *benefits of avoided and deferred equipment replacement costs as conditioned herein."*

Therefore, this protocol describes the recommended approach to quantify the NEBs in these three categories. This recommended approach has been developed jointly by the IEM and the PWC for each category as directed by the Commission.

PROTOCOL L1: NON-ENERGY BENEFITS FOR ELECTRICITY, NATURAL GAS, AND LIQUID PROPANE ("OTHER FUELS")

With many energy efficiency measures installed under Arkansas DSM programs, energy savings is often achieved for more than one fuel type. For example, installing duct sealing or insulation in a building not only reduces natural gas or propane consumption, but also reduces electricity consumption through either reduced fan use or – for homes with air-conditioning – reduced cooling load. Similarly, low flow showerheads and faucet aerators provided to customers through gas energy efficiency programs will provide electric savings for homes with electric water heating.

The benefits of these "other fuel" savings may not be fully captured in current utility cost-effectiveness tests. Protocol L1 describes a consistent methodology for utilities to quantify and document the benefits resulting from reduced energy use of the other fuel-type they do not provide in their program service territory, specifically when this benefit is not already being claimed by another investor-owned utility.[19]

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[19] For example, in joint programs the dual fuel benefits would normally be claimed by both utilities, but in programs run by a single fuel utility that lead to secondary fuel savings these additional benefits can be claimed as NEBs.

The other fuel NEB is calculated using the following equation:

$$Benefit\ =\ Energy\ savings\ X\ Avoided\ other\ fuel\ costs \tag{1}$$

Where:

> Benefit = avoided economic costs per unit of energy savings of the other fuel savings over the lifetime of the measure, expressed in current dollars
>
> Energy savings = annual number of other fuel kWh, therms or gallons of propane saved per measure installed [20]
>
> Avoided costs = present value of the avoided cost per unit energy savings, which is a function of the measure specifications (including measure life) and the avoided cost data provided by other utilities for regulated fuels (e.g. electricity and natural gas) or the market price of unregulated fuels (e.g. liquid propane)

Where applicable, the most current Arkansas TRM should be used as the basis for calculating the secondary fuel electric and natural gas energy savings. Applicable TRM algorithms should also be used to calculate liquid propane savings, with appropriate adjustments for the efficiency of energy conversion at the end-use. When this information is not included in the TRM, other fuel savings should be calculated through the use of EM&V. In addition, EM&V should be used to determine the number of applicable homes or business facilities that qualify for other fuel benefits (e.g., the number of homes with electric water heat that have been provided water-saving devices by a gas utility), and the quantity should be adjusted by any applicable in-service rates, net-to-gross ratios, or other adjustments applied to the primary fuel savings.

The avoided costs for other fuel electric and gas benefits should be calculated as follows:

- When available, avoided cost forecasts should be collected from the associated electric or gas utility (i.e., the utility providing the other fuel benefit) where the participating home or businesses are located.[21] The avoided costs calculated for the other fuel benefit should be identical to the avoided costs being utilized by those same utilities for their own DSM benefit-cost calculations for each program year.
- For municipal utilities or cooperatives, where avoided cost data may be more difficult to collect, the program administrator can use the avoided cost forecasts from the nearest investor-owned utility.
- The discount rates used to calculate the NPV of the avoided cost benefits should be the same as those used for the corresponding cost-effectiveness tests (e.g., when calculating

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[20] Note that for simplicity this Protocol focuses on other fuel energy savings, rather than demand savings. To the extent a measure also produces secondary demand savings (e.g., insulation could lead to summer peak cooling load reductions), these benefits can also be quantified and claimed through the avoided cost assumptions. Similarly, some avoided costs are calculated using different load shapes, so the associated measure avoided cost – which may be higher for certain measures that also lead to peak demand reductions – can alternatively be used.

[21] Where not available, avoided cost forecasts from another Arkansas utility should be used as a proxy (e.g., if EAI avoided cost forecasts are not publicly-available, SWEPCO avoided costs can be used). As discussed at the June 7, 2016 PWC meeting, however, many of the program administrator utilities have been able to access avoided cost data from the associated investor-owned utility in which the other fuel benefits are occurring.

the TRC test, the NPV of the other fuel benefits should be discounted at the same rate as the primary fuel avoided cost benefits).

For propane systems, savings should be calculated per TRM Version 6.0 Volume 2, as if the equipment were natural gas-fueled. To convert natural gas savings to propane savings, use the following conversion factor:

$$Propane\ savings\ (gallons)\ =\ Therm\ savings\ X\ 1.1 \tag{2}$$

This protocol establishes the base price of propane at $2.00/gallon in 2016, based on 2014-2016 weekly data of retail propane rates in Arkansas from the U.S. Energy Information Administration (EIA).[22] When a measure saves propane, both electric and gas utilities shall use the deemed avoided cost of $2.00 per gallon in 2016 and escalate it per annum (using a common assumption for the rate of inflation) for the lifetime of the installed measure. This base value and rate of escalation should be updated at the beginning of each three-year program cycle, using the latest EIA data available at the time of the update.

PROTOCOL L2: NON-ENERGY BENEFITS FOR WATER SAVINGS

Many measures that utilities install to reduce energy consumption also reduce water consumption. In Order 30, the PSC directed the IEM to develop an algorithm for calculating the value of avoided water and wastewater consumption due to measures installed under electric and gas utility efficiency programs (p. 20 of 21).

The actual quantities of avoided water consumption (in gallons) associated with specific measures are provided elsewhere in this TRM. Protocol L.2 uses the marginal retail water rates and average water sewage rates (both on per-gallon basis) to residential and commercial consumers to calculate a statewide, average proxy value for all avoided water usage benefits to be considered under Order No. 30.[23]

Marginal retail water rates charged to end-use customers vary considerably across regions of Arkansas, across water utilities, and across customer classes. For example, many water utilities sell water to their customers in price tiers based on individual usage (e.g., the first 1,000 gallons are sold at one rate, and then the next 1,000 gallons are sold at another rate; sometimes the price charged for the second 1,000 gallons is higher than the first 1,000 gallons, and sometimes lower). Residential customers are also charged different rates than commercial, industrial and agricultural (irrigation) customers, and in many jurisdictions customers located inside city limits are charged differently than customers outside city limits. Finally, these rates vary from utility to utility.

To calculate the marginal cost of water, the IEM collected water and sewage rates from six jurisdictions around the state in 2016, the averages of which are shown in the table below.[24]

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[22] From U.S. Energy Information Agency, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_SAR_DPG&f=W

[23] These marginal water rates ideally should account for the avoided electricity costs of water treatment, pumping, and other uses of electricity to supply potable water and dispose of wastewater.

[24] Bentonville, Rogers, Jonesboro, Central Arkansas, Searcy, and Springdale.

Table 8. Avoided Water Costs in Arkansas

State of Arkansas	**Water Rates (per 1,000 gallons)**		**Sewage Rates (per 1,000 gallons)**		**Total Combined Water Rates (per 1,000 gallons)**	
Customer Class	**First 1,000 Gallons**	**Marginal Gallons**	**First 1,000 Gallons**	**Marginal Gallons**	**First 1,000 Gallons**	**Marginal Gallons**
Residential	$5.65	$3.25	$8.41	$4.39	$14.05	$6.18
Commercial	$3.93	$2.63	$8.57	$3.96	$ 13.35	$6.90
Average Cost $/Gallon	$4.79	$2.97	$8.48	$4.17	$13.70	$6.54

(Source: Based on primary research conducted by the IEM of six Arkansas water districts)

Protocol L.2 takes the marginal cost per gallon of both potable water ($3.25) and sewage ($4.39) and adds them together to estimate the base cost in 2017: $6.18 per 1,000 gallons, or $0.00618/gallon. To calculate future annual avoided water costs, utilities shall use the marginal rate of $0.00618/gallon for programs that serve the residential sector shall use, $0.0069/gallon for programs that serve the commercial or industrial sector, and $0.00654/gallon for programs where the sector is unknown as the base cost per gallon of water in 2017, and increase it per annum by the assumed escalation rate for the lifetime of an installed measure. This estimated base cost of water and escalation rate shall be revisited at the beginning of each three-year program cycle. In addition, program administrators have the option of using alternative water costs if those costs are believed to be more appropriate for the electric and gas service territory, and are made transparent in PSC filings.[25]

Water savings allowed in this protocol only includes direct savings from measures as calculated in the TRM, or as a custom measure that is subject to EM&V.

The avoided cost resulting from the water savings is calculated as follows:

$$Benefit = Water\ savings\ X\ Avoided\ water\ costs \tag{3}$$

Where:

Benefit = avoided cost of water and waste-water savings (per gallon) over the lifetime of the measure, in current dollars

Water savings = annual number of gallons saved, per measure

Avoided water costs = present value of the avoided costs resulting from the savings, which is a function of the measure life and prevailing water rates

The discount rates to calculate the net present value of the avoided water cost benefits should be the same as those used for the corresponding cost-effectiveness tests (e.g., when calculating the TRC test, the NPV of the water benefits should be discounted at the same rate as the primary fuel

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[25] For example, program administrators can use water rates more specific to their service territories, or use long-run marginal costs of water/wastewater supply (which, rather than using water rates, would be more accurate and consistent with the avoided energy cost methodology).

avoided cost benefits). In addition, as with the other fuel savings, the quantity of measures for which water savings are claimed should be adjusted by any applicable in-service rates, NTG ratios, or other adjustments applied to the primary fuel savings.

PROTOCOL L3: NON-ENERGY BENEFITS OF AVOIDED AND DEFERRED EQUIPMENT REPLACEMENT COSTS26

In addition to reducing annual energy consumption, new energy efficient technologies offered through Arkansas investor-owned utility efficiency programs may have longer estimated useful lives ("EULs") than the technologies they are replacing, meaning they will require fewer replacements over the efficient equipment lifetime (i.e., avoiding purchase of baseline efficiency equipment, and thus being referred to as avoided replacement costs). In addition, some measures may qualify for early replacement ("ER"), and thus have replacement costs that differ from a replace-on-burnout ("ROB") scenario since they shift the replacement cycle by accelerating the purchase of new equipment (i.e., deferring the replacement of baseline equipment, thus being referred to as deferred replacement costs).

Order No. 30 directs the utilities to calculate the benefits of avoided and deferred equipment replacement to the customer over time, and to include these costs in utility program cost-effectiveness tests.[27] The avoided and deferred equipment costs are derived from the material and installation labor costs required to provide continued end-use service beyond the Baseline EUL (or RUL in the case of ER measures) through the end of the EUL of the efficient measure. This component of the Baseline Cost is often not accounted for in the TRC calculation of incremental measure cost. It is therefore classified as a "Non-Energy Benefit" (NEB) because its inclusion has the effect of decreasing the incremental measure cost, thereby increasing the TRC net benefit of the program or measure.

This protocol includes three examples, using actual Arkansas program offerings that generate avoided and deferred equipment replacement costs:[28]

- ROB 1 – baseline and efficient measures that have different useful lifetimes under *static* baselines over the lifetime of the measures;
- ROB 2 - baseline and efficient measures that have different useful lifetimes under *changing* baselines over the lifetime of the measures; and
- Early Replacement measures (with static or changing baselines).

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[26] Special thanks to Stephen Waite for presenting much of the material in this section in a memo delivered to the PWC entitled: "Avoided and Deferred Replacement Costs ('Non-Energy Benefits')".

[27] Note the scope of this discussion is limited to the incremental installed (capital plus labor) cost of energy efficiency program measures, taking into account the assumed cost of baseline equipment replacements that would occur if the measure were not installed. Other categories of NEBs, such as avoided operation and maintenance (O&M) expenditures, avoided repair costs, and avoided equipment refurbishment are not included here due to the challenge in quantifying these factors, and the directive from the PSC that the NEBs should be limited to the three NEB categories listed above.

[28] The IEM has also supplied an example of these calculations in an accompanying workbook. Note the original workbook was prepared by Stephen Waite, and modified by the IEM to include examples that incorporate values from the Arkansas TRM and the EM&V studies, where possible.

The avoided and deferred replacement costs, summarized hereafter as the Deferred Replacement Cost, can be summarized mathematically for the three examples as:

$$\textit{Deferred Baseline Replacement Cost} = NPV(RDR,ML,RLCC_t) \tag{4}$$

$$NPV = \textit{Net Present Value function } \sum_{t=1}^{ML} \frac{RLCC_t}{(1+RDR)^t} \tag{5}$$

Where:

RDR = Real Discount Rate = (NDR-ER)/(ER+1) where:
NDR = nominal discount rate
ER = baseline installed cost annual escalation rate
ML = Program Measure Life (EUL)
$RLCC_t$ = Real Levelized Carrying Charge in year t (annualized baseline installed cost at RDR)[29]

The general formula allows for the baseline installed cost to vary over the life of the program measure, so that each future replacement could be a different product or technology. As discussed in the examples below, these adjustments to the cost assumptions (i.e., incorporating the avoided and deferred replacement costs) make the avoided costs consistent with the TRM energy savings calculations.

Case 1. Replace-On-Burnout 1: Measures with Different Useful Lifetimes (EULs) Under Static Baselines

A number of efficient measures, particularly screw-based LED and linear LED lighting, have longer lifetimes than the baseline technology they are assumed to replace. The incremental cost calculations for the efficient measure, therefore, needs to be reduced by the value of the avoided replacement costs for multiple baseline technologies (i.e., the costs associated with replacing the baseline technology over the lifetime of the efficient measure).

If the efficient measure life is greater than or equal to twice the baseline measure life, then the cost of at least one replacement will be avoided and the corresponding incremental cost reduced accordingly. Unless the efficient measure life is divisible by the baseline equipment life, the last baseline replacement will still be in operation at the end of the program measure life. Because the program energy benefits are limited to the avoided cost of energy savings over the useful life of the measure, the present value of the installed cost of the measure does not account for any replacement cost beyond the initial installation cost at the time of participation.[30] The full cost of a baseline replacement that continues to operate beyond the end of the program measure life is therefore not avoided and must be reduced accordingly to account for the remaining useful life

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[29] In ER applications, the RLCC is equal to zero before the time of normal replacement of the existing equipment.

[30] The formulas presented here are based on the assumption that the maximum duration of energy savings is equal to the elapsed time between initial efficient measure installation and the time of first replacement of the efficient measure, which is typically assumed to equal the effective useful life of the efficient equipment.

(RUL) beyond the last year of energy savings attributed to the measure. The last replacement is effectively deferred by the program measure until the end of the measure life.

As an example of this, assume a program is offering commercial customers an incentive on linear LED lamps. The AR TRM Version 7.0 assumes the baseline for calculating savings is a T8 linear fluorescent. While the AR TRM assumes a 15-year expected useful life (EUL) for the LED, the expected lifetime for T8's is only nine years. This means that over the lifetime of the linear LED, the customer would actually have to make two purchases of T8 lamps, paying both the cost of the lamps as well as the labor to install them.

Because the efficient measure life exceeds the life of the baseline equipment, the incremental cost is the difference in the initial installed cost (efficient measure – standard measure) minus the present value of the avoided replacement costs. This can be shown mathematically as:

$$Avoided\ Baseline\ Replacement\ Cost = -PV(RDR,ML-EUL_B,RLCC_B)/(1+RDR)^{EUL_B} \tag{6}$$

Where:

RDR = Real Discount Rate
ML = Program Measure Life
EUL_B= Baseline Equipment Life
$RLCC_B$ = -PMT (RDR,EUL_B,Baseline Installed Cost)

Case 2. Replace-On-Burnout 2: Baseline and Efficient Measures with Different Lifetimes and Changing Baselines

Similar to the example above, screw-based LED lamps have a substantially longer expected useful life than the baseline technology, which for general service lamps in the AR TRM Version 7.0 is a halogen bulb. For example, the AR TRM currently assumes lifetime hours of 15,000 for omnidirectional LEDs, whereas most halogen bulbs only last for approximately 2,000 hours.[31] For an upstream program that assumes a weighted mix of residential and commercial sales, the expected annual hours of use would be 2.68 hours/day,[32] providing an EUL of approximately 15 years for LEDs and 2 years for halogens. A customer would need to install approximately seven halogen bulbs in the same socket in which a single LED would be installed.

Unlike the T8 example, however, the baseline may change over the lifetime of the LED bulb, which this example illustrates: the AR TRM Version 7.0 incorporates a baseline shift beginning after 2022 to account for the backstop provision of the 2007 Energy Independence and Security Act.[33] The savings, therefore, are divided into two streams, one with a delta watts reflecting the

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[31] Note the ENERGY STAR® 2.0 specification, effective January 1, 2017, lowers the lifetime requirement, requiring ENERGY STAR® certified LED lamps last for at least 15,000 hours.

[32] EAI PY2015 Evaluation, p. 40.

[33] Note that the Department of Energy issued a draft ruling in 2016 that proposes to enforce and actually expand the backstop provision (e.g., tightening the future efficacy requirements to that of an LED, rather than a CFL), which is to take effect beginning January 1, 2020. As explained in the residential lighting section of the AR TRM Version 6.0, however, savings in AR are allowed to be claimed through 2022 before shifting to the new baseline. The example in the spreadsheet includes both the current TRM Version 6.0 assumptions for savings (which are based on the

difference between LEDs and halogens (for 2018 through 2022), and one reflecting a more stringent baseline that approximates the usage of a CFL for 2023 and beyond, through the remaining lifetime of the LED. The incremental cost calculation, therefore, needs to also incorporate the dual stream of avoided baseline technology requirements for both the halogen and the CFL.

$$\text{Avoided Baseline Replacement Cost} = \text{Avoided Baseline Replacement Cost (Tier 1)} + \text{Avoided Baseline Replacement Cost (Tier 2)} \tag{7a}$$

$$\text{Avoided Baseline Replacement Cost (Tier I)} = -PV(RDR, NY - EUL_{T1}, RLCC_{T1})/(1+RDR)^{EUL_{T1}} \tag{7b}$$

$$\text{Avoided Baseline Replacement Cost (Tier 2)} = -PV(RDR, ML - NY, RLCC_{T2})/(1+RDR)^{NY} \tag{7c}$$

Where:

RDR= Real Discount Rate
ML = Program Measure Life
EUL_{T1}= Baseline Equipment Life (Tier 1)
$RLCC_{T1}$ = -PMT(RDR,EUL_{T1}, Baseline Installed Cost (Tier 1))
EUL_{T2}= Baseline Equipment Life (Tier 2)
$RLCC_{T2}$ = -PMT(RDR,EUL_{T2}, Baseline Installed Cost (Tier 2))
NY = Number of years of Tier 1 installation

Case 3. Early Replacement Measures

As a third example, the AR TRM Version 7.0 allows for early replacement of certain measures, which has been verified through a number of evaluations.[34] Early replacement measures have the benefit of being able to claim higher energy savings for the remaining useful life (RUL) of the equipment (the efficiency difference between the new, efficient equipment and the existing equipment), and then dropping to lower energy savings rates (under higher baselines) only for the period of the EUL that exceeds the RUL (the difference between new, efficient equipment and a code baseline).

The incremental cost calculation needs to not only reflect this dual savings stream, including a component for the cost of replacing the equipment prior to the end of its EUL, then another component for the incremental cost above normal (ROB) replacement. In addition, the incremental cost needs to reflect that the replacement cycle has been shifted for perpetuity. [35] For ER that

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preliminary backstop provision, not the proposed revision), as well as an example should the proposed ruling become law.

[34] For example, the PY2015 CenterPoint EM&V Report (page 4-19) found that 60% of all furnaces replaced through the Space Heating Program qualified for early replacement.

[35] The savings and incremental cost assumptions, including the calculations, are explained very well in "Early Replacement Measures Study: Phase II Research Report", Northeast Energy Efficiency Partnerships, November 2015, p. 36.

assumes the existing equipment would have been replaced at the end of its RUL with standard efficiency equipment, the following equation is used:

$$Deferred\ Baseline\ Replacement\ Cost = -PV(RDR,ML\text{-}RUL_B,RLCC_B)/(1+RDR)^{RUL_B} \quad \textbf{(8)}$$

Where:

RUL_B = RUL of baseline (existing) equipment
$RLCC_B$ = -PMT(RDR,EUL_B,Baseline Installed Cost)

For ER that assumes the existing equipment would have been replaced at the end of its RUL with efficient equipment (e.g., due to incorporation of a new code/standard), the following equation is used:

$$Deferred\ Baseline\ Replacement\ Cost = -PV(RDR,ML\text{-}RUL_B,RLCC_M)/(1+RDR)^{RUL_B} \quad \textbf{(9)}$$

Where:

RUL_B = RUL of baseline (existing) equipment
$RLCC_M$ = PMT(RDR,EUL_B,Installed Cost of Measure)

Calculation of the NEB When the Avoided or Deferred Replacement Cost is Greater Than the Incremental Cost

Note that in some cases it is possible for the avoided and deferred replacement cost to be greater than the simple first cost difference between efficient and standard equipment. For example, if screw-based LED lamps were to drop to $2/bulb, and halogens were $1/bulb, a customer would spend more money on halogens in just a few years (prior to the end of the useful life of the LED) than the cost of a single LED. In these cases the incremental cost can continue to be calculated as the simple first cost different (e.g., $1 in this case), and the avoided replacement costs of multiple halogens – which will sum to over a dollar – can be treated in the cost-effectiveness calculation as an additional benefit (i.e., in the numerator of the Total Resource Cost test).

Other Cases

The extension of the formulas presented above to measures that combine elements of the three cases is straightforward, e.g., early replacement of equipment with a changing baseline.

Reporting Requirements

The evaluation reports of NEBs shall contain, at a minimum, the following:

1) Information on the underlying calculations and inputs, similar to the reporting of primary fuel savings. These details may be provided in an appendix or in separate spreadsheets.
2) Table 9 referenced below presents the table of information, formatted as a checklist, that is required to be included in the annual report narrative concerning which NEBs were calculated and included in the cost-benefit analysis for each program and each measure. A separate measure category (rows) by NEB category (columns) table shall be included for each program. As illustrated, reports should separate avoided and deferred replacement costs. Each measure would only appear one time per program table (e.g., if a program had 3,000 participants but only 100 qualified for propane savings, the measure would show up once in the table and the column for propane would be checked).
3) As an option, the annual reports and/or evaluation reports can provide the NEBs units (e.g., kWh, therms, gallons) and monetized benefits at the program and measure level, using the format in Table 10 (which is the same format as the NEBs tab in the SARP workbook, but provided at the measure level). As with the required check box table, each measure would only appear one time per program table.[36]

Table 9. Required Reporting Table for NEBs

Program	Electricity Savings*	Gas Savings**	Propane Savings	Water Reduction	Avoided Replacement Cost	Deferred Replacement Cost
Measure 1	✓		✓	✓	✓	
Measure 2					✓	
Measure 3	✓		✓			✓

**For gas utilities*
***For electric utilities*

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[36] If the measure level units and monetized information is not provided in the annual report or evaluation report, then the IEM will summarize this information in the IEM Annual Report based on the SARP workbook in the utility benefit cost analysis workbook tabs.

Table 10. Optional Reporting Table for NEBs

Measure	**TRM Measure**	**Project Type**	**Program**	**Electric Savings**	**NPV ES**	**Natural Gas Savings**	**NPV NGS**	**LPG Savings**	**NPV LPGS**	**Water/ WW Savings**	**NPV Water/ WWS**	**NPV ARP**	**NPV DRP**	**Total NPV**
Name	**Number**	**(NR/ER/RF)**		**(Annual kWh)**	**($)**	**(Annual Therm)**	**($)**	**(Annual gallons)**	**($)**	**(Annual gallons)**	**($)**	**($)**	**($)**	**($)**
														$ -
														$ -
														$ -
														$ -
														$ -
														$ -
														$ -
														$ -
			Portfolio Total	0	$ -	0	$ -	0	$ -	0	$ -	$ -	$ -	$ -

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Glossary

This glossary is drawn from three evaluation-related reference documents:

- 2007 IPMVP
- 2004 California Evaluation Framework
- 2006 DOE EERE Guide for Managing General Program Evaluation Studies

Additionality: A criterion that says avoided emissions should only be recognized for project activities or programs that would not have "happened anyway." While there is general agreement that additionality is important, its meaning and application remain subject to interpretation.

Adjustments: For M&V analyses, factors that modify baseline energy or demand values to account for independent variable values (conditions) in the reporting period.

Allowances: Allowances represent the amount of a pollutant that a source is permitted to emit during a specified time in the future under a cap-and-trade program. Allowances are often confused with credits earned in the context of project-based or offset programs, in which sources trade with other facilities to attain compliance with a conventional regulatory requirement. Cap- and-trade program basics are discussed on the following EPA website: www.epa.gov/airmarkets/cap-trade/index.html.

Analysis of covariance (ANCOVA) model: A type of regression model also referred to as a "fixed effects" model.

Assessment Boundary: The boundary within which all the primary effects and significant secondary effects associated with a project are evaluated.

Baseline: Conditions, including energy consumption and related emissions that would have occurred without implementation of the subject project or program. Baseline conditions are sometimes referred to as "business-as-usual" conditions. Baselines are defined as either project-specific baselines or performance standard baselines.

Baseline period: The period of time selected as representative of facility operations before the energy efficiency activity takes place.

Bias: The extent to which a measurement, sampling or analytic method systematically underestimates or overestimates a value.

California Measurement Advisory Council (CALMAC): An informal committee made up of representatives from the California utilities, state agencies, and other interested parties. CALMAC provides a forum for the development, implementation, presentation, discussion, and review of regional and statewide market assessment and evaluation studies for California energy efficiency programs conducted by member organizations.

Coincident Demand: The metered demand of a device, circuit, or building that occurs at the same time as the peak demand of a utility's system load or at the same time as some other peak of interest, such as building or facility peak demand. This should be expressed in a way that indicates the peak of interest (e.g., "demand coincident with the utility system peak"). Diversity factor is defined as the ratio of the sum of the demands of a group of users to their coincident maximum demand. Therefore, diversity factors are always equal to one or greater.

Co-benefits: The impacts of an energy efficiency program other than energy and demand savings.

Comparison Group: A group of consumers who did not participate in the evaluated program during the program year and who share as many characteristics as possible with the participant group.

Conditional Savings Analysis (CSA): A type of analysis in which change in consumption is modeled using regression analysis to evaluate consumption in the presence or absence of energy efficiency measures.

Confidence: An indication of how close a value is to the true value of the quantity in question. Confidence is the likelihood that the evaluation has captured the true impacts of the program within a certain range of values (i.e., precision).

Cost-effectiveness: An indicator of the relative performance or economic attractiveness of any energy efficiency investment or practice. The present value of the estimated benefits produced by an energy efficiency program is compared to the estimated total costs to determine if the proposed investment or measure is desirable from a variety of perspectives (e.g., whether the estimated benefits exceed the estimated costs from a societal perspective).

Database for Energy-Efficient Resources (DEER): A California database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life.

Deemed Savings: An estimate of an energy savings or energy demand savings outcome (gross savings) for a single unit of an installed energy efficiency measure. This estimate (a) has been developed from data sources and analytical methods that are widely accepted for the measure and purpose and (b) is applicable to the situation being evaluated.

Demand: The time rate of energy flow. Demand usually refers to electric power measured in kW (equals kWh/h) but can also refer to natural gas, usually as Btu/hr., kBtu/hr., therms/day, etc.

Dependent Variable: One that changes and is affected by the independent variables. Examples include weather, energy usage, housing type or location.

Direct Emissions: Direct emissions are changes in emissions at the site (controlled by the project sponsor or owner) where the project takes place. Direct emissions are the source of avoided emissions for thermal energy efficiency measures (e.g., avoided emissions from burning natural gas in a water heater).

Effective Useful Life: An estimate of the median number of years that the efficiency measures installed under a program are still in place and operable.
Energy Efficiency: The use of less energy to provide the same or an improved level of service to the energy consumer in an economically efficient way, or using less energy to perform the same function. "Energy conservation" is a term that has also been used, but it has the connotation of doing without a service in order to save energy rather than using less energy to perform the same function.

Energy Efficiency Measure: Installation of equipment, subsystems or systems, or modification of equipment, subsystems, systems, or operations on the customer side of the meter, for the purpose of reducing energy and/or demand (and, hence, energy and/or demand costs) at a comparable level of service.

Engineering Model: Engineering equations used to calculate energy usage and savings. These models are usually based on a quantitative description of physical processes that transform delivered energy into useful work such as heat, lighting, or motor drive. In practice, these models may be reduced to simple equations in spreadsheets that calculate energy usage or savings as a function of measurable attributes of customers, facilities, or equipment (e.g., lighting use = watts × hours of use).

Error: Deviation of measurements from the true value.

Evaluation: The performance of studies and activities aimed at determining the effects of a program; any of a wide range of assessment activities associated with understanding or documenting program performance, assessing program or program-related markets and market operations; any of a wide range of evaluative efforts including assessing program-induced changes in energy efficiency markets, levels of demand or energy savings, and program cost-effectiveness.

***Ex ante* Savings Estimate:** Forecasted savings used for program and portfolio planning purposes (from the Latin for "beforehand").

***Ex post* Evaluation Estimated Savings:** Savings estimates reported by an evaluator after the energy impact evaluation has been completed (from the Latin for "from something done afterward").

Free Driver: A non-participant who has adopted a particular efficiency measure or practice as a result of the evaluated program.

Free Rider: A program participant who *would have* implemented the program measure or practice in the absence of the program. Free riders can be total, partial, or deferred.

Gross Savings: The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an efficiency program, regardless of why they participated.

Impact Evaluation: An evaluation of the program-specific, directly induced changes (e.g., energy and/or demand usage) attributable to an energy efficiency program.

Independent Variables: The stand-alone factors that affect energy use and demand, but cannot be controlled (e.g., weather, occupancy, age, gender). Regression analysis tries to determine the relationship between dependent and independent variables.

Indirect Emissions: Changes in emissions that occur at the emissions source (e.g., the power plant). Indirect emissions are the source of avoided emissions for electric energy efficiency measures.

Interactive Factors: Applicable to IPMVP Options A and B; changes in energy use or demand occurring beyond the measurement boundary of the M&V analysis.

Leakage: Cross-territory sales that occur when program-incented efficient products are installed outside of the funding utility's service territory.

Load Shapes: Representations such as graphs, tables, and databases that describe energy consumption rates as a function of another variable, such as time or outdoor air temperature.

Market Effect Evaluation: An evaluation of the change in the structure or functioning of a market, or the behavior of participants in a market, that results from one or more program efforts. Typically, the resultant market or behavior change leads to an increase in the adoption of energy efficient products, services, or practices.

Market Transformation: A reduction in market barriers resulting from a market intervention, as evidenced by a set of market effects, that lasts after the intervention has been withdrawn, reduced, or changed.

Measurement: A procedure for assigning a number to an observed object or event.

Measurement and verification (M&V): Data collection, monitoring, and analysis associated with the calculation of gross energy and demand savings from individual sites or projects. M&V can be a subset of program impact evaluation.

Measurement Boundary: The boundary of the analysis for determining direct energy and/or demand savings.

Metering: The collection of energy-consumption data over time through the use of meters. These meters may collect information with respect to an end-use, a circuit, a piece of equipment, or a whole building (or facility). Short-term metering generally refers to data collection for no more than a few weeks. End-use metering refers specifically to separate data collection for one or more end-uses in a facility, such as lighting, air conditioning or refrigeration. Spot metering is an instantaneous measurement (rather than over time) to determine an energy-consumption rate.

Monitoring: Gathering of relevant measurement data, including but not limited to energy-consumption data, over time to evaluate equipment or system performance. Examples include chiller electric demand, inlet evaporator temperature and flow, outlet evaporator temperature, condenser inlet temperature, and ambient dry-bulb temperature and relative humidity or wet-bulb temperature, for use in developing a chiller performance map (e.g., kW/ton vs. cooling load and vs. condenser inlet temperature).

Non-energy Benefit (NEB): As defined by Arkansas Public Service Commission (Commission) in Order No. 30:

- the *benefits of electricity, natural gas, and liquid propane energy savings (i.e., other fuels);*
- *benefits of public water and wastewater savings;*
- *benefits of avoided and deferred equipment replacement costs as conditioned herein."*

Net Savings: The total change in load that is attributable to an energy efficiency program. This change in load may include, implicitly or explicitly, the effects of free drivers, free riders, energy efficiency standards, changes in the level of energy service, and other causes of changes in energy consumption or demand.

Net-to-Gross Ratio (NTGR): A factor representing net program savings divided by gross program savings that is applied to gross program impacts, converting them into net program load impacts after adjustments for free ridership and spillover.

Non-participant: Any consumer who was eligible, but did not participate, in the subject efficiency program in a given program year. Each evaluation plan should provide a definition of a non-participant as it applies to a specific evaluation.

Normalized Annual Consumption (NAC) analysis: A regression-based method that analyzes monthly energy consumption data.

Participant: A consumer who received a service offered through the subject efficiency program in a given program year. The term "service" is used in this definition to suggest that the service can be a wide variety of services, including financial rebates, technical assistance, product installations, training, energy efficiency information or other services, items, or conditions. Each evaluation plan should define "participant" as it applies to the specific evaluation.

Peak Demand: The maximum level of metered demand during a specified period, such as a billing month or a peak demand period.

Persistence study: A study to assess changes in program impacts over time (including retention and degradation).

Portfolio: Either (a) a collection of similar programs addressing the same market (e.g., a portfolio of residential programs), technology (e.g., motor-efficiency programs), or mechanisms (e.g., loan programs) or (b) the set of all programs conducted by one organization, such as a utility (and which could include programs that cover multiple markets, technologies, etc.).

Potential studies: Studies conducted to assess market baselines and savings potentials for different technologies and customer markets. Potential is typically defined in terms of technical potential, market potential, and economic potential.

Precision: The indication of the closeness of agreement among repeated measurements of the same physical quantity.

Primary Effects: Effects that the project or program are intended to achieve. For efficiency programs, this is primarily a reduction in energy use per unit of output.

Process Evaluation: A systematic assessment of an energy efficiency program for the purposes of documenting program operations at the time of the examination, and identifying and recommending improvements to increase the program's efficiency or effectiveness for acquiring energy resources while maintaining high levels of participant satisfaction.

Program: A group of projects, with similar characteristics and installed in similar applications. Examples could include a utility program to install energy-efficient lighting in commercial buildings, a developer's program to build a subdivision of homes that have photovoltaic systems, or a state residential energy efficiency code program.

Project: An activity or course of action involving one or multiple energy efficiency measures, at a single facility or site.

Rebound Effect: A change in energy-using behavior that yields an increased level of service and occurs as a result of taking an energy efficiency action.

Regression Analysis: Analysis of the relationship between a dependent variable (response variable) to specified independent variables (explanatory variables). The mathematical model of their relationship is the regression equation.

Reliability: Refers to the likelihood that the observations can be replicated.

Reporting Period: The time following implementation of an energy efficiency activity during which savings are to be determined.

Resource Acquisition Program: Programs designed to directly achieve energy and/or demand savings, and possibly avoided emissions, through the installation of new equipment.

Retrofit Isolation: The savings measurement approach defined in IPMVP Options A and B, and ASHRAE Guideline 14, that determines energy or demand savings through the use of meters to isolate the energy flows for the system(s) under consideration.

Rigor: The level of expected confidence and precision. The higher the level of rigor, the more confident one is that the results of the evaluation are both accurate and precise.

Secondary Effects: Unintended impacts of the project or program such as rebound effect (e.g., increasing energy use as it becomes more efficient and less costly to use), activity shifting (e.g., movement of generation resources to another location), and market leakage (e.g., emission changes due to changes in supply or demand of commercial markets). These secondary effects can be positive or negative.

Simple Engineering Modeling (SEM): A basic calibrated engineering model used to determine energy impacts in a low-cost way**.**

Snapback (aka "take-back" or "rebound"): The increase in overall energy consumption after the installation of the efficiency measure, due to increased usage.

Spillover: Reductions in energy consumption and/or demand caused by the presence of the energy efficiency program that exceed the program-related gross savings of the participants. There can be participant and/or non-participant spillover rates depending on the rate at which participants (and non-participants) adopt energy efficiency measures or take other types of efficiency actions on their own (i.e., without an incentive being offered).

Statistically adjusted engineering (SAE) models: A category of statistical analysis models that incorporate the engineering estimate of savings as a dependent variable.

Stipulated Values: See “deemed savings.”

Takeback Effect: See “rebound effect.”

Uncertainty: The range or interval of doubt surrounding a measured or calculated value within which the true value is expected to fall with some degree of confidence.

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DEEMED SAVINGS, INSTALLATION & EFFICIENCY STANDARDS

TRM Version 7.0 Volume 2: Deemed Savings

Applicable for Program Year 2018

Submitted to:

Arkansas Public Service Commission

Prepared by:

The Independent Evaluation Monitor

on behalf of the

Parties Working Collaboratively

FINAL

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1. DEEMED SAVINGS OVERVIEW

1.1 Introduction

This update to the Deemed Savings, Installation, and Efficiency Standards section of the Technical Reference Manual (TRM) is the result of efforts by the Arkansas Parties Working Collaboratively (PWC) to identify outdated deemed savings measures, include new measures, and prioritize review of existing measures to identify those requiring additional engineering and/or literature review.

The Independent Evaluation Monitor (IEM) with input from PWC members, have produced the Residential and Commercial measures included in the TRM.

This volume is a compilation of deemed savings values for electric and gas energy efficiency measures being implemented by the Arkansas Investor-Owned Utilities (IOUs), and is intended to serve a range of users and functions, including:

- Electric and gas utilities and energy efficiency program administrators, for cost-effectiveness screening, program planning, tracking, and reporting;
- Regulatory agencies and independent program evaluators, for evaluating the performance of energy efficiency programs relative to statutory goals, and facilitating planning and portfolio review; and
- Markets, mercantile customers, and others, for assessing potential energy savings opportunities.[1]

This volume contains deemed savings values for gas and electric energy annual usage, as well as coincident peak electric demand savings and peak day gas savings. Additionally, certain measures include methods to calculate deemed water savings methods, which may be used to calculate water savings for the evaluation of non-energy benefits.

The Estimated Useful Lives (EULs) are also included in the deemed savings to facilitate economic evaluations, but have no impact on the deemed savings values.

Deemed savings is an approach to estimating energy and demand savings, usually used for programs targeting energy efficiency measures with well-known and consistent performance characteristics. This method involves multiplying the number of installed measures by an estimated (or deemed) savings value derived from engineering analysis and/or historical evaluations. Deemed savings approaches may be complemented by on-site inspections.

Deemed savings are derived through the use of proven analysis of measure performance using field data analysis, accepted engineering calculations, and/or engineered energy efficiency models (simulations) and secondary research. These methods use typical building types, equipment characteristics and operating schedules developed for particular applications, with or without on-site testing or metering. This deemed savings document relies upon engineering calculations, the

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[1] The deemed savings values in this reference manual represent best estimates of the average impact of a measure on the gas or electric utility's system at the customer's meter if installation standards are properly applied. Because these represent averages, they are not appropriate for guaranteeing savings figures to customers. It is the installer's responsibility to evaluate premise and equipment conditions as well as customer usage patterns to properly estimate actual savings. No warranty of savings or the suitability of any measure contained in these documents is implied.

results of evaluations conducted in Arkansas, and the best available data from other jurisdictions that have conducted vetted evaluations. The TRM update process is described more fully in Protocol H in Volume 1 of this TRM.

Use of Best Available Data. The PWC seeks to quantify, measure and verify the savings in the most accurate way possible, while still providing consistency and certainty in the application of savings estimates and results.

In keeping with this approach, the TRM allows for the use of site-specific data, when it is of high quality and available, by program implementers. Site-specific data may be used for any inputs to TRM algorithms presented in this volume; however, deviation from the TRM algorithms would qualify the measures as custom, thus requiring additional data collection by both implementers and evaluators.The use of site-specific data is not required, and default values specified throughout the TRM can be used in lieu of detailed customer information. It must be noted that the TRM does not condone cherry-picking of TRM values or customer inputs solely for the purpose of maximizing claimed program savings.

Annual Evaluation, Measurement and Verification (EM&V) program evaluation reports should be tailored to the approach used by the program implementer. Measure savings which use TRM-deemed values, should be evaluated as compared to requirements and parameters described in the TRM. Data collection by evaluators should not be used to adjust savings if default values from this TRM were used to claim ex ante savings. However, the evaluation should note any differences found and recommended changes for the next TRM update and provide an indication of the expected impact of proposed changes. This will allow for a full vetting of the proposed values prior to their use. Any proposed updates would be assessed before and during the next TRM revision process. EM&V contractors should use customer specific information when verifying savings if program implementers use customer specific information to claim savings. It is the EM&V contractor’s responsibility to utilize evaluation industry best practices for evaluating measures claimed using custom specific inputs. This would include developing a sampling plan, data collection, engineering analysis, and revising savings estimates as needed.

Table 1 shows some examples of the proper use of best available data for several measure types. This is not an all-inclusive list. Questions or concerns about specific measures or evaluation methods should be discussed with the IEM during evaluation planning.

Table 1: Examples of Proper Use of Primary Data

Measure Name and Number	Program Implementer Methodology	EM&V Contractor Methodology	Appropriate Result
2.5.1 Residential Lighting Efficiency	Claimed savings using default hours of use (2.17 hours per day) found in TRM.	Completed a residential lighting metering study for a large, statistically significant sample of participants. Found 3.0 hours per day.	Evaluator uses default values from TRM for evaluated savings. Recommends increasing TRM default hours of use to 3.0 in next TRM update.
3.6 Commercial Lighting Efficiency	Implementation contractor utilizes customer specific lighting HOU and CF (i.e., does not use Table 364).	Evaluation contractor measures site-specific HOU during evaluation site visit for statistically valid sample.	Evaluation contractor uses measured lighting HOU and CF from evaluation site visit, extrapolates realization rate to population wide reported savings following sampling plan.
3.8 Food Service Equipment	Implementation Contractor used default values from TRM for several food service measures.	Evaluation contractor conducted on site verification of specific parameters related to food service measures to help refine deemed assumptions and reported "Verified equipment input".	Evaluation contractor uses default values from TRM during evaluation. Notes their measured parameters are/are not different and recommends TRM update if needed.
3.6 Commercial Lighting Efficiency	Implementation contractor utilizes customer specific lighting HOU and CF (i.e., does not use Table 364) for *office buildings only*, and does use defaults for remaining building types.	Evaluation contractor develops samples which include strata for different implementation approaches. Measures site-specific HOU during evaluation site visit for statistically valid sample.	Evaluation contractor uses measured lighting HOU and CF from evaluation site visits for office buildings and extrapolates realization rate to office building strata only. Verifies remaining lighting savings using default values found in TRM. Extrapolates realization rates to population wide evaluated savings following sampling plan.

Methodology: Estimating deemed savings requires the following steps:

1. Establishing a baseline;
2. Developing reasonable minimum efficiency requirements for eligible energy efficiency measures;
3. Characterizing the typical setting for the majority of installations; and
4. Producing a viable model of customer usage patterns for those measures.

The approaches taken in these steps vary considerably, depending upon the nature of the energy efficiency measure.

Peak gas savings values have been adjusted to account for differences between the "typical meteorological year" (TMY) and the extreme weather conditions used by gas utilities in determining peak day gas usage. This adjustment is further described in Section 1.3.2 of this Overview and in Appendix G: Estimation of Gas Peak Day Savings of Volume 3.

Deemed savings for each measure were developed according to one of the following methods: (1) engineering algorithms combining equipment performance information with annual or seasonal loads and operating conditions; or, (2) annual computer simulations run on an hourly timestep using typical climate conditions for different regions of the state. The chosen approach is noted within each measure section. The baseline for new or replace-on-burnout (ROB) equipment is generally determined by either a federal standard or the locally applicable code. The applicable code for Arkansas is the 2009 edition of the International Energy Conservation Code (IECC).

The calculation of energy savings estimates for the Arkansas Weatherization Program (AWP), as specified by the US Department of Energy (DOE) and used in the AWP in its treatment of severely energy-inefficient homes, may include measures not currently included in the TRM or may differ on a measure basis from those specified in the TRM for non-AWP homes. Where such savings estimates are specified by DOE, they are controlling for the AWP.

Once the baseline and eligibility standards are developed, the estimation of impacts resulting from an eligible installation becomes an engineering task. Non-weather-dependent measures can be represented by engineering calculations, multiplying hours of use by the net change in average hourly or daily demand (for gas or electricity). Peak impacts must be estimated from databases and studies of hourly or monthly loads. The engineering calculations are generally derived from standard industry sources, such as the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

Modelling

Building simulation modeling software was used to develop deemed savings values for many weather-sensitive energy efficiency measures. Original modeling for residential (and commercial measures implemented in converted residences) was performed using EnergyGauge USA® (EnergyGauge) modeling software and TMY2 weather data. Detailed discussion of EnergyGauge modeling software is available at http://www.energygauge.com. Residential envelope measures have been updated using BEopt™, a publicly available modeling platform for residential building simulations from the National Renewable Energy Laboratory (NREL). Prototype model input assumptions were updated and TMY3 weather data was used. More information on BEopt™ is available from NREL at http://beopt.nrel.gov/. For small commercial measures, eQuest modeling software was used. Detailed discussion of the eQuest modeling software is available at www.doe2.com/equest.

Simulations run in both EnergyGauge and eQuest rely on the DOE2 simulation engine. While BEopt™ can run either DOE2 or EnergyPlus, the new simulation modeling engine from the Department of Energy, BEopt™ runs were performed using EnergyPlus[2], as it is a more recent simulation engine combining two major building energy simulation programs, DOE2 and Building Loads Analysis and System Thermodynamics (BLAST). The DOE is now focusing its efforts on the maintenance and development of EnergyPlus. Therefore, BEopt/EnergyPlus will be used for all residential simulation updates.

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[2] Available at: http://apps1.eere.energy.gov/buildings/energyplus/energyplus_about.cfm

Separate deemed savings have been calculated for the most common residential heating and cooling configurations:

- Electric air conditioning with gas heat
- Electric air conditioning with electric resistance heat
- Electric heat pumps
- Gas heating with no air conditioning

Within this document, the term *Converted Residence* (CR) is used to describe a building that was originally constructed as a house, but has been adapted for commercial purposes. A CR differs from a house in its occupancy and operating schedule, but also differs from other commercial buildings in that it has the construction properties of a house.

1.2 Weather

Weather-sensitive measures are separated according to the four weather zones designated for Arkansas by IECC.

Deemed savings for modelled weather-sensitive energy efficiency measures are calculated using data for a Typical Meteorological Year (TMY) available from the NREL National Solar Radiation Database (NSRDB).[3] Depending on when they were developed, deemed savings in this TRM were derived using either TMY2 or TMY3 data series selected as representative of the four weather zones in Arkansas (IECC 2003 climate zones) shown in Figure 1.

The following hourly time series are contained within the TMY data:

- Temperature
- Humidity
- Wind speed and direction
- Cloud cover
- Solar radiation

Building simulation modeling is useful for weather sensitive measures because it can produce hourly energy consumption estimates by applying location-specific historical weather files.

Endnotes referencing the original source materials are used throughout the TRM. All endnotes are italicized (see CDD column in following table) to avoid confusion with footnotes (see Rogers in the following table). At the time of publication, all references and links throughout this document were correct.

Table 2: Arkansas Weather Zones and Design Weather Data[4]

City	IECC Zone	Winter 99% Design °F	HDD_{65}	Summer 1% Design °F	CDD_{65}
Rogers[5]	9	13	4,402	93	1,757
Fort Smith	8	19	3,919	96	2,129
Little Rock	7	21	3,344	95	2,184
El Dorado	6	23	2,946	96	2,622

Climate-sensitive energy efficiency measures are presented for four different regions of the state. The weather zones are described below and graphically illustrated in Figure 1.

- Zone 9 – Northern, using typical weather information for Fayetteville, AR or Rogers, AR

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[3] A TMY is a collection of selected weather data for a specific location, generated from a database containing many years of weather data. It is constructed to present the range of weather phenomena for the location in question while still giving annual averages that are consistent with the location's long term averages. An explanation of TMY weather files can be found on the NREL website and in Section 1 of the User's Manual for TMY3 Data Sets available at: http://rredc.nrel.gov/solar/old_data/nsrdb/.

[4] Design °F data from Manual J Load Calculations, 8th Edition. HDD and CDD values calculated from TMY3 data.

[5] Winter 99% and Summer 1% Manual J Edition 8 design conditions for Fayetteville, AR are taken from Fayetteville as data specific to Rogers are not available in tManual J; available at: http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Outdoor_Design_Conditions_508.pdf.

- Zone 8 – Northeast/North Central, using typical weather information for Fort Smith, AR
- Zone 7 – Central Region, using typical weather information for Little Rock, AR
- Zone 6 – South Region, using typical weather information for El Dorado, AR

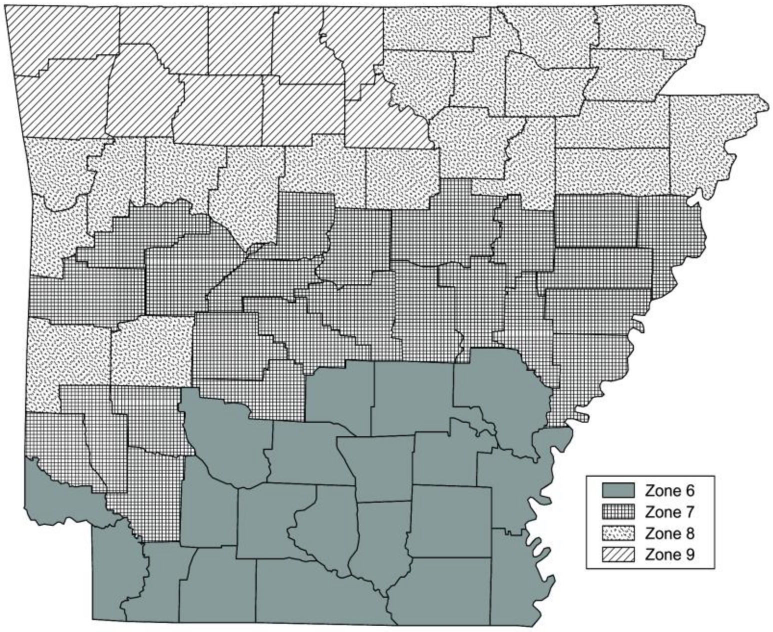

Figure 1: Arkansas Weather Zones (derived from IECC 2003)

1.3 Derivation of Electric and Gas Peak Savings

This section describes how peak gas and electric peak savings presented in Volume 2 of the Arkansas TRM were derived.

Electric utilities generally define peak demand for electricity as the period (measured in hours or fractions of hours) during which the electric production and transmission and distribution system is delivering energy at a maximum rate. Gas peaks are measured in days, rather than hours, and generally reflect the most load intensive conditions the transmission and distribution infrastructure are expected to experience.

The TRM provides deemed savings values or algorithms for the calculation of peak demand. These values have been calculated using one of a small number of calculation and analysis approaches that are described in this section.

1.3.1 Peak Demand for Electricity

On-peak electric demand savings (kW) are defined as the reduction in the demand for electricity that coincides with periods of peak demand for electricity. High summer temperatures are a primary driver of peak demand for electricity in Arkansas. Peaks generally occur on weekdays when residential, commercial, and industrial consumption patterns coincide to produce the highest demand.

For weather sensitive measures, peak demand savings can be estimated by estimating the extent to which measure implementation reduces electricity usage when temperatures are highest.

Case 1: Peak demand for measures relying on building simulation models

For all measures for which building simulation models were used to estimate deemed savings, usage in the base case and improved case models were extracted from the hourly outputs for the specific hours in which the weekday criterion and temperature criterion (greater than the 1% design temperature)[6] are met in a statistically determined "typical meteorological year" (TMY). Taking the difference between average energy use in those hours in the base case and improved case models, peak demand savings are calculated by averaging the top sixteen designated peak hours (from TMY2 or TMY3 weather file) for each weather zone.

Finally, total average demand savings are normalized by the method stated in each specific measure (e.g. per square foot of treated area for insulation, radiant barrier, and window film measures or per cubic feet per minute (CFM) of infiltration reduction for air infiltration).

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[6] One percent design temperatures are taken from the Air Conditioning Contractors of America (ACCA) Manual J, 8th Edition (as reproduced in Table 2).

Table 3: Case 1 Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.2	Duct Insulation
	Envelope	2.2.1	Attic Knee Wall Insulation
		2.2.2	Ceiling Insulation
		2.2.3	Wall Insulation
		2.2.4	Floor Insulation
		2.2.5	Roof Deck Insulation
		2.2.6	Radiant Barriers
		2.2.7	ENERGY STAR® Windows
		2.2.8	Window Film
		2.2.9	Air Infiltration
Commercial	HVAC	3.1.11	Duct Efficiency Improvements
		3.1.12	Duct Insulation (Converted Residences)
		3.1.13	Duct Insulation (Small Commercial)
		3.1.14	Occupancy-Based PTAC/PTHP Controls
	Envelope	3.2.1	Ceiling Insulation (Converted Residences)
		3.2.2	Ceiling Insulation (Small Commercial)
		3.2.3	Cool Roofs
		3.2.4	Air Infiltration (Converted Residences Only)
		3.2.5	Roof Deck Insulation (Small Commercial)
		3.2.7	Wall Insulation (Converted Residences Only)
		3.2.8	Window Awnings (Small Commercial Only)
		3.2.9	Window Film (Converted Residences)
		3.2.10	Window Film (Small Commercial)

Case 2: Peak demand savings for measures where annual energy savings are multiplied by a peak cooling ratio (specified per measure)

Peak cooling ratios are derived by taking the product of two ratios: the ratio of on-peak energy use for water heating to average hourly energy use for water heating according to the daily hot water energy use relationships as presented by the Building America Benchmark project, and an estimated ratio of peak month energy use to average month energy use. The first half of the ratio takes into account the fact that energy use for water heating in the mid to late afternoon peak hours generally exceeds average hourly use. The latter half of the ratio accounts for the reduced water heating energy use of summer months due to higher inlet water temperatures. The product of the two values is the ratio of water heating energy use in peak hours compared to the energy use in the average hour. This value is divided by 8,760 to normalize the annual energy savings by which the peak cooling ratio is multiplied to estimate the demand savings.

$$kW_{savings} = kWh_{\ savings} \times Peak\ Cooling\ Ratio \tag{1}$$

Table 4: Case 2 Measure List

Sector	Section	Measure Number	Measure Name
Residential	DHW	2.3.1	Water Heater Replacement
		2.3.4	Faucet Aerators
		2.3.5	Low-Flow Showerheads

Case 3: Peak demand savings for measures utilizing algorithms to calculate peak savings

The following calculation methodologies are used to derive peak demand savings:

Case 3a: Based on system capacity, efficiency or change in efficiency, and coincidence factor (specified per measure)

Peak demand savings are calculated by multiplying capacity by coincidence factor (CF) and dividing by efficiency or change in efficiency (η). Other conversion factors are outlined in each measure.

$$kW_{savings} = Capacity\ \times \frac{1}{\eta} \times CF \times conversion\ factors \tag{2}$$

or

$$kW_{savings} = Capacity\ \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times CF \times conversion\ factors \tag{3}$$

Table 5: Case 3a Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.5	Central Air Conditioner and Heat Pump Tune-Up
		2.1.6	Central Air Conditioner Replacement
		2.1.8	Central Heat Pump Replacement
		2.1.10	Window Air Conditioner Replacement
Commercial	HVAC	3.1.7	Central Air Conditioner and Heat Pump Tune-Up
		3.1.15	Packaged Terminal AC/HP (PTAC/PTHP) Equipment
		3.1.18	Unitary and Split System AC/HP Equipment
		3.1.19	Air or Water Cooled Chilling Equipment (Chillers)
		3.2.11	Commercial Door Air Infiltration

Case 3b: Based on horsepower, load factor, and change in efficiency

Peak demand savings are calculated by multiplying rated horsepower (HP) by load factor (LF) and dividing by change in efficiency. Other conversion factors are outlined in each measure.

$$kW_{savings} = HP \times LF \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times conversion\ factors$$

(4)

Table 6: Case 3b Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Motors	3.4.2	Premium Efficiency Motors

Case 3c: Based on discharge rate, latent heat, and efficiency

Peak demand savings are calculated by multiplying discharge rate by the latent heat of vaporization (h) and dividing by efficiency. Other conversion factors are outlined in each measure.

$$kW_{savings} = Steam\ Trap\ Discharge\ Rate\ \times h \times \frac{1}{\eta} \times conversion\ factors$$

(5)

Table 7: Case 3c Measure List

Sector	Section	Measure Number	Measure Name
Commercial	HVAC	3.1.17	Steam Trap Replacement

Case 3d: Based on flow rate, change in temperature, and efficiency or change in efficiency (specified per measure)

Peak demand savings are calculated by multiplying water density (ρ) by the specific heat of water (C_p), flow rate, and change in temperature and dividing by efficiency or change in efficiency. Other conversion factors are outlined in each measure.

$$kW_{savings} = \rho \times C_P \times \Delta Flow\ Rate \times \left(T_{hot\ water} - T_{supply}\right) \times \frac{1}{\eta} \times conversion\ factors$$

(6)

or

$$kW_{savings} = \rho \times C_P \times \Delta Flow\ Rate \times \left(T_{hot\ water} - T_{supply}\right) \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times conversion\ factors$$

(7)

Table 8: Case 3d Measure List

Sector	Section	Measure Number	Measure Name
Commercial	DHW	3.3.1	Water Heater Replacement
		3.3.2	Faucet Aerators
		3.3.5	Low-Flow Showerheads
	Food Service	3.8.11	Low-Flow Pre-Rinse Spray Valves

Case 3e: Based on U-value, surface area, change in temperature, and efficiency (specified per measure)

Peak demand savings are calculated by multiplying the change in heat transfer, U-value (calculated as 1 ÷ R-value) by surface area and change in temperature and dividing by efficiency. Other conversion factors are outlined in each measure.

$$kW_{savings} = \left(U_{pre} - U_{post}\right) \times A \times (T_{in} - T_{out}) \times \frac{1}{\eta} \times conversion\ factors$$

(8)

Table 9: Case 3e Measure List

Sector	Section	Measure Number	Measure Name
Residential	DHW	2.3.3	Water Heater Pipe Insulation
Commercial		3.3.3	Water Heater Jackets
		3.3.4	Water Heater Pipe Insulation

Case 3f: Based on change in wattage, in service-rate, HVAC interactive effects, and coincidence factor (specified per measure)

Peak demand savings are calculated by multiplying the change in fixture wattage by the in-service rate (ISR), HVAC interactive effects (IEF), and coincidence factor (CF).

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right)\ ISR\ \times\ IEF \times CF$$

(9)

Table 10: Case 3f Measure List

Sector	Section	Measure Number	Measure Name
Residential	Lighting	2.5.1	Lighting Efficiency
Commercial		3.6.1	Light Emitting Diode (LED) Traffic Signals
		3.6.3	Lighting Efficiency

Case 3g: Based on number of fixtures, fixture wattage, control power adjustment factor, HVAC interactive effects, and coincidence factor

Peak demand savings are calculated by multiplying the number of fixtures by fixture wattage, change in control power (1-PAF), HVAC interactive effects (IEF), and coincidence factor (CF).

$$kW_{savings} = N_{fixt} \times \frac{W_{fixt}}{1000} \times (1 - PAF) \times IEF \times CF$$

(10)

Table 11: Case 3g Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Lighting	3.6.2	Lighting Controls

Case 3h: Based on connected load and bonus factor (specified per measure)

Peak demand savings are calculated by multiplying the connected load of a typical reach-in cooler or freezer door with a heater and the bonus factor (BF) for reducing cooling load from eliminating heat generated by the door heater from entering the cooler or freezer. Other adjustment factors (if applicable) are outlined in each measure.

$$kW_{savings} = kW_{connected\ load} \times BF \times adjustment\ factors$$

(11)

Table 12: Case 3h Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Other	3.7.9	Zero Energy Doors
		3.7.10	Evaporator Fan Controls

Case 3i: Based on annual energy savings, operating hours, and coincidence factor (specified per measure)

Peak demand savings are calculated by dividing the measure specific annual energy savings (kWh) by the measure specific operating hours and multiplying by any appropriate coincidence factors (CF) or other specified peak adjustment factors. These factors are defined in each specific measure.

$$kW_{savings} = \frac{kWh_{savings}}{hours} \times CF$$

(12)

Table 13: Case 3i Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.11	Duct Sealing
	Appliances	2.4.1	ENERGY STAR® Clothes Washers
		2.4.2	ENERGY STAR® Dishwashers
		2.4.3	ENERGY STAR® Refrigerators
		2.4.4	Advanced Power Strips
		2.4.5	ENERGY STAR® Pool Pumps
Commercial	Other	3.7.2	Advanced Power Strips
		3.7.3	Computer Power Management
		3.7.5	Door Heater Controls for Refrigerated Display Cases
		3.7.7	Strip Curtains for Walk-in Coolers and Freezers
		3.7.11	Commercial Kitchen Demand Ventilation Controls
	Food Service	3.8.2	Commercial Ice Makers
		3.8.3	Commercial Griddles
		3.8.4	Commercial Ovens
		3.8.5	Combination Ovens
		3.8.6	Commercial Fryers
		3.8.7	Commercial Steam Cookers
		3.8.10	ENERGY STAR® Commercial Dishwashers

Case 4: Peak demand savings for measures where peak savings extracted from referenced studies

For a small sub-set of measures, peak demand savings values were taken directly from a referenced study.

Table 14: Case 4 Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.7	Ground Source Heat Pumps
		2.1.12	Smart Thermostats
Commercial	Motors	3.4.1	Electronically Commutated Motors for Refrigeration and HVAC Applications
	Other	3.7.4	Vending Machine Occupancy Controls
		3.7.8	Door Gaskets for Walk-in and Reach-in Coolers and Freezers

Case 5: Peak demand savings for measures where the methodology for peak savings is undocumented or incomplete

Undocumented or incomplete peak demand savings methodologies will be updated at the time that each measure is selected for update in a future TRM update.

Subcase 5a: Proprietary Analysis

For a small sub-set of measures, electric peak demand savings were derived using proprietary analysis unavailable to the TRM development team.

Table 15: Case 5a Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Appliances	3.5.1	Solid-Door Refrigerator and Freezers
	Other	3.7.1	Plug Load Occupancy Sensors

Subcase 5b: Incomplete Methodology Description

For a small sub-set of measures, electric peak demand savings were derived by developing a load profile for the applicable measure and calibrating using metered end-use data obtained from utility metering studies. This approach is described in detail in the measure referenced below.

Table 16: Case 5b Measure List

Sector	Section	Measure Number	Measure Name
Residential	DHW	2.3.2	Water Heater Jackets

Subcase 5c: Missing Information

For a single measure, electric peak demand savings were derived using a methodology that is not specified in the measure description.

Table 17: Case 5c Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Food Service	3.8.8	Commercial Underfired Broilers

Case 6: Measures where no peak savings are specified

For a small sub-set of measures, there are no applicable peak demand savings.

Table 18: Case 6 Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Other	3.7.6	Refrigerated Case Night Covers
	Food Service	3.8.9	Commercial Conveyor Broilers

1.3.2 Peak Demand for Gas

During the TRM version 7.0 (for 2018) update, the Arkansas Parties Working Collaboratively (PWC) decided that peak gas savings do not need to be reported. Therefore, peak gas savings do not need to be calculated by evaluation contractors. The sections and equations pertaining to peak gas savings are maintained in the TRM in case they are needed for future reporting.

Case 7: Peak demand savings for measures

Gas utilities require estimates of their peak day consumption for capacity planning; however, the impact of energy efficiency measures on that peak day consumption cannot be calculated directly using TMY data. Whereas TMY data sets are drawn from historic weather data (e.g. TMY3 are drawn from the period from 1976-2005) to represent typical weather conditions, gas utilities apply the most extreme temperature and wind data over the past 25 to 30 years for their capacity planning.

To calculate the peak day gas consumption impact of each measure, a statistical relationship was derived that expresses daily gas consumption as a function of two weather variables: average daily temperature and average wind speed. This statistical relationship (described in Appendix G: Adjustments to Gas Peak Day Impacts) is robust for most energy efficiency measures and is detailed in Appendix G of TRM Volume 3. To calculate gas peak day savings, a gas utility must simply enter the hourly output from a building simulation model run against TMY data into the regression spreadsheet, which will map the annual gas consumption to the most extreme daily average temperature and wind speed using the appropriate equation and return the peak day therms savings.

Table 19: Case 7 Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.2	Duct Insulation
		2.1.9	Hydronic Heating
	Envelope	2.2.1	Attic Knee Wall Insulation
		2.2.2	Ceiling Insulation
		2.2.3	Wall Insulation
		2.2.4	Floor Insulation
		2.2.5	Roof Deck Insulation
		2.2.6	Radiant Barriers
		2.2.7	ENERGY STAR® Windows
		2.2.8	Window Film
		2.2.9	Air Infiltration

Sector	Section	Measure Number	Measure Name
Commercial	HVAC	3.1.11	Duct Efficiency Improvements
		3.1.12	Duct Insulation (Converted Residences)
		3.1.13	Duct Insulation (Small Commercial)
	Envelope	3.2.1	Ceiling Insulation (Converted Residences)
		3.2.2	Ceiling Insulation (Small Commercial)
		3.2.3	Cool Roofs
		3.2.4	Air Infiltration (Converted Residences Only)
		3.2.5	Roof Deck Insulation (Small Commercial)
		3.2.7	Wall Insulation (Converted Residences Only)
		3.2.8	Window Awnings (Small Commercial Only)
		3.2.9	Window Film (Converted Residences)
		3.2.10	Window Film (Small Commercial)

Case 8: Peak demand savings for measures where annual therms savings are multiplied by a peak heating ratio (specified per measure)

Peak heating ratios are derived using TMY3 data. Annual heating degree days (HDD) were calculated using a base temperature of 65°F. The peak heating ratio is a result of dividing the number of HDD on the coldest day by the total annual HDDs. Then, peak demand savings are calculated by multiplying the peak heating ratio against the annual therms savings.

$$\boldsymbol{peak\ therms_{\ savings} = therms_{\ savings} \times Peak\ Heating\ Ratio} \tag{13}$$

Table 20: Case 8 Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.1	Direct Vent Heaters
		2.1.3	Gas Furnace Replacement
		2.1.4	Gas Furnace Tune-Up
	DHW	2.3.1	Water Heater Replacement
		2.3.4	Faucet Aerators
		2.3.5	Low-Flow Showerheads
Commercial	HVAC	3.1.10	Direct Vent Heaters (Small Commercial/Converted Residences)

Case 9: Peak demand savings for measures utilizing algorithms to calculate peak savings

The following calculation methodologies are used to derive peak demand savings:

Case 9a: Based on system capacity and efficiency or change in efficiency (specified per measure)

Peak day therms savings are calculated by dividing capacity by efficiency or change in efficiency (η). Other conversion factors are outlined in each measure.

$$peak\ therms_{savings} = Capacity \times \frac{1}{\eta} \times conversion\ factors \tag{14}$$

or

$$peak\ therms_{savings} = Capacity \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times conversion\ factors \tag{15}$$

Table 21: Case 9a Measure List

Sector	Section	Measure Number	Measure Name
Commercial	HVAC	3.1.5	Boiler Tune-Up
		3.1.6	Burner Replacement for Commercial Boilers
		3.1.8	Commercial and Industrial Boilers
		3.1.9	Commercial Furnaces

Case 9b: Based on flow rate, change in temperature, and efficiency or change in efficiency (specified per measure)

Peak demand savings are calculated by multiplying water density (ρ) by the specific heat of water (C_p), flow rate, and change in temperature and dividing by efficiency or change in efficiency. Other conversion factors are outlined in each measure.

$$peak\ therms_{savings} = \rho \times C_P \times \Delta Flow\ Rate \times \left(T_{hot\ water} - T_{supply}\right) \times \frac{1}{\eta} \times conversion\ factors \tag{16}$$

or

$$peak\ therms_{savings} = \rho \times C_P \times \Delta Flow\ Rate \times \left(T_{hot\ water} - T_{supply}\right) \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times conversion\ factors \tag{17}$$

Table 22: Case 9b Measure List

Sector	Section	Measure Number	Measure Name
Commercial	DHW	3.3.1	Water Heater Replacement
		3.3.2	Faucet Aerators
		3.3.5	Low-Flow Showerheads

Case 9c: Based on U-value, surface area, change in temperature, and efficiency (specified per measure)

Peak demand savings are calculated by multiplying the change in heat transfer, U-value (calculated as 1 ÷ R-value) by surface area and change in temperature and dividing by efficiency. Other conversion factors are outlined in each measure.

$$peak\ therms_{savings} = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{in} - T_{out}\right) \times \frac{1}{\eta} \times conversion\ factors$$

(18)

Table 23: Case 9c Measure List

Sector	Section	Measure Number	Measure Name
Residential	DHW	2.3.3	Water Heater Pipe Insulation
Commercial		3.3.3	Water Heater Jackets
		3.3.4	Water Heater Pipe Insulation

Case 9d: Based on annual energy savings and annual operating hours (specified per measure)

Peak demand savings are calculated by dividing the measure specific annual energy savings (therms) by the measure specific annual operating hours.

$$peak\ therms_{savings} = \frac{therms_{savings}}{hours}$$

(19)

Table 24: Case 9d Measure List

Sector	Section	Measure Number	Measure Name
Commercial	HVAC	3.2.11	Commercial Door Air Infiltration

Case 9e: Based on annual energy savings and annual operating days

Peak demand savings are calculated by dividing the measure specific annual energy savings (therms) by the measure specific annual operating days.

$$peak\ therms_{savings} = \frac{therms_{savings}}{days}$$

(20)

Table 25: Case 9e Measure List

Sector	Section	Measure Number	Measure Name
Commercial	Food Service	3.8.11	Low-Flow Pre-Rinse Spray Valves

Case 10: Peak demand savings for measures where peak savings extracted from referenced studies

For a single measure, peak demand savings were taken directly from a referenced study.

Table 26: Case 10 Measure List

Sector	Section	Measure Number	Measure Name
Residential	HVAC	2.1.12	Smart Thermostats

Case 11: Peak demand savings for measures where the methodology for peak savings is undocumented or incomplete

Undocumented or incomplete peak demand savings methodologies will be updated at the time that each measure is selected for update in a future TRM update.

Subcase 11a: Incomplete Methodology Description

For a single measure, electric peak demand savings were derived by developing a load profile for the applicable measure and calibrating using metered end-use data obtained from utility metering studies. This approach is described in detail in the measure referenced below.

Table 27: Case 11a Measure List

Sector	Section	Measure Number	Measure Name
Residential	DHW	2.3.2	Water Heater Jackets

Case 12: Measures where no peak savings are specified

For a small sub-set of measures, there are no applicable peak demand savings.

Table 28: Case 12 Measure List

Sector	Section	Measure Number	Measure Name
Commercial	HVAC	3.1.2	Boiler Cut-Out Controls
		3.1.3	Boiler or Furnace Vent Dampers
		3.1.4	Boiler Reset Controls

1.4 General Installation Standards

If pre-application is a program requirement, installed equipment should exceed applicable state and federal energy standards adopted at the time the project is approved, or at the time the project invoice is submitted to the utility. The deemed savings are based on the assumption that installed equipment is new; deemed savings are not available for used or reconditioned equipment. All projects must follow all applicable state and local building codes.

1.5 Effective Dates for Measure Calculations

Once approved by the Commission, the deemed savings estimates contained herein should generally be used for all subsequent estimates of energy efficiency savings filed with the Commission.

To ensure that the savings are accurately calculated, and to provide sufficient time for the utilities, the third-party administrators, and program implementers to collect data to conform to the new tracking requirements as defined in Protocol A-Database Tracking, Volume 1, the effective date for determining savings for the affected measures will be either January 1, 2018 or 60 days after approval by the Commission, whichever date is later. For measures that do not require the collection of additional information, TRM Version 7.0 methodologies for calculating deemed savings should be used for program year 2018.

Measures that have been updated, and thus may require additional data collection fields or other tracking changes include, but are not necessarily limited to, the following:

- **Residential Heating, Ventilation, & Air Conditioning (HVAC) Measures**
    - 2.1.8 Heat Pump Replacement
    - 2.1.12 Smart Thermostats
    - 2.1.13 ENERGY STAR® Ventilations Fans
- **Residential Envelop Measures**
    - 2.2.2 Ceiling Insulation
- **Residential Domestic Hot Water Measures**
    - 2.3.1 Water Heater Replacement
    - 2.3.6 Showerhead Thermostatic Restrictor Valve
    - 2.3.7 Tub Spout and Showerhead Thermostatic Restrictor Valve
- **Residential Appliances Measures**
    - 2.4.2 ENERGY STAR® Dishwasher
    - 2.4.6 ENERGY STAR® Dehumidifier
- **Residential Lighting Measures**
    - 2.5.1.1 ENERGY STAR® Compact Fluorescent Lamps (CFLs)
    - 2.5.1.2 ENERGY STAR® Specialty Compact Fluorescent Lamps (CFLs)
    - 2.5.1.3 ENERGY STAR® Specialty LEDs
    - 2.5.1.4 ENERGY STAR® Omni-Directional LEDs
- **Commercial Heating, Ventilation, & Air Conditioning (HVAC) Measures**
    - 3.1.7 Central Air Conditioner and Heat Pump Tune-up
- **Commercial Domestic Hot Water Measures**
    - 3.3.1 Water Heater Replacement
- **Commercial Appliances Measures**
    - 3.5.1 Solid Door Refrigerators and Freezers
- **Commercial Food Service Measures**
    - 3.8.4 Commercial Oven
    - 3.8.4.3 Rack ovens
    - 3.8.5 Combination Ovens
    - 3.8.6 Commercial Fryers
    - 3.8.8 Commercial Underfired Broilers

- 3.8.9 Commercial Conveyor Broilers

Any other TRM measure in which the required data to estimate measure savings were not tracked in the current database system, including requiring changes in formulae for estimating savings, or adding data fields to conform with the new tracking requirements.

1.6 Clarification for Additional Data Collection or Tracking Requirements

The following list summarizes the newly required data collection inputs based on the changes made in Version 7.0 of the TRM.

Residential Heating, Ventilation, & Air Conditioning (HVAC) Measures

2.1.8 Central Heat Pump Replacement

Tracking Changes:

1. No actual update to measure; however, clarified language to include all air-source heat pumps for residential applications.

2.1.12 Smart Thermostats

Tracking Changes:

1. No actual update to measure; however, included language that the new smart thermostats must be be ENERGY STAR® qualifying.

2.1.13 ENERGY STAR® Ventilations Fans

Tracking Changes:

1. Measure was included to the Version 7.0 TRM

New Inputs:

1. Nameplate airflow (CFM) of installed ventilation fan;
2. Efficacy of installed ENERGY STAR® ventialation fan;
3. Annual operating hours of new ventilation fan;

Residential Envelop Measures

2.2.2 Ceiling Insulation

Tracking Changes:

1. Updated baseline efficieny ranges to include R-values between whole numbers

Residential Domestic Hot Water Measures

2.3.1 Water Heater Replacement

Tracking Changes:

1. Updated baseline standard to be consistent with federal standard

New Inputs:

1. Draw patter based on FHR of installed unit

2.3.6 Showerhead Thermostatic Restrictor Valve

Tracking Changes:

1. New measure added to Version 7.0 of the TRM

New Inputs:

1. Showerhead flow rate (GPM)

2. Behavoral waste of baseline showerhead
3. Recovery efficiency based on the hot water system type

2.3.6 Showerhead Thermostatic Restrictor Valve

Tracking Changes:

2. New measure added to Version 7.0 of the TRM

New Inputs:

4. Showerhead flow rate (GPM)
5. Behavoral waste of baseline showerhead
6. Recovery efficiency based on the hot water system type

Residential Appliance Measures

2.4.2 ENERGY STAR® Dishwasher

Tracking Changes:

1. Deemed savings values were updated to be consistent with ENERGY STAR® requirements effective 1/29/2016.

2.4.6 ENERGY STAR® Dehumidifier

Tracking Changes:

1. New measure added to Version 7.0 of the TRM

New Inputs:

1. Baseline and efficient dehumidifier capcities

Commercial Heating, Ventilation, & Air Conditioning (HVAC) Measures

3.1.7 Central Air Conditioner and Heat Pump Tune-up

Tracking Changes:

1. Included a second method to determine pre and post-case EER of units.
2. Incldued guidance regarding the determination of the post-case unit efficiency when only the pre-case efficiency was measured and corresponding energy savings methodology.

Commercial Domestic Hot Water Measures

3.3.1 Water Heater Replacement

Tracking Changes:

1. Updated baseline standard to be consistent with federal standard for residential size units

New Inputs:

1. Draw patter based on FHR for residential size units

Commercial Appliance Measures

3.5.1 Solid Door Refrigerators and Freezers

Tracking Changes:

1. Efficiency levels of the baseline and ENERGY STAR® rated equipment was updated to March 27,2017 standards.

Commercial Food Service Measures

3.8.4 Commercial Ovens

Tracking Changes:

1. Updated efficient model cooking energy efficieny for electric ovens.
2. Updated idle energy rate and production capacity of efficient gas ovens.

3.8.4.3 Rack Ovens

Tracking Changes:

1. Updated idle energy rate and cooking efficiency for the efficient single rack ovens.

3.8.5 Combination Ovens

Tracking Changes:

1. Preheat energy, convection production capacity, and steam production capacity were updated for the efficient units.

3.8.6 Commercial Fryers

Tracking Changes:

1. Heavy-Load cooking energy efficieny and idle energy rate parameters were updated for electric fryers.

3.8.8 Commercial Underfired Broilers

Tracking Changes:

1. New measure, includes deemed inputs and savings values for efficient underfired broilers

3.8.9 Commercial Conveyor Broilers

Tracking Changes:

1. New measure, includes deemed inputs and savings values for efficient conveyor broilers

1.7 Organization of this Volume

This volume is organized into the following sections and subsections:

2. Residential Deemed Savings, Installation and Efficiency Standards
    - 2.1. Heating, Ventilation & Air Conditioning (HVAC) Measures
    - 2.2. Envelope Measures
    - 2.3. Domestic Hot Water
    - 2.4. Appliances
    - 2.5. Lighting

3. Commercial, Industrial, and Small Commercial Deemed Savings, Installation and Efficiency Standards
    - 3.1. Heating, Ventilation and Air Conditioning (HVAC) Measures
    - 3.2. Envelope Measures
    - 3.3. Domestic Hot Water
    - 3.4. Motors
    - 3.5. Appliances
    - 3.6. Lighting
    - 3.7. Other
    - 3.8. Food Service Equipment

4. General Reference Information
    - 4.1 Acronyms and Abbreviations
    - 4.2 Coincidence Factors for HVAC
    - 4.3 Equivalent Full Load Hours Calculation
    - 4.4 Commercial Measure References

Each section describing a measure is formatted as follows:

- 2.0 Measure General Market
- 2.1 Measure Category
- 2.1.1 Measure Name
    - Measure Description
    - Baseline and Efficiency Standards
    - Estimated Useful Life
    - Deemed Savings Values
    - Calculation of Deemed Savings

To provide additional guidance to the reader, Section 4 provides general reference information in the following ways:

- Section 4.1 - The definition of key terms and abbreviations
- Section 4.2 - Description of coincidence factors for HVAC measures
- Section 4.3 - Description of equivalent full load hours to use for calculations in
- Section 4.4 - Endnotes referencing the original source materials used throughout the TRM. All endnotes are italicized to avoid confusion with footnotes. At the time of publication, all references and links throughout this document were correct.

1.8 Early Retirement

Early retirement occurs when existing, functional, actively used equipment is replaced with similar, higher efficiency equipment. The equipment being replaced should have at least one year of remaining useful life (RUL) unless otherwise specified in the measure.

In the case of early retirement, a dual baseline may be applied to more accurately assess savings over the effective useful life (EUL) of the measure. When a dual baseline is used, there are two baselines, where:

1. Pre-existing equipment baseline for savings during the RUL period; and
2. Code requirements or industry standard practices baseline for the balance of the EUL period for the new equipment (EUL – RUL).

For projects or programs where several pieces of equipment are being replaced, calculation of the average age of existing equipment for the purposes of determining a single RUL, rather than using separate EULs for each piece of equipment is allowed.

The following measures include provisions for the optional early retirement baseline:

- 2.1.1 Direct Vent Heaters
- 2.1.3 Gas Furnace Replacement
- 2.1.6 Central Air Conditioner Replacement
- 2.1.8 Heat Pump Replacement
- 2.4.3 ENERGY STAR® Refrigerators
- 3.1.8 Commercial and Industrial Boilers
- 3.1.15 Packaged Terminal AC/HP (PTAC/PTHP) Equipment
- 3.1.18 Unitary and Split System AC/HP Equipment
- 3.1.19 Air or Water Cooled Chilling Equipment (Chillers)
- 3.4.2 Premium Efficiency Motors

1.8.1 Derivation of RUL

The EUL for a measure is the expected median number of years that a measure is in place and operational after installation[7], consistent with the age at which 50 percent of systems installed in a given year will no longer be in service. The expected trend in equipment retirement is calculated using survival functions specified in DOE technical support documents (TSD) for a given measure. Measure specific TSDs are referenced in each individual measure with an optional early retirement baseline.

The method used for estimating the RUL of a replaced system uses the age of the existing equipment to re-estimate the survival function over the life of the measure. The age of the system being replaced and corresponding survival rate is plotted on a chart using the Weibull distribution specified in the DOE TSD for that measure. The Weibull distribution is a probability distribution function commonly used to measure failure rates.[8] Its form is similar to an exponential distribution, which would model a fixed failure rate, except that it allows for a failure rate which changes over time in a particular fashion. The Weibull survival function takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}}\ for\ x > \theta\ and\ P(X) = 1\ for\ x \leq \theta \tag{21}$$

Where:

$P(x)$ = probability that the appliance is still in use at age x

x = appliance age

α = the scale parameter, which is the decay length in an exponential distribution (defined in measure TSD)

β = the shape parameter, which determines the way in which the failure rate changes in time (defined in measure TSD)

Θ = the delay parameter, which allows for delay before any failure occurs (defined in measure TSD)

As shown in Figure 2, after plotting the survival function, the age of the existing equipment is identified in the figure, and the corresponding percentage of surviving systems is determined from this chart.

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[7] Violette, D. 2013 Navigant Consulting, "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Chapter 13: Assessing Persistence and Other Evaluation Issues Cross-Cutting Protocols", National Renewable Energy Laboratory (NREL) http://energy.gov/sites/prod/files/2013/11/f5/53827-13.pdf

[8] National Institute of Standards and Technology (NIST), "NIST/SEMATECH e-Handbook of Statistical Methods." www.itl.nist.gov/div898/handbook/

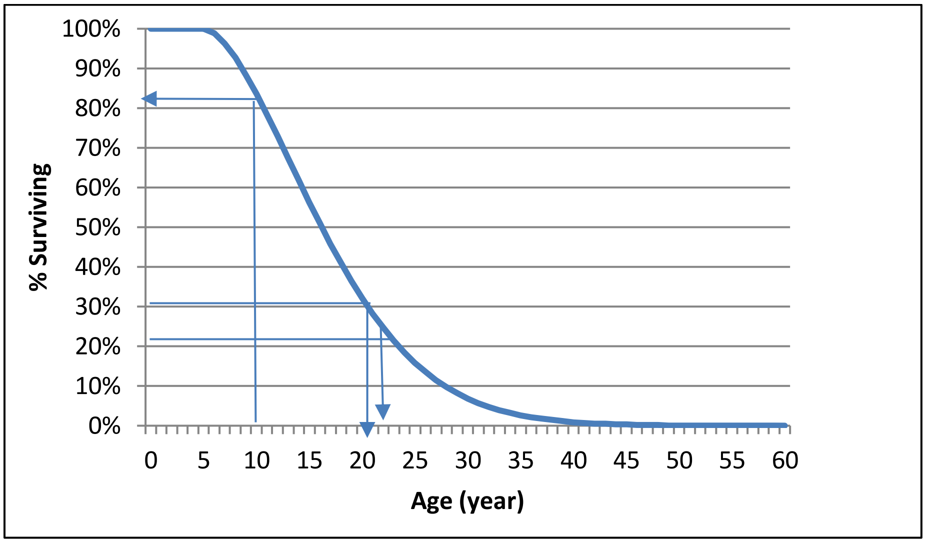

Figure 2: Example Survival Function for ENERGY STAR® Refrigerators

For example, referring to Figure 2, if the unit is 10 years old, the number of surviving units is 82 percent.

The surviving percentage value is then divided in half to identify the equipment age representing 50 percent survival for the adjusted survival function. This is done to account for the percentage of units that have already failed, and to isolate only the remaining fully functioning equipment and re-estimate the survival function.

For example, if the number of surviving units is 82 percent, half the surviving percentage value is 41 percent.

Then, the age (year) that corresponds to this new percentage is read from the chart.

For example, referring to Figure 2, the age at a surviving percentage of 41 percent, is 17.8 years.

RUL is estimated as the difference between that age and the current age of the system being replaced, representing the estimated age at which 50 percent of the systems still functioning will no longer be in service.

For example, referring to Table 31, the RUL of a 10-year-old refrigerator is 17.8 years – 10 years = 7.8 years.

In most cases, these percentages will not align with a year rounded to the nearest whole number. Linear interpolation is applied to identify age estimates to one decimal place.

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure. This guideline also applies to samples of multiple systems. Individual systems exceeding this maximum lifetime should not be included in any sample. Those systems should use the replace-on-burnout baseline.

In the example, referring to Figure 2, the maximum age of the unit is 22 years. Systems exceeding 22 years must use the replace-on-burnout baseline.

Additional, specific, application information is provided in each measure where the early retirement methodology is applied.

1.8.2 Annual and Lifetime Savings

To apply a dual baseline, annual kW, kWh, and therms savings must be calculated separately for two time periods:

1. For the deemed remaining life of the equipment that is being removed (RUL period)
2. The remaining time in the EUL period (EUL – RUL)

Step 1: Calculate First Year Savings

First year savings (as reported to the PSC) are the savings claimed during the RUL period. This savings value will be calculated by using the less stringent baseline and savings calculation methodologies specified in the installed measure.

Step 2: Calculate after RUL Savings

Savings may be claimed during the remaining time in the EUL period after the RUL has been exceeded. This savings value is calculated using the more stringent baseline and savings calculation methodologies specified in the installed measure.

The savings calculation methodology should not change when calculating the first year and second tier savings values. The only difference is the use of a different, more stringent baseline.

Step 3: Calculate Lifetime Savings

Lifetime savings are the savings claimed during the entire EUL of the measure. These savings are represented by the sum of the savings during the RUL period and the savings after the RUL period, or EUL – RUL. Lifetime kW, kWh, and therms savings for early retirement projects are calculated as follows:

$$Lifetime\ kW_{Savings} = \left(kW_{Savings,ER} \times RUL\right) + \left[kW_{Savings,ROB} \times (EUL - RUL)\right] \tag{22}$$

$$Lifetime\ kWh_{Savings} = \left(kWh_{Savings,ER} \times RUL\right) + \left[kWh_{Savings,ROB} \times (EUL - RUL)\right] \tag{23}$$

$$Lifetime\ therms_{Savings} = \left(therms_{Savings,ER} \times RUL\right) + \left[therms_{Savings,ROB} \times (EUL - RUL)\right] \tag{24}$$

Where:

ER = Early Retirement

ROB = Replace-on-Burnout

1.8.3 Early Retirement Savings Examples

Early retirement savings are calculated differently depending on the measure. However, applying the early retirement baseline will always result in an initial set of demand and energy savings that will be applied over the RUL period and a second set of demand and energy savings that will be applied over the remainder of the EUL period (EUL – RUL).

Example 1:

Below is an example of an early retirement of a 12-year-old refrigerator. Table 29 contains the initial savings for the RUL period and the secondary savings for the RUL-EUL period. The RUL for a 12-year old refrigerator is seven years and the EUL for the ENERGY STAR® Refrigerator measure is 17 years.

Table 29: Early Retirement Savings Tiers

Savings Tier	EUL	RUL	kW Savings	kWh Savings	Measure Life
ER	17.0	7.0	6.0	1,000	RUL = 7.0
ROB			3.0	500	EUL – RUL = 17.0 – 7.0 = 10.0

First year annual savings are 6.0 kW and 1,000 kWh. Those savings may be claimed annually for the first 7 years of the measure life. In year eight, annual savings should be reduced to 3.0 kW and 500 kWh. Those savings should be claimed annually for years 8 through 17 of the measure life.

Lifetime kW and kWh savings for early retirement projects are calculated as follows:

$$kW_{Savings} = (6.0 \times 7.0) + [3.0 \times (17.0 - 7.0)] = 42.0 + 30.0 = 72.0\ kW$$

$$kWh_{Savings} = (1{,}000 \times 7.0) + [500 \times (17.0 - 7.0)] = 7{,}000 + 5{,}000 = 12{,}000\ kWh$$

Example 2:

For a project with several pieces of equipment of varying age, the average RUL can be used to determine the RUL for the early retirement project. In this example, five functional refrigerators of various ages are replaced with new ENERGY STAR® refrigerators. Equipment RUL is taken from Table 31. The sampled equipment should not include any individual systems with a system age that exceeds the specified maximum lifetime to be eligible for early retirement.

Table 30: Inventory of Refrigerator Age for Example Project

Equipment #	Equipment Age	Equipment RUL
1	6	10.3
2	7	9.6
3	9	8.3
4	12	7.0
5	15	6.0
Average	**9.8**	**8.2**

Table 31: RUL of Replaced Refrigerator

Equipment Age	RUL	Equipment Age	RUL
6	10.3	15	6.0
7	9.6	16	5.8
8	8.9	17	5.5
9	8.3	18	5.3
10	7.8	19	5.1
11	7.4	20	4.9
12	7.0	21	4.8
13	6.6	22	4.6
14	6.3	23 +	0.0

Using the average equipment RUL of 8.2 years and the ER and ROB savings from Example 1 annual and lifetime savings should be applied as follows:

Table 32: Early Retirement Savings Tiers

Savings Tier	EUL	RUL	kW Savings	kWh Savings	Measure Life
ER	17.0	8.2	6.0	1,000	RUL = 8.2
ROB			3.0	500	EUL – RUL = 17.0 – 8.2 = 8.8

First year annual savings are 6.0 kW and 1,000 kWh. Those savings should be claimed annually for the first 7.8 years of the measure life. For the remaining 9.2 years, annual savings should be reduced to 3.0 kW and 500 kWh. Those savings should be claimed annually for the last 0.2 years of year 8 and for years 9 through 17 of the measure life.

Lifetime kW and kWh savings for early retirement projects are calculated as follows:

$$kW_{Savings} = (6.0 \times 8.2) + [3.0 \times (17.0 - 8.2)] = 49.2 + 26.4 = 75.6\ kW$$

$$kWh_{Savings} = (1{,}000 \times 8.2) + [500 \times (17.0 - 8.2)] = 8{,}200 + 4{,}400 = 12{,}600\ kWh$$

2. RESIDENTIAL DEEMED SAVINGS MEASURES

2.1 Heating, Ventilation & Air Conditioning (HVAC) Measures

2.1.1 Direct Vent Heaters

Measure Description

This measure applies to a direct vent, natural gas-fired, wall-type furnace with electronic ignition for small open areas not requiring ducted air distribution.[9] Typical applications include single-room areas such as living room areas, and bedrooms. This measure applies to all residential applications.

Baseline and Efficiency Standards

Direct vent furnaces are available in sizes from 5,000 BTU/hr to 60,000 BTU/hr input and rated up to 82 percent efficient. Direct vent wall furnaces are installed in exterior walls, utilizing outside air for combustion and directly discharging combustion products to the outside area. The energy savings are a result of utilizing a more efficient furnace.

The baseline for replace-on-burnout projects is the Federal Energy Conservation Standard for direct heating equipment manufactured after April 16, 2013. The baseline for early retirement projects is the Federal Energy Conservation Standard for direct heating equipment manufactured after January 1, 1990 and before April 16, 2013.[10] The minimum efficiency requirements as listed in Table 33 are based on a review of available direct heating equipment from the Air Conditioning, Heating and Refrigeration Institute (AHRI) database. The equipment must meet the American National Standards Institute Z21.86 (latest standard) for Fan Type Direct-Vent Wall Furnaces.

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

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[9] Due to the hazard of carbon monoxide gas, non-vented space heaters were not considered.

[10] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/68

Table 33: Direct-Vent Heaters – Baseline and Efficiency Standards

Category	Baseline: Replace-on-Burnout AFUE %	Baseline: Early Retirement AFUE%	Efficiency Standard AFUE %
Gas wall fan type up to 42,000 Btu/hour	75	73	80
Gas wall fan type over 42,000 Btu/hour	76	74	
Gas wall gravity type up to 10,000 Btu/hour	65	59	70
Gas wall gravity type over 10,000 Btu/hour up to 12,000 Btu/hour		60	
Gas wall gravity type over 12,000 Btu/hour up to 15,000 Btu/hour		61	
Gas wall gravity type over 15,000 Btu/hour up to 19,000 Btu/hour		62	
Gas wall gravity type over 19,000 Btu/hour up to 27,000 Btu/hour		63	
Gas wall gravity type over 27,000 Btu/hour up to 46,000 Btu/hour	66	64	
Gas wall gravity type over 46,000 Btu/hour	67	65	

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, the same as gas furnaces. The California Database of Energy Efficiency Resources (DEER) does not list Direct-Vent Heaters as a separate technology. The current technology for direct-vent heaters is similar to the gas furnaces listed in DEER 2008.

Calculation of Deemed Savings

Annual Therm Savings

Replace-on-Burnout (ROB)

Deemed savings for replace-on-burnout projects can be calculated using the following equation:

$$Annual\ Therm\ Savings = Heat\ load \times \left({}^{1}\!/_{AFUE_{base}} - {}^{1}\!/_{AFUE_{eff}} \right)$$

(25)

$$Heat\ load = \frac{therms/_{heated\ area}}{year} \times heated\ area$$

(26)

Where:

$heated\ area$ = square footage of the heated area; see Table 35 for estimates of $\frac{\frac{\text{therms}}{\text{ft}^2}}{\text{year}}$, or if $heated\ area$ is unknown, use installed capacity (btuh)/30 (btuh/ft^2) [11]

$AFUE_{base}$ = baseline efficiency of the wall furnace, see Table 33

$AFUE_{eff}$ = efficiency of the new wall furnace installed, in AFUE

Early Retirement (ER)

Annual savings must be calculated separately for two time periods:

1. The estimated remaining life (RUL, see Table 34) of the equipment that is being removed, designated the first N years, and
2. Years EUL - N through EUL, where EUL is 20 years.

For the first N years:

Deemed savings for early retirement projects can be calculated using the same equation as used for replace-on-burnout projects, but replacing the $AFUE_{base}$ factor with the $AFUE_{base\_early}$ factor using either field measurements of the AFUE of the existing system, or as described by the following equation:[12]

$$AFUE_{base\_early} = (Base\ AFUE) \times (1 - M)^{age}$$

(27)

Where:

$Base\ AFUE$= efficiency of the existing equipment when new, in AFUE, see Table 33

M[13] = maintenance factor, 0.01

age = the age of the existing equipment, in years

For Years EUL - N through EUL:

Savings should be calculated exactly as they are for ROB projects.

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[11] Rule of thumb for system sizing.

[12] Calculation of baseline efficiency for early retirement projects taken from the October 2010 National Renewable Energy publication "Building America House Simulation Protocols," page 38.

[13] Maintenance factor of 0.01 is the average maintenance factor for gas furnaces taken from the October 2010 National Renewable Energy publication "Building America House Simulation Protocols," Table 30.

Lifetime savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ therm_{savings} = \left(therm_{savings,ER} \times RUL\right) + \left[therm_{savings,ROB} \times (EUL - RUL)\right]$$

(28)

Peak Therm Savings

Peak day therm savings can be calculated using the following equation:

$$Peak\ Day\ Therm\ Savings = Annual\ Therm\ Savings\ \times Peak\ Heating\ Ratio$$

(29)

Where:

$Peak\ Heating\ Ratio$ = Percent of heating expected to occur on the coldest day of the year, see Table 36

Table 34: Remaining Useful Life (RUL) of Direct Vent Heaters[14]

Age of Replaced Wall Furnace (years)	RUL (years)
5	14.7
6	13.7
7	12.7
8	11.8
9	10.9
10	10.0
11	9.1
12	8.3
13	7.5
14	6.8
15	6.2
16	5.5
17	4.5
18	4.0
19	3.6
20	3.2
21	2.9
22	2.6
23	2.4
24	2.1
25 +	0.0

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[14] Use of the early retirement baseline is capped at 24 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 24 years should use the ROB baseline.

Derivation of RULs

Residential gas furnaces have an estimated useful life of 20 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described in Figure 3.

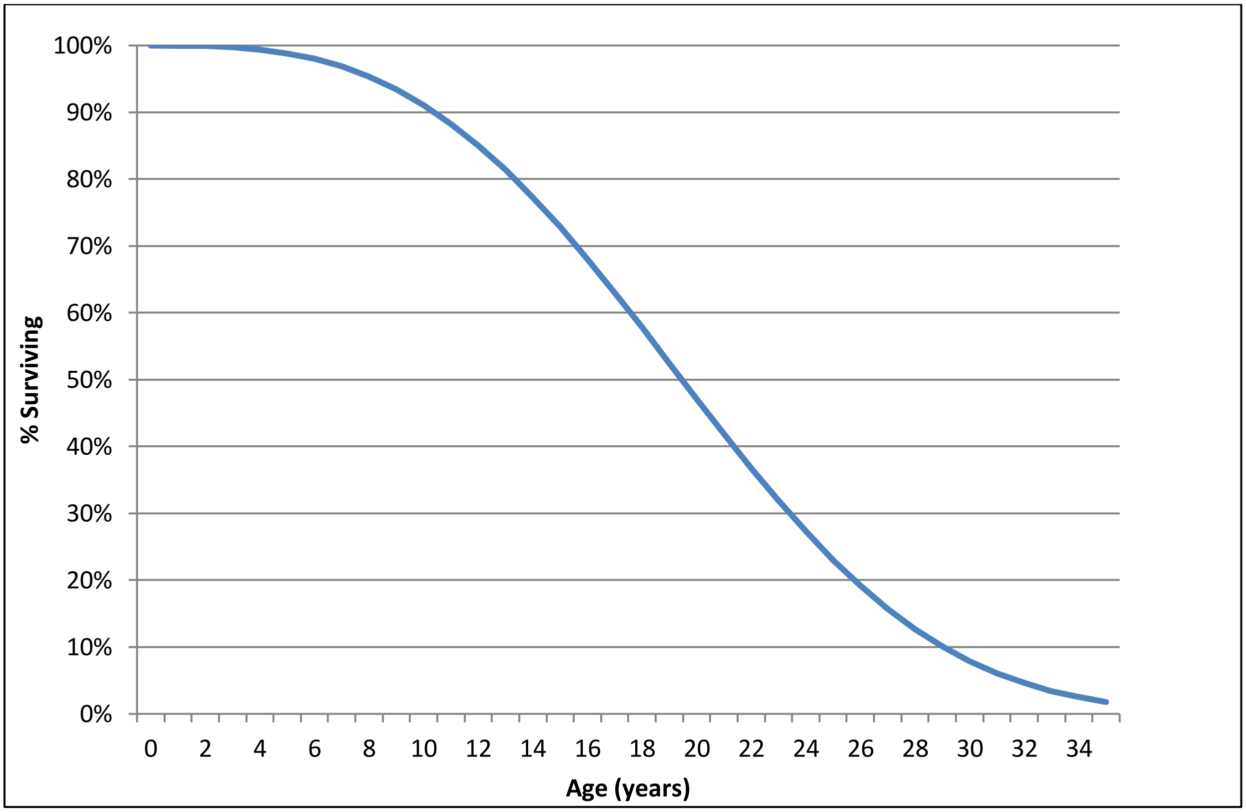

Figure 3: Survival Function for Residential Direct Vent Heaters[15]

The method used for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 3. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[15] RUL was determined by modifying the weibull distribution offered in the DOE's Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html. The modification included changing the scale parameter to 24 and the shape parameter to 2.34 to reflect the EUL of the gas furnace at 20 years.

To determine the heat load for use in calculating deemed savings, the following table may be used:

Table 35: Annual Direct Vent Heating Load[16]

Weather Zone	Heating Load (therms/sq. ft./year)
All Zones 6-9	0.1847

Table 36: Direct Vent Heating Peak Heating Ratio[17]

Weather Zone	Peak Heating Ratio
Zone 9 - Rogers[18]	0.019
Zone 8 - Ft. Smith	0.015
Zone 7 - Little Rock	0.016
Zone 6 - El Dorado	0.015

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[16] Annual direct vent heating load was derived by taking the average reported space heating consumption for gas-fired direct heating equipment in Arkansas from the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECs), and multiplying it by the average AFUE as listed in the Federal Energy Conservation Standard for direct heating equipment manufactured After January 1, 1990 and before April 16, 2013: 65% AFUE, and then dividing it by the average heated square footage for Arkansas homes that use direct heating as their primary heat source as reported in RECs.

[17] The Peak Heating Ratio was derived using TMY3 data. Annual heating degree days (HDD) were calculated using a reference temperature of 65°F. The ratio is the result of dividing the number of HDD on the coldest day by the annual HDD.

[18] Heating Ratio for zone 9 used data for Fayetteville, AR.

2.1.2 Duct Insulation

Measure Description

This measure consists of adding duct insulation with an R-value of 5.6 or 8.0 to uninsulated metal supply and return ductwork, located in unconditioned space that previously had no existing insulation. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline for this measure is uninsulated sheet metal ducts or insulated metal ducts in which the insulation has failed. Failed insulation is insulation which has non-repairable tears to the vapor barrier, exhibits gaps with exposed metal between the insulation, or insulation which is failing. Flex ducts, and fiber board ducts are not eligible for this measure. The ducts must be located in unconditioned spaces, such as attics or crawl spaces. Old ductwork insulation must be removed prior to installation of new duct wrap insulation.

Unconditioned space is defined as a space which is neither directly nor indirectly conditioned and is isolated from conditioned space by partitions, such as walls and/or closeable doors, and ceilings. It is also classified as space in which the temperature of the area traversed by the ductwork is greater than 100 degrees Fahrenheit during the cooling season and lower than 50 degrees Fahrenheit during the heating season. The following table provides a quick guide for determining if the area in which the ductwork is located may be considered unconditioned space.

The efficiency upgrade for this measure requires that ducts must be insulated with duct wrap to an R-value of 5.6 or 8.0. The R-value of 5.6 is the required duct insulation value in accordance with the Arkansas Energy Code Table 503.3.3.3.[19]

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years according to the National Energy Audit Tool (NEAT) v. 8.6.

Deemed Savings Values

Please note that the savings are a factor to be multiplied by the conditioned square footage of the home. Gas Heat (no AC) kWh applies to forced-air furnace systems only.

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[19] Source: http://www.sos.arkansas.gov/rulesRegs/Arkansas%20Register/2013/july13/168.00.11-003.pdf

Table 37: Duct Insulation – Deemed Savings Values - Zone 9 Northwest Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.080	0	0.016	0.426	0.419	0.00015	0.00064
Attic to R-5.6	0.041	0	0.008	0.219	0.214	0.00008	0.00033
Crawl Space to R-8	0.058	0	0.019	0.402	0.388	0.00005	0.00054
Crawl Space to R-5.6	0.029	0	0.010	0.205	0.198	0.00002	0.00028

Table 38: Duct Insulation – Deemed Savings Values - Zone 8 Northeast/North Central Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms[20]
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.098	0	0.016	0.445	0.436	0.00017	0.00053
Attic to R-5.6	0.050	0	0.008	0.227	0.224	0.00009	0.00027
Crawl Space to R-8	0.067	0	0.020	0.425	0.420	0.00004	0.00048
Crawl Space to R-5.6	0.034	0	0.010	0.217	0.215	0.00002	0.00025

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[20] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.929 (Attic to R-8), m = 0.930 (Attic to R-5.6), m = 0.1.05 (Crawlspace to R-8), m = 1.05 (Crawlspace to R-5.6). For Fort Smith, m = 0.878 (Attic to R-8), m = 0.878 (Attic to R-5.6), m = 0.987 (Crawlspace to R-8), m = 0.987 (Crawlspace to R-5.6).

Table 39: Duct Insulation – Deemed Savings Values - Zone 7 Central Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat (no AC) Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.109	0	0.015	0.432	0.383	0.00017	0.00050
Attic to R-5.6	0.055	0	0.007	0.221	0.196	0.00009	0.00026
Crawl Space to R-8	0.072	0	0.018	0.421	0.383	0.00002	0.00063
Crawl Space to R-5.6	0.037	0	0.009	0.215	0.197	0.00001	0.00032

Table 40: Duct Insulation – Deemed Savings Values - Zone 6 South Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.125	0	0.011	0.380	0.350	0.00019	0.00048
Attic to R-5.6	0.064	0	0.006	0.194	0.180	0.00010	0.000245
Crawl Space to R-8	0.081	0	0.012	0.368	0.319	0.00007	0.00055
Crawl Space to R-5.6	0.041	0	0.006	0.188	0.164	0.00003	0.00028

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent upon the R-value of the duct insulation pre- and post-retrofit. Deemed savings values are calculated based on the replacement of failed duct insulation with insulation that has an R-value of 5.6 or 8.0.

EnergyGauge USA® (EnergyGauge), a building load simulation software that calculates hourly load data, was used to estimate energy savings for a series of models. Since duct insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the EnergyGauge building model are outlined in Appendix A of TRM Volume 3.

2.1.3 Gas Furnace Replacement

Measure Description

This measure applies to the replacement of a residential gas furnace with an ENERGY STAR® qualified gas furnace. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline is assumed to be a new gas furnace with an AFUE of 80 percent. A survey of equipment listed in the AHRI Directory of Certified Product Performance[21] reveals a minimum available AFUE of 80 percent.

The new furnace should be properly sized to the dwelling, based on ASHRAE or the Air Conditioning Contractor of America (ACCA) Manual J standards[22], and, if coupled with central air conditioning, consistent with the furnace matching guidelines of the equipment manufacturer.

Equipment must, at a minimum, meet the ENERGY STAR® efficiency levels to be eligible. Current ENERGY STAR® levels require the AFUE, per federal test method 10 CFR 430, Appendix N to Subpart B, for U.S. South gas furnaces, to be 90 percent or higher.[23]

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Table 41: Gas Furnace Replacement – Baseline and Efficiency Levels

Baseline	Minimum Efficiency Level
80% AFUE	ENERGY STAR® 90% AFUE

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, based on the DEER 2008.

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[21] http://www.ahridirectory.org/ahridirectory/pages/home.aspx. Accessed June 2013.

[22] https://www.acca.org/store/product.php?pid=172

[23] http://www.energystar.gov/index.cfm?c=furnaces.pr_crit_furnaces

Calculation of Deemed Savings

Annual Therm Savings

Replace-on-Burnout (ROB)

Deemed savings for replace-on-burnout projects can be calculated using the following equation:

$$Annual\ Therm\ Savings\ = Heat\ load \times \left({}^{1}\!/_{AFUE_{base}} - {}^{1}\!/_{AFUE_{eff}}\right)$$

(30)

$$Heat\ load = \frac{therms\!/_{site\ area}}{year} \times site\ area$$

(31)

Where:

$site\ area$ = square footage of the project site; see Table 43 for estimates of $\frac{\frac{\text{therms}}{\text{ft}^2}}{\text{year}}$, or if site area is unknown, use installed input capacity (btuh)/30 (btuh/ft^2) [24]

$AFUE_{base}$ = baseline efficiency of the furnace, 80% AFUE

$AFUE_{eff}$ = efficiency of the new furnace installed, in AFUE

Early Retirement (ER)

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life (RUL, see Table 42) of the equipment that is being removed, designated the first N years, and
2. Years EUL - N through EUL, where EUL is 20 years.

For the first N years:

Deemed savings for early retirement projects can be calculated using the same equation as used for replace-on-burnout projects, but replacing the $AFUE_{base}$ factor with the $AFUE_{base\_early}$ factor using either field measurements of the AFUE of the existing system, or as described by the following equation.[25]

$$AFUE_{base\_early} = (Base\ AFUE) \times (1 - M)^{age}$$

(32)

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[24] Rule of thumb for system sizing.

[25] Calculation of baseline efficiency for early retirement projects taken from the October 2010 National Renewable Energy publication *"Building America House Simulation Protocols,"* p. 38.

Where:

$Base\ AFUE$ = efficiency of the existing equipment when new, 78% AFUE

M[26] = maintenance factor, 0.01

age = the age of the existing equipment, in years

For Years EUL - N through EUL:

Savings should be calculated exactly as they are for replace on burnout projects

Lifetime savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ therm_{savings} = \left(therm_{savings,ER} \times RUL\right) + \left[therm_{savings,ROB} \times (EUL - RUL)\right] \tag{33}$$

Peak Therm Savings

Peak day therm savings are calculated using the following equation:

$$Peak\ Day\ Therm\ Savings = Annual\ Therm\ Savings\ \times Peak\ Heating\ Ratio \tag{34}$$

Where:

$Peak\ Heating\ Ratio$ = Percent of heating expecting to occur on the coldest day of the year; see Table 44

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[26] Maintenance factor of 0.01 is the average maintenance factor for gas furnaces taken from the October 2010 National Renewable Energy publication "*Building America House Simulation Protocols,*" Table 30.

Table 42: Remaining Useful Life (RUL) of Gas Furnaces[27]

Age of Replaced Furnace (years)	RUL (years)
5	14.7
6	13.7
7	12.7
8	11.8
9	10.9
10	10.0
11	9.1
12	8.3
13	7.5
14	6.8
15	6.2
16	5.5
17	4.5
18	4.0
19	3.6
20	3.2
21	2.9
22	2.6
23	2.4
24	2.1
25 +	0.0

---

[27] Use of the early retirement baseline is capped at 24 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 24 years should use the ROB baseline.

Derivation of RULs

Residential gas furnaces have an estimated useful life of 20 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described in Figure 4.

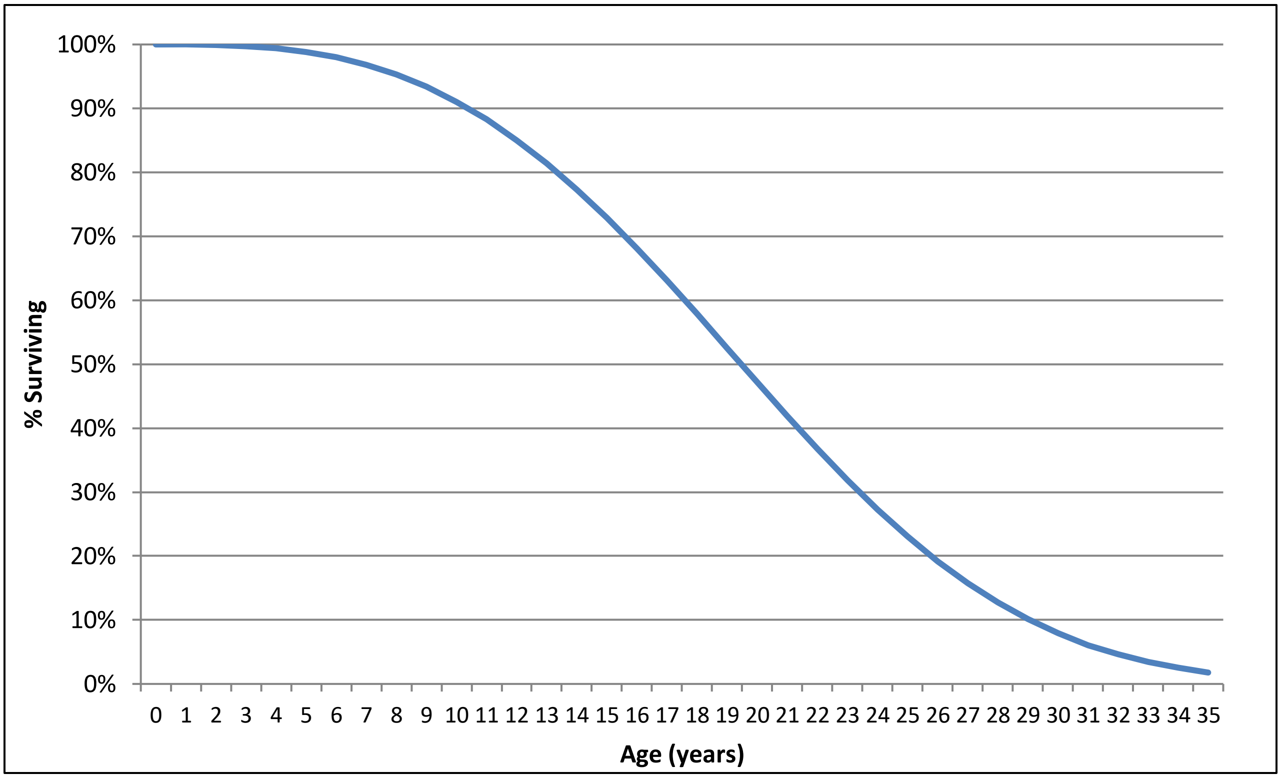

Figure 4: Survival Function for Residential Gas Furnaces[28]

The method used for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 4. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[28] RUL was determined by modifying the weibull distribution offered in the DOE's Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls".

www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html. The modification included changing the scale parameter to 24 and the shape parameter to 2.34 to reflect the EUL of the gas furnace at 20 years.

To determine the heat load for use in calculating deemed savings, the following table may be used:

Table 43: Annual Furnace Heating Load[29,30]

Construction Date	**Heating load (therms/sq. ft./year)**			
	Zone 9 – Rogers	**Zone 8 – Ft. Smith**	**Zone 7 – Little Rock**	**Zone 6 – El Dorado**
Pre-1970-1979	0.404	0.360	0.336	0.296
1980-1989	0.303	0.270	0.252	0.222
1990-1999	0.202	0.180	0.168	0.148
2000-Present	0.152	0.135	0.126	0.111

Table 44: Gas Furnace Peak Heating Ratio[31]

Weather Zone	**Peak Heating Ratio**
Zone 9 - Rogers[32]	0.019
Zone 8 - Ft. Smith	0.015
Zone 7 - Little Rock	0.016
Zone 6 - El Dorado	0.015

---

[29] Annual furnace heating load was derived using the ENERGY STAR® Furnace calculator. For heating load of homes of unknown age, we multiplied the ratio of heating degree days to regional average heating degree days by the average home heating load, weighted by year of construction, to produce an annual heat load. Reference used for zones 8 and 7.

[30] ADM Associates, Inc. 2015, *"Arkansas Residential Furnace Load Research."* July 13. Reference used for zones 9 and 6.

[31] The Peak Heating Ratio was derived using TMY3 data. Annual heating degree days (HDD) were calculated using a reference temperature of 65°F. The ratio is the result of dividing the number of HDD on the coldest day by the annual HDD.

[32] Data for zone 9 was taken from Fayetteville, AR.

2.1.4 Gas Furnace Tune-Up

Measure Description

This measure consists of a tune-up of an existing residential gas furnace, including any adjustments necessary to increase steady state efficiency (SSE). This measure applies to all residential applications.

Baseline and Efficiency Standards

Calculation of gas savings for this measure requires measurement of steady state furnace efficiency before and after tune-up using an electronic combustion analyzer. Alternatively, before and after tune-up efficiency may be measured following the method described in ANSI/ASHRAE Standard 103-2007, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers. Maximum post tune-up efficiency that can be used in claiming savings cannot exceed the nameplate efficiency of the furnace. Technicians performing tune-ups must provide documentation of before- and after-combustion analysis results.

Estimated Useful Life (EUL)

The average lifetime of this measure is three years, according to the National Energy Audit Tool (NEAT) v. 8.6.

Calculation of Deemed Savings

$$\frac{\Delta Therms}{yr} = \left(\frac{furnace\ rating}{100{,}000\ \mathrm{BTU/therm}}\right) \times EFLH \times \left(\frac{1}{SSE_b} - \frac{1}{\mathrm{SSE}_a}\right)$$

(35)

$$Peak\ Day\ Therm\ Savings = \Delta Therms/yr \times GM$$

(36)

Where:

$\Delta Therms$ = gross annual energy savings

$furnace\ rating$ measured in BTU per hr

$EFLH$ = heating equivalent full load hours for the appropriate weather zone (from Table 45)

SSE_b = steady state efficiency before tune-up

SSE_a = steady state efficiency after tune-up

GM = Gas Multiplier (from Table 46)

Example: For a 90,000 BTU/hr furnace with a steady state efficiency measured at 75 percent prior to tune up and 78 percent after tune-up, in Zone 7, annual gas savings would be:[33,34]

90,000/100,000 x 1682 hrs/yr. x (1/0.75 – 1/0.78) = 77.6 Therms/yr.

Table 45: Heating Equivalent Full Load Operating Hours[35]

Weather Zone	$EFLH_H$
9 Fayetteville	1,868
8 Fort Smith	1,738
7 Little Rock	1,681
6 El Dorado	1,521

Table 46: Peak Day to Annual Therms Ratio (Gas Multiplier)

Weather Zone	GM (Peak Day Therms per Annual Therms)
9 Fayetteville	0.0152195
8 Fort Smith	0.0181406
7 Little Rock	0.0179136
6 El Dorado	0.0244927

---

[33] Dethman, L. & Kunkle, R. 2007. "*Building Tune-up and Operations Program Evaluation*," Energy Trust of Oregon. Energy savings on the order of two to five were realized from a furnace and boiler tune-up program in the Pacific Northwest.

[34] Midwest Weatherization Best Practices, www.waptac.org

[35] ENERGY STAR® Central HP Calculator: www.energystar.gov/products/certified-products/detail/heat-pumps-air-source.

2.1.5 Central Air Conditioner and Heat Pump Tune-Up

Measure Description

This measure applies to central air conditioners and heat pumps. An AC tune-up, in general terms, involves checking, adjusting and resetting the equipment to factory conditions, such that it operates closer to the performance level of a new unit. This measure applies to all residential applications.

For this measure, the service technician must complete the following tasks according to industry best practices:

Air Conditioner Inspection and Tune-Up Checklist[36]

- Inspect and clean condenser, evaporator coils, and blower.
- Inspect refrigerant level and adjust to manufacturer specifications.
- Measure the static pressure across the cooling coil to verify adequate system airflow and adjust to manufacturer specifications.
- Inspect, clean, or change air filters.
- Calibrate thermostat on/off set points based on building occupancy.
- Tighten all electrical connections, and measure voltage and current on motors.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the starting cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Provide documentation showing completion of the above checklist to the utility or the utility’s representative.

Baseline and Efficiency Standards

The baseline is a system with demonstrated imbalances of refrigerant charge or pre-tune-up field measured efficiency.

After the tune-up, the equipment must meet airflow and refrigerant charge requirements. To ensure the greatest savings when conducting tune-up services, the eligibility minimum requirement for airflow is the manufacturer specified design flow rate, or 350 CFM/ton, if unknown. Also, the refrigerant charge must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or a capillary.

The efficiency standard, or efficiency after the tune-up, is assumed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, or the calculated or measured system EER as detailed below.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life for refrigerant charge correction is 10 years.

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[36] Based on ENERGY STAR® HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance

Calculation of Deemed Savings

Deemed peak demand and annual energy savings for unitary AC/HP tune-up should be calculated using the following formulas:

$$kW_{savings} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times CF$$

(37)

$$kWh_{savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right)$$

(38)

$$kWh_{savings,H} = CAP_H \times \frac{1\ kW}{1{,}000\ W} \times\times EFLH_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right)$$

(39)

$$kWh_{savings,AC} = kWh_{savings,C}$$

(40)

$$kWh_{savings,HP} = kWh_{savings,C} + kWh_{savings,H}$$

(41)

Where:

CAP_C = Rated or calculated equipment cooling capacity (Btu/hr)
CAP_H = Rated or calculated equipment heating capacity (Btu/hr)
EER_{pre} = Calculated or measured efficiency of the equipment for cooling before tune-up Equation (42)
EER_{post} = Nameplate , measured or calculated efficiency of the existing equipment for cooling; if unknown, use 11.2 EER (default)[37]

Note: Site measurements may be substituted for EER_{pre} and EER_{post}, providing that the measurements are taken on the same site visit and under similar operating conditions using reliable, industry accepted techniques.

$HSPF_{pre}$ = Calculated or measured efficiency of the equipment for heating before tune-up Equation (45)

$HSPF_{post}$ = Nameplate , measured or calculated efficiency of the existing equipment for heating; if unknown, use 7.7 HSPF (default)

CF = Coincidence Factor = 0.87 (default)[38]

$EFLH_C$ = Equivalent full-load cooling hours (Table 49)

$EFLH_H$ = Equivalent full-load heating hours (Table 49)

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[37] Code specified SEER value (13 SEER from federal standard effective January 23, 2006 through January 1, 2015) converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). *"Building America House Simulation Protocols."* U.S. DOE. Revised October 2010. www.nrel.gov/docs/fy11osti/49246.pdf.

[38] See Section 4.2 General Reference Information: Coincidence Factors for HVAC.

There are two methods for calculating system pre and post efficiencies as described below:

Method 1: Change of efficiency based on change in system charge.

In method 1, the efficiency improvement resulting from the refrigerant charge adjustment depends on the pre-adjustment refrigerant charge. This method may be used for air conditioners and heat pumps operating in cooling mode.

$$EER_{pre} = (1 - EL) \times EER_{post}$$

(42)

Where:

EER_{pre} = Calculated efficiency of the equipment for cooling before tune-up

EER_{post} = Nameplate efficiency of the existing equipment for cooling; if unknown, use 11.2 EER (default)

EL = Efficiency Loss (Fixed Orifice: Table 47; TXV: Table 48) determined by averaging reported efficiency losses from multiple studies.[39,40,41,42,43] Interpolation of the efficiency loss values presented is allowed. Extrapolation is not allowed.

Table 47: Efficiency Loss Percentage by Refrigerant Charge Level (Fixed Orifice)

% Charged	EL
$\leq$ 70	0.37
75	0.29
80	0.20
85	0.15
90	0.10
95	0.05
100	0.00
$\geq$ 120	0.03

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[39] Architectural Energy Corporation, managed by New Buildings Institute. 2003 "*Small HVAC System Design Guide.*" Prepared for the California Energy Commission. Figure 11.

[40] Davis Energy Group. "HVAC Energy Efficiency Maintenance Study." California Measurement Advisory Council (CALMAC). December 29, 2010. Figure 14.

[41] Proctor Engineering Group. "Innovative Peak Load Reduction Program CheckMe!® Commercial and Residential AC Tune-Up Project." California Energy Commission. November 6, 2003. Table 6-3.

[42] Proctor Engineering Group. PEG Tune-Up Calculations spreadsheet.

[43] *Pennsylvania Technical Reference Manual* June 2012. Measure 3.3.2, Table 3-96.

Table 48: Efficiency Loss Percentage by Refrigerant Charge Level (TXV)

% Charged	EL
≤ 70	0.12
75	0.09
80	0.07
85	0.06
90	0.05
95	0.03
100	0.00
≥ 120	0.04

Method 2: Calculation of savings based on pre or pre and post measurement of system efficiency, and age of equipment

In calculation method 2, direct site measurements of EER pre and post are used. Pre and post EER measurements should be conducted and the measurements should be taken on the same site visit and under similar operating conditions using reliable, industry accepted techniques.

If onsite measurements are used to determine savings for improvements other than refrigerant charge, then the implementer should use an EUL of three years.

When using this approach, the system capacity (CAPc) is adjusted using the following calculation:

$$\boldsymbol{CAPc = CAP_{nameplate} * EER_{post} / EER_{namplate}} \tag{43}$$

In cases where only a pre-tune up efficiency can be completed, then post tune-up efficiency may be estimated using the lesser of the nameplate efficiency or the results of Equation 44. Equation 44 estimates the efficiency of the unit based on the age as well as typical maintenance practices of the customer.

$$\boldsymbol{EER_{post} = \frac{(EER_{pre})}{(1-M)^{age}}} \tag{44}$$

Where:

M = Maintenance factor[44], use 0.01 if annual maintenance conducted or 0.03 if maintenance is seldom; use default value of 0.03 if maintenance history is unknown.\

Age = Age of equipment in years, up to a maximum of 20 years, use a default of 10 years if unknown.

Heat Pump Heating Credit

For heat pump systems, an additional saving credit may be taken as follows:

$$HSPF_{pre} = (HSPF_{post}) \times (1-M)^{age}$$

(45)

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[44] "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. Table 32. Page 40. http://www.nrel.gov/docs/fy11osti/49246.pdf.

Where:

$HSPF_{post}$ = Nameplate efficiency of the existing equipment for heating; if unknown use 7.7 HSPF (default)

M = Maintenance factor[45], use 0.01 if annual maintenance conducted or 0.03 if maintenance is seldom; use default value of 0.03 if maintenance history is unknown.

Age = Age of equipment in years, up to a maximum of 20 years, use a default of 10 years if unknown.

Table 49: Equivalent Full-Load Cooling/Heating Hours[46]

Weather Zone	Location	$EFLH_C$	$EFLH_H$
9	Fayetteville	1,305	1,868
8	Fort Smith	1,432	1,738
7	Little Rock	1,583	1,681
6	El Dorado	1,738	1,521

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[45] "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. Table 32. Page 40. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[46] ENERGY STAR® Central HP Calculator: www.energystar.gov/products/certified-products/detail/heat-pumps-air-source.

2.1.6 Central Air Conditioner Replacement

Measure Description

This measure involves a residential retrofit with a new central air conditioning system or the installation of a new central air conditioning system in a residential new construction (packaged unit, or split system consisting of an indoor unit with a matching remote condensing unit). Maximum cooling capacity per unit is 65,000 BTU/hour. This measure applies to all residential applications.

Baseline and Efficiency Standards

The current federal minimum standard[47] became effective January 1, 2015.

For new construction (NC) and ROB projects, the cooling baseline is 14 SEER, consistent with the current federal minimum standard.

For ER projects, the baseline is consistent with the previous federal standard. The cooling baseline is 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 13 SEER.

For ER, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Air conditioning equipment shall be properly sized to the dwelling, based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed air conditioning equipment or the AHRI reference number must be provided to the utility. The installed central air conditioning equipment must be AHRI certified.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

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[47] DOE minimum efficiency standard for residential air conditioners/heat pumps. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

Table 50: Central Air Conditioner Replacement – Baseline and Efficiency Standards[48]

Project Type	Baseline Before 1/23/2006	Baseline After 1/23/2006	Baseline As of 1/1/2015
New Construction Replace-on-Burnout	13 SEER 11.2 EER		14 SEER 11.8 EER
Early Retirement	10 SEER (Split) 9.7 SEER (Packaged) 9.2 EER	13 SEER 11.2 EER	

Estimated Useful Life (EUL)

The average lifetime of this measure is 19 years, according to the US DOE.[49]

Calculation of Deemed Savings

Replace-on-Burnout

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{post}}\right) \times CF \tag{46}$$

$$kWh_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{post}}\right) \tag{47}$$

Where:

CAP_C = Rated equipment cooling capacity of the new unit (Btu/hr)

EER_{base} = Full-load energy efficiency rating of the baseline equipment for cooling (Table 50)

EER_{post} = Nameplate full-load energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 50)

$SEER_{base}$ = Seasonal energy efficiency rating of the baseline equipment for cooling (Table 50)

$SEER_{post}$ = Nameplate seasonal energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 50)

CF = Coincidence factor = 0.87 (default)[50]

$EFLH_C$ = Equivalent full-load cooling hours (Table 51)

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[48] Code specified SEER values converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL) 2010, *"Building America House Simulation Protocols."* U.S. DOE. Revised October www.nrel.gov/docs/fy11osti/49246.pdf.

[49] U.S. DOE, 2011 *Technical Support Document:* "*Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime.*" June www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[50] See Section 4.2 General Reference Information: Coincidence Factors for HVAC.

Table 51: Central AC Replacement – Equivalent Full-Load Cooling Hours[51]

Weather Zone	Location	$EFLH_C$
9	Rogers[52]	1,305
8	Ft. Smith	1,432
7	Little Rock	1,583
6	El Dorado[53]	1,738

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (19 – RUL)

For the RUL (Table 52):

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{post}}\right) \times CF \tag{48}$$

$$kWh_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{post}}\right) \tag{49}$$

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[51] ENERGY STAR®: www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75; Central AC Calculator: www.energystar.gov/products/certified-products/detail/air-conditioning-central.

[52] Rogers, AR not listed. Used average of Springfield, MO and Ft. Smith, AR.

[53] El Dorado, AR not listed. Used average of Little Rock, AR and Shreveport, LA.

For the remaining time in the EUL period (19 – RUL):

> Calculate annual savings as you would for a replace-on-burnout project using Equations (46) and (47).

Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kWh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(50)

Where:

ROB = Replace-on-Burnout

ER = Early Retirement

CAP_C= Rated equipment cooling capacity of the new unit (Btu/hr)

EER_{base} = Full-load energy efficiency rating of the baseline equipment for cooling (Table 50)

EER_{post} = Nameplate full-load energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 50)

$SEER_{base}$ = Seasonal energy efficiency rating of the baseline equipment for cooling (Table 50)

$SEER_{post}$ = Nameplate seasonal energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 50)CF = Coincidence factor = 0.87 (default)[54]

$EFLH_C$ = Equivalent full-load cooling hours (Table 51)

RUL = Remaining Useful Life (Table 52)

EUL = Estimated Useful Life = 19 years

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[54] See Section 4.2 General Reference Information: Coincidence Factors for HVAC.

Table 52: Remaining Useful Life (RUL) of Replaced Systems[55]

Age of Replaced System (Years)	RUL (Years)
2	15.8
3	14.9
4	14.1
5	13.3
6	12.6
7	11.9
8	11.3
9	10.8
10	10.3
11	9.8
12	9.4
13	9.0
14	8.6
15	8.2
16	7.9
17	7.6
18	7.3
19	7.1
20	6.8
21	6.8
22	6.4
23	6.2
24	6.0
25	5.8
26 +	0.0

---

[55] Use of the early retirement baseline is capped at 25 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 25 years should use the ROB baseline.

Derivation of RULs

Central air conditioners have an estimated useful life of 19 years. This estimate is consistent with the age at which approximately 50 percent of the central air conditioners installed in a given year will no longer be in service, as described by the survival function in Figure 5.

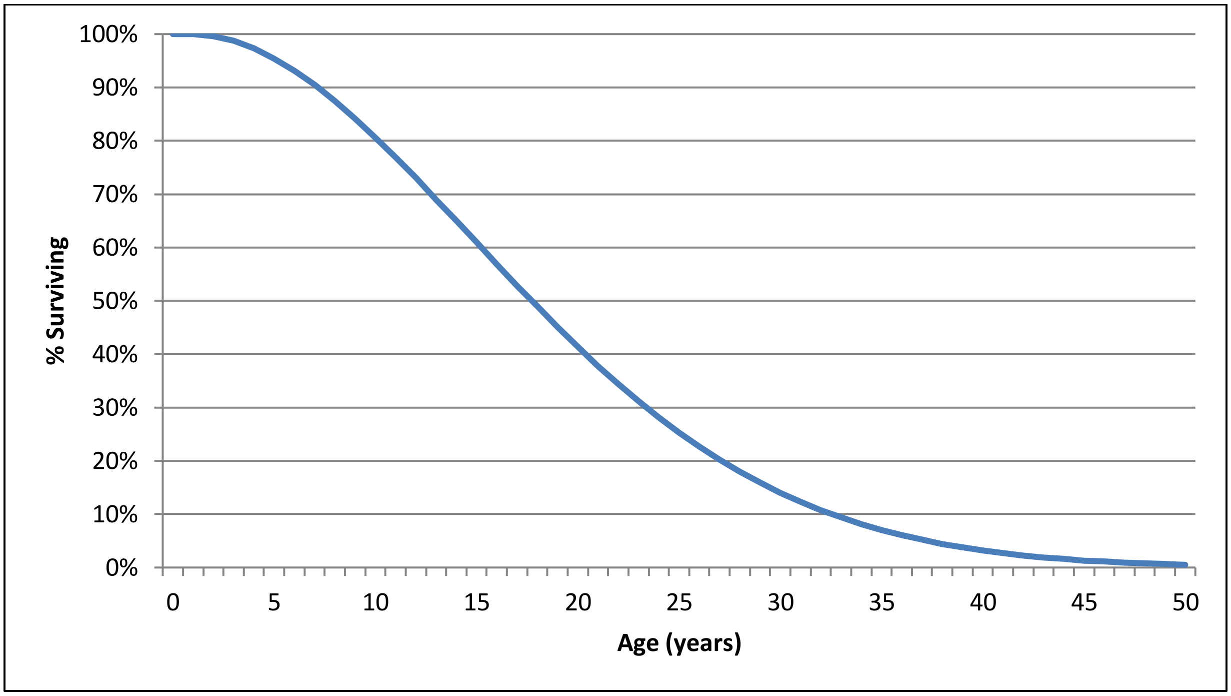

Figure 5: Survival Function for Central Air Conditioners[56]

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 5. The age of the central air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving air conditioners is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[56] U.S. DOE 2011, *Technical Support Document: "Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime"*. June. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.
Download TSD at: www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

2.1.7 Ground Source Heat Pumps

Measure Description

This measure involves the installation of a water-to-air ground source heat pump as a replacement for an existing air source heat pump (ASHP) or other combination of electric heating and air-to-air cooling system. This measure is only applicable for single-family applications.

The deemed savings apply to units with a capacity of ≤ 65,000 BTU/hr.

Baseline and Efficiency Standards

The baseline unit is assumed to be an ASHP compliant with the current federal minimum standard[57], effective January 1, 2015.

The installed ground source heat pump must meet the minimum requirements of the ENERGY STAR® Tier 3 geothermal heat pump key product criteria, effective January 1, 2012, to be eligible for these deemed savings.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

Table 53: Ground Source Heat Pump – Baseline and Efficiency Standards

Baseline **Before January 1, 2015**	**Baseline** **Effective January 1, 2015**	**ENERGY STAR® Criteria** **effective January 1, 2012**		
Air Source Heat Pump 13 SEER, 7.7 HSPF (or 2.26 COP)[58]	Air Source Heat Pump 14 SEER, 8.2 HSPF[59] (or 2.40 COP)[60]	Closed Loop Water-to-Air	17.1 EER	3.6 COP
		Open Loop Water-to-Air	21.1 EER	4.1 COP

Estimated Useful Life (EUL)

The average lifetime of this measure is 25 years, based on the DOE's estimated measure life for the inside component.[61]

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[57] DOE minimum efficiency standard for residential air conditioners/heat pumps. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

[58] COP = HSPF x 1055 J/BTU / 3600J/W-hr

[59] Standard is 8.2 for split systems and 8.0 HSPF for packaged systems. 8.2 is assumed because it is more conservative and because it is more likely that a split system would be installed in a residential setting.

[60] COP = HSPF x 1055 J/BTU / 3600J/W-hr

[61] Source DOE Energy Savers website: www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640

Deemed Savings Values

The existing deemed savings values will continue to be applied until this measure can be updated to reflect the updated baseline, effective January 1, 2015, and updated efficiency standard, effective January 1, 2012. However, projects must still comply with the current baseline and efficiency standard as outlined above.

Table 54: Ground Source Heat Pump – Deemed Savings Values - Zone 9 Northwest Region

Desuperheater		
GSHP Efficiency	**Energy Savings (kWh/ton)**	**Demand Savings (kW/ton)**
17.1 EER and above Units	1,104	0.322
No Desuperheater		
17.1 EER and above Units	1,038	0.246

Table 55: Ground Source Heat Pump – Deemed Savings Values - Zone 8 Northeast/North Central Region

Desuperheater		
GSHP Efficiency	**Energy Savings (kWh/ton)**	**Demand Savings (kW/ton)**
17.1 EER and above Units	1,053	0.467
No Desuperheater		
17.1 EER and above Units	947	0.397

Table 56: Ground Source Heat Pump – Deemed Savings Values - Zone 7 Central Region

Desuperheater		
GSHP Efficiency	**Energy Savings (kWh/ton)**	**Demand Savings (kW/ton)**
17.1 EER and above Units	1,034	0.404
No Desuperheater		
17.1 EER and above Units	919	0.333

Table 57: Ground Source Heat Pump – Deemed Savings Values - Zone 6 South Region

Desuperheater		
GSHP Efficiency	**Energy Savings (kWh/ton)**	**Demand Savings (kW/ton)**
17.1 EER and above Units	892	0.419
No Desuperheater		
17.1 EER and above Units	721	0.356

Calculation of Deemed Savings

Deemed savings for this measure were adapted from the Deemed Energy and Demand Savings for Residential Ground Source Heat Pumps Retrofits in the State of Texas study completed by Oak Ridge National Laboratory (ORNL).[62] Adjustments to the Texas values were based on weather factors comparing the heating and cooling degree days of each of the Arkansas weather climates to those studied in the Texas analysis.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to replacement of air source heat pumps with ground source heat pumps. These estimates were found to be within five percent of actual post-retrofit savings. Building models were developed using TRNSYS.[63]

Using the Fort Polk models, the ORNL study assumed a baseline of a 1.5 ton, 10 SEER air source heat pump. Simulations of low-, medium-, and high-efficiency ground source heat pumps with and without desuperheaters were compared against the baseline unit. The models were run using TMY-2 weather profiles for Texas weather zones. Energy and demand differences between the pre- and post-retrofit models were used to estimate average savings per ton of cooling capacity.

In the 1998 analysis, low-efficiency GSHPs were assumed to be units with an EER of 12.4 and capacity of 19 kBtuh, while medium-efficiency units had an EER of 16.8 and capacity of 21 kBtuh. High-efficiency units had an EER of 18.3, with a capacity of 22 kBtuh.

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[62] Shonder, J. A., Hughes, P. & Thornton, J. 2001. *Development of Deemed Energy and Demand Savings for Residential Ground Source Heat Pump Retrofits in the State of Texas*. Transactions-American Society of Heating, Refrigerating, and Air Conditioning Engineers. 108, no. 1: 953-961. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf.

[63] Klein, S. A. 1996. *TRNSYS Manual: A Transient Simulation Program,* Solar Engineering Laboratory, University of Wisconsin-Madison, Version 14.2 for Windows, September.

2.1.8 Heat Pump Replacement

Measure Description[64]

This measure consists of a residential retrofit with a new heat pump system or the installation of a new central heat pump system in residential new construction (central unit, packaged unit, split system consisting of an indoor unit with one or more matching remote condensing units, or mini-split system). Maximum cooling capacity per unit is 65,000 BTU/hour. This measure applies to all residential applications.

Baseline and Efficiency Standards

The current federal minimum standard[65] became effective January 1, 2015. For new construction (NC) and replace-on-burnout (ROB) projects, the cooling baseline is 14 SEER and the heating baseline is 8.2 HSPF for central and split systems and 8.0 HSPF for packaged systems, consistent with the current federal minimum standard.

For early retirement (ER) projects, the baseline is consistent with the previous federal standard. The cooling baseline for central and split systems is 10 SEER, and the heating baseline is 6.8 HSPF. For packaged systems, the cooling baseline is 9.7 SEER and heating baseline is 6.6 HSPF, consistent with the federal minimum standard[66] in place until January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 13 SEER and 7.7 HSPF. The heating baseline for early retirement of an electric resistance furnace is 3.41 HSPF.[67]

For early retirement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Heat pump equipment shall be properly sized to the dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets for installed air conditioning equipment, or AHRI equivalent combined compressor and coil SEER, must be provided to the utility. The installed central heat pump equipment must be AHRI certified.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

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[64] Updates Measure #5 from Initial Filing.

[65] DOE minimum efficiency standard for residential air conditioners/heat pumps. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

[66] DOE minimum efficiency standard for residential air conditioners/heat pumps. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[67] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

Table 58: Heat Pump Replacement – Baseline and Efficiency Standards[68]

Project Type	Baseline Before 1/23/2006	Baseline After 1/23/2006	Baseline After 1/1/2015
New Construction Replace-on-Burnout	13 SEER 11.2 EER 7.7 HSPF		14 SEER 11.8 EER 8.2 HSPF (Split) 8.0 HSPF (Packaged)
Early Retirement, Heat Pumps	10 SEER (Split) 9.7 SEER (Packaged) 9.2 EER 6.8 HSPF (Split) 6.6 HSPF (Packaged)	13 SEER 11.2 EER 7.7 HSPF (Split) 7.7 HSPF (Packaged)	
Early Retirement, Electric Resistance	10 SEER 9.2 EER 3.41 HSPF	13 SEER 11.2 EER 3.41 HSPF	

Estimated Useful Life (EUL)

The average lifetime of this measure is 16 years, according to the US DOE.[69]

Calculation of Deemed Savings

Replace-on-Burnout

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{post}}\right) \times CF$$

(51)

$$kWh_{Savings} = kWh_{Savings,C} + kWh_{Savings,H}$$

(52)

$$kWh_{Savings,C} = CAP_C \times \frac{1\ kW}{1000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{post}}\right)$$

(53)

$$kWh_{Savings,H} = CAP_H \times \frac{1\ kW}{1000\ W} \times EFLH_H \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{post}}\right)$$

(54)

Where:

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[68] Code specified SEER values converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x SEER. National Renewable Energy Laboratory (NREL). US. U.S. DOE, "*Building America House Simulation Protocols*, 2010." Revised October. www.nrel.gov/docs/fy11osti/49246.pdf.

[69] US U.S. DOE, 2011. *Technical Support Document: "Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime*". June. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

Download TSD at: www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

CAP_C = Rated equipment cooling capacity of the new unit (Btu/hr)

CAP_H = Rated equipment heating capacity of the new unit (Btu/hr)

EER_{base} = Full-load energy efficiency rating of the baseline equipment for cooling (Table 58)

EER_{post} = Nameplate full-load energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 58)

$SEER_{base}$ = Seasonal energy efficiency rating of the baseline equipment for cooling (Table 58)

$SEER_{post}$ = Nameplate seasonal energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 58)

$HSPF_{base}$ = Heating seasonal performance factor rating of the baseline equipment for heating (Table 58)

$HSPF_{post}$ = Nameplate heating seasonal performance factor rating of the installed equipment for heating (at least equal to value from Table 58)

CF = Coincidence factor = 0.87 (default)[70]

$EFLH_C$ = Equivalent full-load cooling hours (Table 59)

$EFLH_H$ = Equivalent full-load heating hours (Table 59)

Table 59: HP Replacement – Equivalent Full-Load Cooling/Heating Hours[71]

Weather Zone	Location	$EFLH_C$	$EFLH_H$
9	Rogers[72]	1,305	1,868
8	Ft. Smith	1,432	1,738
7	Little Rock	1,583	1,681
6	El Dorado[73]	1,738	1,521

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (16 – RUL).

For the RUL (Table 60):

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[70] See Section 4.2 General Reference Information: Coincidence Factors for HVAC.

[71] ENERGY STAR® Central HP Calculator: www.energystar.gov/products/certified-products/detail/heat-pumps-air-source.

[72] Rogers, AR not listed. Used average of Springfield, MO and Ft. Smith, AR.

[73] El Dorado, AR not listed. Used average of Little Rock, AR and Shreveport, LA.

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1000\ W} \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{post}}\right) \times CF$$

(55)

$$kWh_{Savings} = kWh_{Savings,C} + kWh_{Savings,H}$$

(56)

$$kWh_{Savings,C} = CAP_C \times \frac{1\ kW}{1000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{post}}\right)$$

(57)

$$kWh_{Savings,H} = CAP_H \times \frac{1\ kW}{1000\ W} \times EFLH_H \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{post}}\right)$$

(58)

For the remaining time in the EUL period (19 – RUL):

> Calculate annual savings as you would for a replace-on-burnout project using Equations (51), (53), and (54).

Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kWh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(59)

Where:

ROB = Replace-on-Burnout

ER = Early Retirement

CAP_C= Rated equipment cooling capacity of the new unit (Btu/hr)

EER_{base} = Full-load energy efficiency rating of the baseline equipment for cooling (Table 58)

EER_{post}= Nameplate full-load energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 58)

$SEER_{base}$ = Seasonal energy efficiency rating of the baseline equipment for cooling (Table 58)

$SEER_{post}$= Nameplate seasonal energy efficiency rating of the installed equipment for cooling (at least equal to value from Table 58)

$HSPF_{base}$ = Heating seasonal performance factor rating of the baseline equipment for heating (Table 58)

$HSPF_{post}$= Nameplate heating seasonal performance factor rating of the installed equipment for heating (at least equal to value from Table 58)

CF = Coincidence factor = 0.87 (default)[74]

$EFLH_C$ = Equivalent full-load cooling hours (Table 59)

$EFLH_H$ = Equivalent full-load cooling hours (Table 59)

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[74] See Section 4.2 General Reference Information: Coincidence Factors for HVAC.

RUL = Remaining Useful Life (Table 60)

EUL = Estimated Useful Life = 16 years

Table 60: Remaining Useful Life (RUL) of Replaced Systems[75]

Age of Replaced System (Years)	RUL (Years)	Age of Replaced System (Years)	RUL (Years)
2	12.7	13	7.6
3	12.0	14	7.3
4	11.3	15	7.1
5	10.7	16	6.9
6	10.2	17	6.7
7	9.7	18	6.5
8	9.3	19	6.3
9	8.9	20	6.1
10	8.5	21	6.1
11	8.2	22 +	0.0
12	7.9		

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[75] Use of the early retirement baseline is capped at 21 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 21 years should use the ROB baseline.

Derivation of RULs

Central heat pumps have an estimated useful life of 16 years. This estimate is consistent with the age at which approximately 50 percent of the central heat pumps installed in a given year will no longer be in service, as described by the survival function in Figure 6.

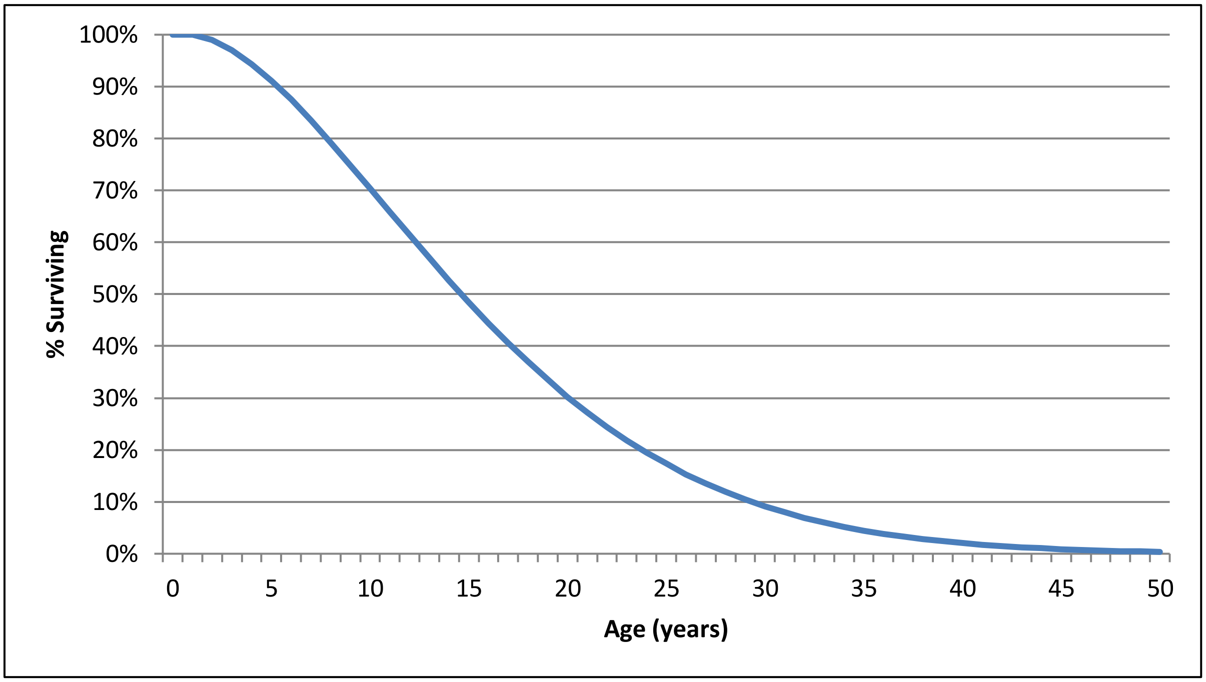

Figure 6: Survival Function for Central Heat Pumps[76]

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 6. The age of the central heat pump being replaced is found on the horizontal axis, and the corresponding percentage of surviving heat pumps is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[76] US U.S. DOE, 2011, *Technical Support Document: "Residential Central Air Conditioners, Heat Pumps, and Furnaces, 8.2.3.5 Lifetime,".* June. www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

Download TSD at: www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

2.1.9 Hydronic Heating

Measure Description

Hydronic heating systems require installation of both a fan coil air handler and one or more tankless gas water heaters and accessories. These systems are expensive as they require extensive piping to install correctly and possibly more than one tankless water heater in order to meet the heating loads of the home. In addition, a secondary heat exchanger may be required by local codes. Given the high incremental costs, customers should be aware that these systems may not be cost effective, even with high gas savings. This measure is only applicable for single-family applications.

Baseline and Efficiency Standards

This measure applies to newly constructed homes only. The baseline for this measure is a new home that meets the state of Arkansas’s residential energy code. All jurisdictions in Arkansas have adopted the 2009 IECC. The baseline home assumes the installation of a gas furnace and gas water heater that meets the current minimum federal standard efficiency requirements.

To be eligible for this program, the hydronic furnace must have a minimum AFUE rating of 90 percent. The installed tankless water heaters should have a minimum Energy Factor of 0.82.

Estimated Useful Life (EUL)

The estimated measure life is based on the 20-year life of the instantaneous water heater, according to DEER 2008.

Deemed Savings Values

Please note that the savings are a factor to be multiplied by the MBH (kBTU/hr) rating of the installed equipment. Gas Heat (with no AC) kWh applies to forced air furnace systems only.

Table 61: Hydronic Heating – Deemed Savings Values - Zone 9 Northwest Region

Unit	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC Peak Savings (kW)	Peak Gas Savings (Therms)
Hydronic System	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**
90% AFUE and 0.89 EF	0	0	2.16	0	0.03795
90% AFUE and 0.82 EF	0	0	2.00	0	0.03744

Table 62: Hydronic Heating – Deemed Savings Values - Zone 8 Northeast/North Central Region

Unit	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC Peak Savings (kW)	Peak Gas Savings (Therms)[77]
Hydronic System	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**
90% AFUE and 0.89 EF	0	0	2.16	0	0.03333
90% AFUE and 0.82 EF	0	0	2.00	0	0.03282

Table 63: Hydronic Heating – Deemed Savings Values - Zone 7 Central Region

Unit	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC Peak Savings (kW)	Peak Gas Savings (Therms)
Hydronic System	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**
90% AFUE and 0.89 EF	0	0	1.96	0	0.02830
90% AFUE and 0.82 EF	0	0	1.81	0	0.02785

Table 64: Hydronic Heating – Deemed Savings Values - Zone 6: South Region

Unit	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC Peak Savings (kW)	Peak Gas Savings (Therms)
Hydronic System	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**	**/ MBH**
90% AFUE and 0.89 EF	0	0	1.72	0	0.03086
90% AFUE and 0.82 EF	0	0	1.58	0	0.03036

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent upon the AFUE and Energy Factor of the equipment, and are presented as annual therm savings per kBTUh of furnace capacity, or output.

EnergyGauge USA was used to estimate energy savings for a series of models. Since hydronic heating savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the EnergyGauge building model are outlined in Appendix A.

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[77] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For the 0.89 EF Systems: for Jonesboro, m = 0.9196. For Fort Smith, m = 0.8825. For the 0.82 EF Systems: for Jonesboro, m = 0.9174. For Fort Smith, m = 0.8797.

2.1.10 Window Air Conditioner Replacement

Measure Description

This measure involves replacement of an existing window air conditioner with a new window air conditioner. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline is assumed to be a new air conditioning unit with a combined energy efficiency ratio (CEER) rating that meets the current federal standard, which became effective on June 1, 2014.[78]

Installed units must meet the current ENERGY STAR® specification of 10 percent more efficient than the federal standard for all categories. The baseline and efficiency standards are summarized in Table 65 below.

Table 65: Window AC Replacement – Baseline and Efficiency Standards[79]

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Baseline Efficiency (CEER)	Efficiency Standard (EER)
No	Yes	< 8,000	11.0	12.1
		≥ 8,000 and < 14,000	10.9	12.0
		≥ 14,000 and < 20,000	10.7	11.8
		≥ 20,000	9.4	10.3
No	No	< 8,000	10.0	11.0
		≥ 8,000	9.6	10.6
Yes	Yes	< 20,000	9.8	10.8
		≥ 20,000	9.3	10.2
Yes	No	< 14,000	9.3	10.2
		≥ 14,000	8.7	9.6

Estimated Useful Life (EUL)

According to the DOE's *Technical Support Document, Chapter 8: Life Cycle Cost and Payback Period Analyses 2011*, the measure life is 10.5 years.

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[78] 10 CFR 430.32(b). https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52&action=viewlive#current_standards

[79] Current federal standards, as well as ENERGY STAR® criteria for room air conditioners can be found on the ENERGY STAR® website at www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac.

Calculation of Deemed Savings

$$kW_{Savings} = CAP \times \frac{1\ kW}{1000\ W} \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \times CF \tag{60}$$

$$kWh_{Savings} = CAP \times \frac{1\ kW}{1000\ W} \times RAF \times EFLH_C \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \tag{61}$$

Where:

CAP = Rated equipment cooling capacity of the new unit (Btu/hr)

η_{base} = Energy efficiency rating (EER) of the baseline cooling equipment (Table 65)

η_{post} = Energy efficiency rating (EER) of the installed cooling equipment (at least equal to value from Table 65)

CF = Coincidence factor = 0.87 (default)[80]

RAF = Room AC adjustment factor = 0.49 (default); derivation described in Table 67.

$EFLH_C$ = Equivalent full-load cooling hours (Table 66)

Table 66: Room AC Replacement – Equivalent Full-Load Cooling Hours[81]

Weather Zone	Location	$EFLH_C$
9	Rogers[82]	1,305
8	Ft. Smith	1,432
7	Little Rock	1,583
6	El Dorado[83]	1,738

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[80] See Section 4.2 General Reference Information: Coincidence Factors for HVAC .

[81] ENERGY STAR® Room AC Calculator: www.energystar.gov/products/certified-products/detail/air-conditioning-room.

[82] Rogers, AR not listed. Used average of Springfield, MO and Ft. Smith, AR.

[83] El Dorado, AR not listed. Used average of Little Rock, AR and Shreveport, LA.

The EFLHs from the ENERGY STAR® Room AC savings are the same as those used for the ENERGY STAR® Central AC savings calculator. This is not appropriate as room AC units typically to not run as many hours as central systems. To correct this issue, an adjustment factor of 49 percent is applied to the ENERGY STAR® EFLHs.

This adjustment factor is derived by taking the ratio of average run hours from two sources to the ENERGY STAR® EFLHs. The derivation of this factor is described in Table 67.

Table 67: RAF Derivation

Weather Zone	Location	ES EFLH$_C$	RLW Adj Hours[84]	AHAM Hours[85]	Avg. Hours	RAF
9	Rogers[86]	1,305	431	833	632	0.48
8	Ft. Smith	1,432	473	978	725	0.51
7	Little Rock	1,583	522	1,009	766	0.48
6	El Dorado[87]	1,738	573	1,061	817	0.47
					Average:	**0.49**

The values in the ES EFLHC column are taken directly from the ENERGY STAR® Room AC savings calculator assumptions. The values in the RLW Adj Hours column were calculated by multiplying the ES EFLHC values by a 0.33 factor. The 0.33 factor was derived by taking the ratio of EFLHC specified in a study performed by RLW Analytics for the Northeast Energy Efficiency Partnerships' New England Evaluation and State Program Working Group to the EFLHC values from the ENERGY STAR® Room AC savings calculator for the same reference cities. The values in the AHAM Hours column are taken directly from the Association of Home Manufacturers (AHAM) Room Air Conditioner calculator.

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[84] RLW Analytics: *Final Report Coincidence Factor Study Residential Room Air Conditioners*, www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf. Derived by taking the average ratio of EFLH for Room ACs (from the RLW Analytics report) to EFLHs for Central ACs for the same location (from the ENERGY STAR® Central AC Calculator).

[85] Association of Home Appliance Manufacturers Room Air Conditioner calculator. www.cooloff.org/sub_cool.html.

[86] Rogers, AR not listed. Used average of Springfield, MO and Ft. Smith, AR.

[87] El Dorado, AR not listed. Used average of Little Rock, AR and Shreveport, LA.

2.1.11 Duct Sealing

Measure Description

This measure involves sealing leaks in supply and return ducts of the distribution systems of homes or converted residences with either central air conditioning or a ducted heating system. This measure applies to all residential applications.

Baseline and Efficiency Standards

The savings calculation methods for this measure are valid up to a maximum pre-installation leakage rate of 40 percent of total fan flow.[88] Data from nearly 28,000 single-family and manufactured home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[89] However, Arkansas specific measurements indicate that higher leakages in manufactured homes are common. Therefore, the cap for manufactured homes only is set to fifty percent of total fan flow.[90]

Engineering calculations show that the interior temperature in those settings that exceed 40 percent total leakage would be above the thermally acceptable comfort levels published by ASHRAE in its 2009 *Fundamentals* publication. Homeowners would likely take steps to remedy the situation independent of the program long before their duct system reached these leakage levels, and certainly before the rated useful life of the duct leakage measure. The proposed pre-installation leakage limits will help ensure that the deemed savings are an accurate reflection of the program’s impacts, and that the program focus is on scenarios where leakage conditions are likely to persist if unaddressed for several years.

Materials used should be long-lasting materials, such as mastics, UL 181A or UL 181B approved foil tape, or aerosol-based sealants. Fabric-based duct tape is not allowed.

Estimated Useful Life (EUL)

According to DEER 2008, the Estimated Useful Life is 18 years for duct sealing.

Calculation of Deemed Savings

Two methodologies for estimating duct sealing energy savings are provided. The first method, which is the preferred approach, requires duct leakage testing using either a duct pressurization device (e.g., Duct Blaster™), or a combination duct pressurization and blower door. The second method requires careful inspection of the existing ducts.

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[88] Total Fan Flow = Cooling Capacity (tons) × 400

[89] Based on data collected by Frontier Associates, LLC for investor-owned utilities in Texas.

[90] Duct leakage measurement data obtained in 2016 from EAI duct sealing measure participation.

1. Duct Leakage Testing - Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. In applications where a majority of the ducts are in an unconditioned space, the most commonly-used acceptable test method is the Duct Blaster™ (or equivalent) Total Duct Leakage test. In applications where duct leakage-to-outside must be directly measured, the Project Sponsor may use the Combination Duct Blaster™ (or equivalent) and Blower Door method. Other tests – such as the blower door subtraction method -- may be accepted at the utility's discretion.

   Prior to beginning any installations, the Project Sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician Excellence (NATE) certification.

   Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[91]

2. Evaluation of Distribution Efficiency - This methodology is based on an assumed 5 percent increase in distribution system efficiency (DSE). This assumed value is based on expected DSE improvements determined through evaluation the Building Performance Institute's (BPI) Distribution Efficiency Look-up Table.[92] By assuming an improvement from "significant leaks" to "some observable leaks" or "some observable leaks to "no observable leaks," or "connections sealed with mastic," a conservative estimate of five percent can be identified as typical regardless of duct location and duct insulation value.[93]

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[91] See RESNET Technical Committee, Proposed Amendment: *Chapter 8 RESNET Standards, 800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing*; Section 803.2 and Table 803.1.

[92] Distribution Efficiency Lookup Table. Building Performance Institute Inc. Updated January 2012. www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf.

[93] In the referenced table, there are five categories of duct leakage. For duct systems with R-4 to R-7 insulation that are 50% or more outside the conditioned space, the distribution efficiencies associated with the five leakage categories are:

- Connections sealed with mastic: 80%
- No observable leaks: 74%
- Some observable leaks: 70%
- Significant leaks: 65%
- Catastrophic leaks: 60%

For leakage reduction that does not involve any diagnostic testing, and is based solely on the contractors' visual estimate of leakage reduction, the deemed savings are calculated based on the average leakage reduction that would occur if the duct system were improved by one category (e.g., going from "Significant leaks" to "Some observable leaks" or "No observable leaks" to "Connections sealed with mastic"). The percent improvement (per step) going from the leakiest to the tightest leakage category are 5%, 5%, 4%, and 6%. Averaging these improvements yields a deemed improvement of five percent per step.

Cooling Savings (Electric):

$$kWh_{savings,C} = \frac{(DL_{pre} - DL_{post}) \times EFLH_C \times (h_{out}\rho_{out} - h_{in}\rho_{in}) \times 60}{1{,}000 \times SEER}$$

(62)

OR

$$kWh_{savings,C} = \frac{\Delta DSE \times EFLH_C \times CAP}{1{,}000 \times SEER}$$

(63)

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft^3/min)

DL_{post} = Post-improvement duct leakage at 25 Pa (ft^3/min)

ΔDSE = Assumed improvement in distribution system efficiency = 5% = 0.05

$EFLH_C$= Equivalent full load cooling hours (Table 69)

h_{out}= Outdoor design enthalpy (Btu/lb) (Table 68)

h_{in} = Indoor design enthalpy (Btu/lb) (Table 68)

Table 68: Enthalpy at Design Conditions[94]

Weather Zone	Location	h_{out}	$h_{,in}$
9	Rogers[95]	39	30
8	Fort Smith	39	29
7	Little Rock	40	30
6	El Dorado	40	30

ρ_{out}= Density of outdoor air at 95°F = 0.0740 (lb/ft^3)[96]

ρ_{in} = Density of conditioned air at 75°F = 0.0756 (lb/ft^3)[4]

60 = Constant to convert from minutes to hours

CAP = Cooling capacity (BTU/hr)

1,000 = Constant to convert from W to kW

$SEER$ = Seasonal Energy Efficiency Ratio of existing system (Btu/W·hr) = 11.5 (default)[97]
As an example, assume the duct leakage before sealing was measured at 360 CFM and the leakage after sealing was 90 CFM for a house in weather zone 7. Using the SEER value of 11.5 Btu/W·hr, the annual savings would be:

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[94] ANSI/ASHRAE Standard 152-2004, Table 6.3b

[95] Rogers, AR not available, used data for Forth Smith, AR.

[96] ASHRAE Fundamentals 2009, *Chapter 1: Psychometrics*, Equation 11, Equation 41, Table 2

[97] Average of US U.S. DOE minimum allowed SEER for new air conditioners from 1992-2006 (10 SEER) and after January 23, 2006 (13 SEER)

kWh/year = (360 – 90) × 1669 × (40 × 0.074 – 30 × 0.0756) × 60 / (1000 × 11.5)

= 1627 kWh/year

Heating Savings (Heat Pump):

$$kWh_{savings,H} = \frac{\left(DL_{pre} - DL_{post}\right) \times 60 \times HDD \times 24 \times 0.018}{1{,}000 \times HSPF} \tag{64}$$

OR

$$kWh_{savings,H} = \frac{\Delta DSE \times EFLH_H \times CAP}{1{,}000 \times HSPF} \tag{65}$$

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft^3/min)

DL_{post} = Post-improvement duct leakage at 25 Pa (ft^3/min)

ΔDSE = Assumed improvement in distribution system efficiency = 5% = 0.05

$EFLH_H$ = Equivalent full load heating hours (Table 69)

60 = Constant to convert from minutes to hours

HDD = Heating degree days (Table 2)

24 = Constant to convert from days to hours

0.018 = Volumetric heat capacity of air (Btu/ft^3°F)

CAP = Heating capacity (Btu/hr)

1,000 = Constant to convert from W to kW

$HSPF$ = Heating Seasonal Performance Factor of existing system (Btu/W·hr) = 7.30 (default)[98]

Heating Savings (Electric Resistance):

$$kWh_{savings,H} = \frac{\left(DL_{pre} - DL_{post}\right) \times 60 \times HDD \times 24 \times 0.018}{3{,}412} \tag{66}$$

OR

$$kWh_{savings,H} = \frac{\Delta DSE \times EFLH_H \times CAP}{3{,}412} \tag{67}$$

---

[98] Average of DOE minimum allowed HSPF for new heat pumps from 1992-2006 (6.8 HSPF) and after January 23, 2006 (7.7 HSPF).

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft^3/min)

DL_{post} = Post-improvement duct leakage at 25 Pa (ft^3/min)

ΔDSE = Assumed improvement in distribution system efficiency = 5% = 0.05

60 = Constant to convert from minutes to hours

HDD = Heating degree days (Table 2)

24 = Constant to convert from days to hours

0.018 = Volumetric heat capacity of air (Btu/ft^3°F)

$EFLH_H$ = Equivalent full load heating hours (Table 69)

CAP = Heating capacity (BTU/hr)

3,412 = Constant to convert from Btu to kWh

Heating Savings (Gas Furnace):

$$Therms_{savings,H} = \frac{\left(DL_{pre} - DL_{post}\right) \times 60 \times HDD \times 24 \times 0.018}{100{,}000 \times AFUE} \tag{68}$$

OR

$$Therms_{savings,H} = \frac{\Delta DSE \times EFLH_H \times CAP}{100{,}000 \times AFUE} \tag{69}$$

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft^3/min)

DL_{post} = Post-improvement duct leakage at 25 Pa (ft^3/min)

ΔDSE = Assumed improvement in distribution system efficiency = 5% = 0.05

60 = Constant to convert from minutes to hours

HDD = Heating degree days (Table 2)

24 = Constant to convert from days to hours

0.018 = Volumetric heat capacity of air (Btu/ft^3°F)

$EFLH_H$ = Equivalent full load heating hours (Table 69)

CAP = Heating capacity (Btuh or BTU/hr)

100,000 = Constant to convert from Btu to therms

AFUE = Annual Fuel Utilization Efficiency of existing system = 0.78 (default)[99]

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[99] www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/72.

Demand Savings (Cooling):

$$kW_{savings,C} = \frac{kWh_{savings,C}}{EFLH_C} \times CF$$

(70)

Where:

$kW_{savings,C}$ = Calculated kWh savings for cooling

$EFLH_C$ = Equivalent full load cooling hours (Table 69)

CF = Coincidence factor = 0.87[100]

Table 69: Equivalent Full Load Hours for Heating and Cooling[101]

Weather Zone	$EFLH_C$	$EFLH_H$
9 Rogers[102]	1,305	1,868
8 Fort Smith	1,432	1,738
7 Little Rock	1,583	1,681
6 El Dorado[103]	1,738	1,521

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[100] Please see General Reference Information: Coincidence Factors for HVAC.

[101] ENERGY STAR® Central HP Calculator: www.energystar.gov/products/certified-products/detail/heat-pumps-air-source.

[102] Rogers, AR not listed. Used average of Springfield, MO and Ft. Smith, AR.

[103] El Dorado, AR not listed. Used average of Little Rock, AR and Shreveport, LA.

2.1.12 Smart Thermostats

Measure Description

The Smart Thermostats[104] measure involves the replacement of a manually operated or programmable thermostat with a smart programmable thermostat. This measure applies to all residential applications.

Recent research[105] indicates that today's programmable thermostat is evolving into a more usable, capable, and connected device. Smart thermostats are the next generation of programmable thermostats, which provide an array of features including automatic occupancy sensing and set-point adjustment. An energy management system that includes a communicating climate control will provide energy users with vastly improved and potentially real-time information on heating, ventilation, and air conditioning (HVAC) consumption and cost. Armed with these capabilities, consumers are able to take immediate action to reduce energy use and see the results in real-time.

The location of the smart thermostat can affect its performance and efficiency. To operate properly, a thermostat must be installed on an interior wall away from direct sunlight, drafts, doorways, skylights, and windows.[106] Additionally, thermostats should be installed in a location with the house that is regularly occupied while residents are home.

For homes with a heat pump, smart thermostats must be professionally installed and commissioned. Smart thermostats on heat pumps must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.

Smart thermostats have capabilities beyond those found in a traditional programmable thermostat. To qualify as a smart thermostat, the units installed, at a minimum, should have the following capabilities and installation parameters:

1. Successful connection to existing WIFI
2. Remote adjustment via smart phone or online
3. Automatic scheduling
4. Energy history
5. Occupancy sensing (set "on" as a default)

Other optional features include:

1. Early on function to allow desired set points to be met at onset of occupancy
2. Filter reminders
3. On screen indication when temperature is set to an energy saving value
4. For heat pumps, smart thermostat must be able to control heat pump to optimize energy use and minimize the use of backup electric resistance heat

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[104] Due to expected primary research for PY 2017, the PWC decided to not update smart thermostats for this version.

[105] Archived ENERGY STAR® Programmable Thermostat Specification. www.energystar.gov/index.cfm?c=archives.thermostats_spec.

[106] U.S. DOE, "Thermostats." May 7, 2015. http://energy.gov/energysaver/articles/thermostats.

Baseline and Efficiency Standards

The baseline condition is a manually operated or properly programmed thermostat. A default condition when the baseline thermostat is of unknown type or status is also provided.

The high efficiency condition is an ENERGY STAR® qualifying smart thermostat. Traditional programmable thermostats are not an eligible high efficiency condition.

The ENERGY STAR® specification for programmable thermostats was suspended on December 31, 2009, and the ENERGY STAR® label is no longer available for this category. While the EPA recognizes the potential for programmable thermostats to save significant amounts of energy, there continue to be questions concerning the net energy savings and environmental benefits achieved under the previous ENERGY STAR® programmable thermostat specification. The main problem is that residents do not always use programmable thermostats in the way that they are intended. Often, programmable thermostats are not programmed correctly or are manually overridden, negating expected energy savings. Furthermore, some studies[107] have shown while less energy was used during times the home was unoccupied, people would set the cooling set point much lower during the times they were home. Traditional programmable thermostats are not eligible for this measure.

Cooling savings should only be claimed for homes with central air conditioning. Heating savings may only be claimed for homes with electric resistance, heat pump, or gas heating.

Estimated Useful Life (EUL)

According to DEER 2014, the estimated useful life for thermostats is 11 years.[108]

Deemed Savings Values

For homes with both electric cooling and heating, the deemed savings presented below are additive. Savings values are normalized based on an average square footage of 1,484 SF based on an implementer-reported average size of homes in a population of 17,677 homes receiving air conditioning upgrade measures.

Table 70: Smart Thermostats – Deemed Savings Values per Square Foot of Conditioned Space

Baseline	% of population	Electric Cooling Energy Savings (kWh/SF)	Electric Resistance Heating Energy Savings (kWh/SF)	Electric HP Heating Energy Savings (kWh/SF)	Gas Heating Energy Savings (therms/SF)
Manual or manually operated T'stat	85%	0.450	0.845	0.395	0.037
Properly programmed Programmable T'stat	15%	0.113	0.212	0.099	0.009
Default		0.399	0.750	0.351	0.033

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[107] Lopes, J.S. and Agnew, P., 2010, "*FPL Residential Thermostat Load Control Pilot Project Evaluation.*" Florida Power & Light. http://aceee.org/files/proceedings/2010/data/papers/1953.pdf.

[108] Database for Energy Efficient Resources (2014). www.deeresources.com/.

A valuable feature of smart thermostats is that they can be used to create demand savings by demand reduction or load shifting based on utility-called demand response events. Demand savings from smart thermostats realized through demand response (DR) should be claimed through residential demand response program measurement and verification (M&V). No demand savings should be claimed for this measure, but there may be savings that can be claimed via DR programs.

Calculation of Deemed Savings

Energy savings for this measure are derived from secondary research. Many evaluations and papers were reviewed in the development of savings. Particular studies that were used in the savings calculation include the following:

1. The Cadmus Group, 2015, "*Evaluation of the 2013–2014 Programmable and Smart Thermostat Program.*" Vectren Corporation. January 29.
2. The Cadmus Group, 2015*, "Evaluation of the 2013–2014 Programmable and Smart Thermostat Program*" Northern Indiana PSCo (NIPSCO), Cadmus 2015
3. Navigant Energy, *Residential Smart Thermostats Impact Analysis - Electric Findings*, Prepared for ComEd and the Illinois Stakeholder Advisory Group (ISAG), Navigant, February 26, 2016
4. Navigant Energy, *Residential Smart Thermostats Impact Analysis - Gas Preliminary Findings* Prepared for the Illinois Stakeholder Advisory Group (ISAG), Navigant, December 16, 2015
5. Nest Labs, 2015, "*Nest White Paper: Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results*" February. https://nest.com/downloads/press/documents/energy-savings-white-paper.pdf.

This group of evaluations included study of smart thermostats in the Illinois (ISAG), Indiana (Vectren and NIPSCO), and around the country (Nest). The evaluated energy savings from the NIPSCO, Vectren and Nest white papers were similar, while the studies for Illinois, which included both unknown thermostat types in the baseline, showed somewhat less savings.

Table 71 and Table 72 present study findings and adjustments for Arkansas for electric and gas savings, respectively.

Table 71: Evaluation Results and Calculation Summary for Smart Thermostats, Electric, Annual

		kWh Savings Calculation Summary					
Study	**City**	**Evaluated Savings**	**EFLHc eval**	**EFLH AR**	**Savings v. Manual**	**Savings v. Prog**	**Saving v. Unknown**
Vectren - Smart	Indianapolis	429	948	1508	682	418	550
NIPSCO - Smart	South Bend	388	710	1508	824	502	663
ISAG	Chicago	168	683	1508	371	227	299
Nest	Continental US	585	1,112	1508	793	485	639

		kWh Savings Calculation Summary					
Study	**City**	**Evaluated Savings**	**EFLHc eval**	**EFLH AR**	**Savings v. Manual**	**Savings v. Prog**	**Saving v. Unknown**
Vectren - Prog	IN-Indianapolis	332	948	1508	528		
NIPSCO - Prog	IN-South Bend	303	710	1508	643		
Savings	**Little Rock & Ft. Smith**	**393**	**863**	**1508**	**668**	**408**	**538**

Table 72: Evaluation Results and Calculation Summary for Smart Thermostats, Natural Gas, Annual

		Therm Savings Calculation Summary					
Study	**City**	**Evaluated Savings**	**EFLHh eval**	**EFLH AR**	**Savings v. Manual**	**Savings v. Prog**	**Saving v. Unknown**
Vectren - Smart	IN-Indianapolis	69	2152	1710	55	43	49
NIPSCO - Smart	IN-South Bend	106	2391	1710	76	55	66
ISAG	IL-Chicago	61	2459	1710	42	32	37
Nest	Average Cont US	56	2,063	1710	46	35	41
Vectren - Prog	IN-Indianapolis	30	2152	1710	24		
NIPSCO - Prog	IN-South Bend	57	2391	1710	41		
Savings	**Little Rock & Ft. Smith**	**73**	**2266**	**1710**	**55**	**41**	**48**

Weather adjustments have been made based on the assumption that savings changes in proportion with published equivalent full load hours (EFLH) for locations representing the evaluation regions v. Arkansas.

Accepting that assumption, savings were adjusted as follows:

$$Savings_{Arkansas} = Savings_{Evluation\ region} \cdot \frac{EFLH_{Arkansas}}{EFLH_{Evaluation\ region}}$$

(71)

Applying the ratio of average EFLH[109] values result in the manual thermostat deemed savings presented in Table71. Cooling savings uses EFLHc values, while heating uses EFLHh values.

Heating savings are converted to kWh for homes with electric resistance heating and heat pumps assuming 100% electric efficiency, a furnace AFUE of 78% and a seasonal heat pump efficiency (HSPF) of 7.3.

For the case of programmable thermostat baselines, the savings calculation relied on Vectren and NIPSCO studies which explicitly calculate savings for both smart and programmable thermostats. Because not all thermostats are programmed correctly, default deemed savings calculation assumes that fifty percent of thermostats are programmable and thirty percent[110] of the baseline programmable thermostats are properly programmed.

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[109] EFLH values from Energy Star Central Air Conditioner Calculator (Calc_CAC.xls).

[110] *How People Actually Use Thermostats,* A. Meier, C. Aragon, B. Hurwitz, T. PEffer, M Pritoni ACEEE 2010 Summer Study on Energy Efficiency in Buildings,

2.1.13 ENERGY STAR® Ventilation Fans

Measure Description

This measure applies to bathroom and utility room fans that meet the requirements for ventilation fans outlined in ENERGY STAR® Version 4.0 (effective 10/25/2016). The new ventilation fan must have a capacity that is between 10 cfm and 500 cfm.

Baseline and Efficiency Standards

ENERGY STAR® does not specify a baseline efficacy for existing residential ventilation fans. The efficacy of the existing ventilation fan should be used. If the ventilation fan efficacy is not known, or installation in new construction, a conservative improvement of 15% should be used above the baseline. The resulting baseline efficacy values are shown in Table 73 below.

Table 73: Baseline Residential Ventilating Fan Efficacy

Air Flow	Baseline Efficacy Level (cfm/W)
Bathroom and Utility Room Fans – 10 to 89 cfm	≥ 1.2
Bathroom and Utility Room Fans – 90 to 500 cfm (max)	≥ 2.4

The efficient baseline ventilation fan must meet the ENERGY STAR® efficacy and sound level standards, which are provided in Table 74 and Table 75 below.

Table 74: ENERGY STAR® Qualified Residential Ventilating Fans - Minimum Efficacy Levels

Air Flow	Minimum Efficacy Level (cfm/W)
Bathroom and Utility Room Fans – 10 to 89 cfm	≥ 1.4
Bathroom and Utility Room Fans – 90 to 500 cfm (max)	≥ 2.8

Table 75: ENERGY STAR® Qualified Residential Ventilating Fans - Maximum Sound Levels

Air Flow	Maximum Allowable Sound level (Sones)
Bathroom and Utility Room Fans – 10 to 89 cfm	2.0
Bathroom and Utility Room Fans – 90 to 500 cfm (max)	3.0

Estimated Useful Life (EUL)

The expected measure life is assumed to be 19 years[111].

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[111] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC Measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

Calculation of Deemed Savings

Energy Savings

The annual energy savings are calculated using the following equation:

$$Annual\ Energy\ Savings = \left[CFM\ x\ \frac{\left(\frac{1}{\eta_{Baseline}} - \frac{1}{\eta_{Efficient}}\right)}{1000}\right] x\ Hours$$

(72)

Where:

CFM = Nominal capacity of the exhaust fan

= between 10 – 500 CFM, or default of 70 CFM

$\eta_{Baseline}$ = Average efficacy for baseline fan
= Refer to Table 73

$\eta_{Efficient}$ = Average efficacy for the ENERGY STAR® fan
= actual, or refer to efficacy listed in Table 74 based on the CFM of the installed fan

Hours = annual operation hours
= Actual, or default 438[112] hours per year

Demand Savings

The peak demand electric savings are calculated using the following equation:

$$Peak\ Demand\ Savings = \left[CFM\ x\ \frac{\left(\frac{1}{\eta_{Baseline}} - \frac{1}{\eta_{Efficient}}\right)}{1000}\right] x\ CF$$

(73)

Where:

CF = summer peak coincidence factor
= 0.1[113]

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[112] A conservative of assumption of 438 hours/year was used. A DOE lighting end use study found that a bathroom light runs for 1.2 hours day, or 438 hours per year (1.2 x 365 = 438). It was assumed that the vent fan was in operation whenever the bathroom light was on. Reference: https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_residential-lighting-study.pdf. Page 50. Accessed on August 8, 2017

[113] Assumed to be the same summer coincidence factor as the residential lighting measures.

2.2 Envelope Measures

The residential envelope measures are updated for TRM Version 6.0. Note that Zone 9 (Northwest Region) savings values used TMY3 weather data from Rogers, Arkansas. This is a change from using Fayetteville weather in prior TRM versions because weather in Rogers is more representative of the Northwestern Arkansas climate.

2.2.1 Attic Knee Wall Insulation

Measure Description

This measure involves adding attic knee wall insulation to uninsulated knee wall areas in residential dwellings of existing construction. A wall with an insulation value of R-0 has no insulation, but does have a nominal wall R-value made up of interior and exterior wall materials, air film and wood studs. This measure applies to all residential applications.

Baseline and Efficiency Standards

This measure applies to existing construction only.

Table 76: Attic Knee Wall Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Uninsulated knee wall	Minimum R-19 or R-30

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, based on NEAT v. 8.6.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the attic knee wall area that is being insulated. Gas Heat (no AC) kWh applies to forced air furnace systems only.

Table 77: Knee Wall Insulation – Deemed Savings Values - Zone 9 Northwest Region

Insulation Level Installed	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
R-19	1.104	0.131	0.176	5.073465	2.682	0.00079	0.00264
R-30	1.166	0.139	0.187	5.372651	2.839	0.00083	0.00279

Table 78: Knee Wall Insulation – Deemed Savings Values - Zone 8 Northeast/North Central Region

Insulation Level Installed	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms[114]
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
R-19	1.219	0.114	0.158	4.804	2.489	0.00090	0.00271
R-30	1.289	0.121	0.167	5.086	2.634	0.00094	0.00286

Table 79: Knee Wall Insulation – Deemed Savings Values - Zone 7 Central Region

Insulation Level Installed	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
R-19	1.230	0.100	0.140	4.405	2.298	0.00090	0.00244
R-30	1.300	0.106	0.148	4.662	2.430	0.00095	0.00258

Table 80: Knee Wall Insulation – Deemed Savings Values - Zone 6 South Region

Insulation Level Installed	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
R-19	1.389	0.089	0.123	4.215	2.255	0.00091	0.00226
R-30	1.468	0.094	0.131	4.461	2.384	0.00096	0.00239

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent on the R-value of the attic knee wall, pre- and post-retrofit.

BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since attic knee wall insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions was used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

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[114] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.887 (R-19), 0.887 (R-30). For Fort Smith, m = 0.858 (R-19), 0.858 (R-30).

2.2.2 Ceiling Insulation

Measure Description

This measure requires adding ceiling insulation above a conditioned area in a residential dwelling of existing construction to a minimum ceiling insulation value of R-38. Savings are also estimated for an optional final insulation level of R-49. This measure applies to all residential applications.

This measure pertains to ceiling insulation only (attic floor). There is a separate measure (Measure 2.2.5) for roof deck insulation.

Baseline and Efficiency Standards

In existing construction, ceiling insulation levels vary greatly, depending on the age of the home, type of insulation, and attic space utilization (such as using the attic for storage and HVAC equipment). The average pre-retrofit insulation level of the treated area will be determined and documented by the insulation contractor according to the ranges in Table 81. Degradation due to age and condition of the existing insulation will need to be considered by the insulation contractor. Care must be exercised in differentiating between an existing R-value in the 0-1 range versus in the 2-4 range as the resulting savings are very sensitive in the lower ranges.

The eligibility standard for this measure (minimum final R-value) is R-38, as specified in IECC 2009. Savings are also provided for R-49 as an optional final R-value, as specified for IECC climate zone 4 beginning in IECC 2012.

Table 81: Ceiling Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
R-0 to R-1	R-38 or R-49
R-1 to R-5	
R-5 to R-8	
R-8 to R-15	
R-15 to R-22	

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, according to DEER 2008.

Deemed Savings Values

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are based on the R-value of the ceiling insulation pre-retrofit and a combined post-retrofit R-value (R-values of the existing insulation and the insulation being added) of at least R-38. Savings are also provided for R-49, and linear interpolation may be used to claim savings for final R-values between R-38 and R-49.

Note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space that is being insulated. Gas Heat (no AC) kWh applies to forced air furnace systems only.

For deemed savings for installation between the range of R-38 to R-49, linear interpolation can be used to determine the value that can be claimed as savings.

Deemed Savings for R-38

Table 82: Ceiling Insulation (R-38) – Deemed Savings Values - Zone 9 Northwest Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.716	0.254	0.342	9.366	5.071	0.00140	0.00541
> 1 and ≤ 5	0.969	0.141	0.189	5.212	2.764	0.00080	0.00283
> 5 and ≤ 8	0.586	0.084	0.114	3.136	1.653	0.00050	0.00164
> 8 and ≤ 15	0.364	0.052	0.070	1.926	1.013	0.00032	0.00100
> 15 and ≤ 22	0.172	0.025	0.034	0.931	0.486	0.00014	0.00047

Table 83: Ceiling Insulation (R-38) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings[115] (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.8642	0.2203	0.3060	8.734	4.572	0.00107	0.00539
> 1 and ≤ 5	1.0497	0.1215	0.1687	4.846	2.495	0.00061	0.00284
> 5 and ≤ 8	0.6330	0.0728	0.1011	2.909	1.495	0.00038	0.00165
> 8 and ≤ 15	0.3909	0.0446	0.0618	1.784	0.917	0.00025	0.00099
> 15 and ≤ 22	0.1847	0.0216	0.0299	0.858	0.439	0.00011	0.00048

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[115] Data in table are for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m=0.890 (0-1), m = 0.901 (2 to 4), 0.906 (5 to 8), 0.907 (9 to 14), 0.918 (15 to 22). For Fort Smith, m=0.859 (0-1), m = 0.872 (2 to 4), 0.878 (5 to 8), 0.879 (9 to 14), 0.891 (15 to 22).

Table 84: Ceiling Insulation (R-38) – Deemed Savings Values - Zone 7 Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.8820	0.1933	0.2700	7.936	4.067	0.00201	0.00482
> 1 and ≤ 5	1.0505	0.1070	0.1495	4.401	2.252	0.00118	0.00254
> 5 and ≤ 8	0.6315	0.0643	0.0898	2.643	1.355	0.00073	0.00149
> 8 and ≤ 15	0.3901	0.0394	0.0551	1.624	0.834	0.00047	0.00090
> 15 and ≤ 22	0.1854	0.0190	0.0266	0.781	0.400	0.00022	0.00043

Table 85: Ceiling Insulation (R-38) – Deemed Savings Values - Zone 6 South Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	2.1230	0.1703	0.2378	7.482	3.873	0.00203	0.00440
> 1 and ≤ 5	1.1967	0.0954	0.1331	4.200	2.180	0.00118	0.00235
> 5 and ≤ 8	0.7242	0.0578	0.0806	2.545	1.324	0.00073	0.00137
> 8and ≤ 15	0.4497	0.0356	0.0497	1.574	0.820	0.00047	0.00082
> 15 and ≤ 22	0.2116	0.0172	0.0240	0.753	0.391	0.00021	0.00040

Deemed Savings for R-49

Table 86: Ceiling Insulation (R-49) – Deemed Savings Values - Zone 9 Northwest Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.756	0.260	0.350	9.578	5.182	0.00143	0.00581
> 1 and ≤ 5	1.009	0.146	0.197	5.424	2.876	0.00084	0.00310
> 5 and ≤ 8	0.626	0.090	0.121	3.348	1.764	0.00053	0.00185
> 8 and ≤ 15	0.404	0.057	0.077	2.139	1.124	0.00036	0.00116
> 15 and ≤ 22	0.212	0.031	0.041	1.143	0.597	0.00018	0.00061

Table 87: Ceiling Insulation (R-49) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings[116] (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.907	0.225	0.313	8.931	4.673	0.00109	0.00550
> 1 and ≤ 5	1.093	0.126	0.176	5.043	2.596	0.00064	0.00295
> 5 and ≤ 8	0.676	0.077	0.108	3.105	1.596	0.00040	0.00176
> 9 and ≤ 14	0.434	0.049	0.069	1.981	1.018	0.00027	0.00110
> 15 and ≤ 22	0.228	0.026	0.037	1.055	0.539	0.00013	0.00058

Table 88: Ceiling Insulation (R-49) – Deemed Savings Values - Zone 7 Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	1.925	0.198	0.276	8.115	4.159	0.00207	0.00492
> 1 and ≤ 5	1.093	0.111	0.156	4.581	2.344	0.00124	0.00264
> 5 and ≤ 8	0.674	0.069	0.096	2.822	1.447	0.00079	0.00159
> 9 and ≤ 14	0.433	0.044	0.061	1.803	0.926	0.00053	0.00100
> 15 and ≤ 22	0.228	0.023	0.033	0.960	0.492	0.00027	0.00053

Table 89: Ceiling Insulation (R-49) – Deemed Savings Values - Zone 6 South Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
≤ 1	2.173	0.174	0.243	7.657	3.964	0.00208	0.00449
> 1 and ≤ 5	1.247	0.099	0.139	4.375	2.271	0.00123	0.00244
> 5 and ≤ 8	0.774	0.061	0.086	2.719	1.415	0.00078	0.00146
> 9 and ≤ 14	0.500	0.039	0.055	1.748	0.911	0.00053	0.00090
> 15 and ≤ 22	0.262	0.021	0.030	0.928	0.482	0.00027	0.00048

Calculation of Deemed Savings

BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine; available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

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[116] Data in table are for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m=0.897 (0-1), m = 0.904 (2 to 4), 0.907 (5 to 8), 0.907 (9 to 14), 0.918 (15 to 22). For Fort Smith, m=0.869 (0-1), m = 0.878 (2 to 4), 0.883 (5 to 8), 0.883 (9 to 14), 0.894 (15 to 22).

2.2.3 Wall Insulation

Measure Description

This measure consists of adding wall insulation in the wall cavity in residential dwellings of existing construction. This measure applies to all residential applications.

Baseline and Efficiency Standards

In order to qualify for this measure, there must be no existing wall cavity insulation. Post-retrofit condition will be a wall cavity filled with either fiberglass or cellulose insulation (R-13 nominal value), open cell insulation (R-13 nominal value), or closed cell foam insulation (R-23 nominal value). Each type of insulation's nominal R-value depends on a full thickness application within the cavity of a wall with 2x4 inch studs.

Table 90: Wall Insulation – Baseline and Efficiency Standards

Baseline	**Efficiency Standard (Nominal R-Values)**	
Uninsulated wall cavity	Fiberglass/Cellulose	R-13
	Open Cell Foam	R-13
	Closed Cell Foam	R-23

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, according to DEER 2008.

Deemed Savings Values

The savings per square foot is a factor to be multiplied by the square footage of the net wall area insulated. Wall area must be part of the thermal envelope of the home, and shall not include window or door area. Electrical energy savings for Gas Heat (no AC) are the reduction in electricity used by the furnace's air handler during the heating season.

Deemed savings for R-13 can be achieved with either fiberglass, cellulose, or open cell foam insulation. Deemed savings for R-23 is only applicable to closed cell insulation. The R-value represents the nominal value of the cavity insulation and not the R-value of the wall assembly.

For deemed savings for installation between the range of R-13 to R-23, linear interpolation can be used to determine the value that can be claimed as savings.

Table 91: Wall Insulation – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings / sq. ft.		kW Peak Savings / sq. ft.		Therms Savings / sq. ft.		Peak Therm Savings / sq. ft.	
	R-13	R-23	R-13	R-23	R-13	R-23	R-13	R-23
Electric Cooling with Gas Heat	0.527	0.563	0.00041	0.00048	0.267	0.295	0.0043	0.00454
Gas Heat (No AC)	0.206	0.226	n/a		0.278	0.305	0.0045	0.00454
Electric Cooling with Electric Resistance Heat	6.644	7.324	0.00041	0.00048	n/a		n/a	
Electric Cooling with Electric Heat Pump	3.424	3.447	0.00041	0.00048	n/a		n/a	

Table 92: Wall Insulation – Deemed Savings Values - Zone 8: Northeast/North Central Region

Equipment Type	kWh Savings / sq. ft.		kW Peak Savings / sq. ft.		Therms Savings / sq. ft.		Peak Therm Savings / sq. ft.[117]	
	R-13	R-23	R-13	R-23	R-13	R-23	R-13	R-23
Electric Cooling with Gas Heat	0.586	0.625	0.00027	0.00029	0.239	0.264	0.00409	0.00429
Gas Heat (No AC)	0.179	0.197	n/a		0.249	0.275	0.00409	0.00429
Electric Cooling with Electric Resistance Heat	6.059	6.689	0.00027	0.00029	n/a		n/a	
Electric Cooling with Electric Heat Pump	2.946	2.980	0.00023	0.00025	n/a		n/a	

Table 93: Wall Insulation – Deemed Savings Values - Zone 7: Central Region

Equipment Type	kWh Savings / sq. ft.		kW Peak Savings / sq. ft.		Therms Savings / sq. ft.		Peak Therm Savings / sq. ft.	
	R-13	R-23	R-13	R-23	R-13	R-23	R-13	R-23
Electric Cooling with Gas Heat	0.570	0.607	0.00047	0.00071	0.207	0.230	0.00368	0.00377
Gas Heat (No AC)	0.156	0.173	n/a		0.218	0.242	0.00368	0.00377
Electric Cooling with Electric Resistance Heat	5.315	5.900	0.00047	0.00072	n/a		n/a	
Electric Cooling with Electric Heat Pump	2.479	2.592	0.00047	0.00061	n/a		n/a	

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[117] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.899. For Fort Smith, m = 0.869.

Table 94: Wall Insulation – Deemed Savings Values - Zone 6: South Region

Equipment Type	kWh Savings / sq. ft.		kW Peak Savings / sq. ft.		Therms Savings / sq. ft.		Peak Therm Savings / sq. ft.	
	R-13	R-23	R-13	R-23	R-13	R-23	R-13	R-23
Electric Cooling with Gas Heat	0.712	0.751	0.00046	0.00084	0.178	0.202	0.00333	0.00354
Gas Heat (No AC)	0.134	0.151	n/a		0.188	0.211	0.00333	0.00354
Electric Cooling with Electric Resistance Heat	4.798	5.389	0.00046	0.00084	n/a		n/a	
Electric Cooling with Electric Heat Pump	2.223	2.388	0.00046	0.00071	n/a		n/a	

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent on the R-value of the wall pre- and post-retrofit. BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since wall insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

2.2.4 Floor Insulation

Measure Description

This measure presents two eligible scenarios for retrofitting a crawl space underneath an uninsulated floor[118]:

1. Insulating the underside of the floor (above the vented crawl space), where the floor previously had no insulation
2. "Encapsulating" the crawl space – sealing and insulating the vented perimeter skirt or stem wall between the ground (finished grade) and the first floor of the house, leaving the underside of the first floor structure uninsulated

This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline is considered to be a house with pier and beam construction, no insulation under the floor of the conditioned space, and a vented crawl space. In order to qualify for deemed savings, either the floor can be insulated to a minimum of R-19 or the crawl space can be encapsulated as described below. Deemed savings are provided for each option.

Option 1 – Insulating the underside of the floor to a minimum of R-19.

Option 2 – Encapsulating the crawl space: The crawl space perimeter skirt or stem walls are sealed in a sound and durable manner and the ground (floor of the crawl space) is sealed with a heavy plastic vapor barrier. The skirt or stem wall interior surfaces are insulated to R-13 (minimum) with closed cell foam.[119] The underside of the floor above the crawlspace is left uninsulated. A small flow of conditioned air to the crawl space is recommended to moderate humidity levels.[120]

Occupational Safety and Health Administration (OSHA) standards and applicable versions of the IECC and IRC codes will be pertinent to the installation. Note that this will include ensuring that any oil or gas-fueled furnaces or water heaters located in the crawlspace be provided with dedicated combustion air supply or be sealed-combustion units equipped with a powered combustion system.[121]

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[118] U.S. DOE publication *"Building America Best Practices Series, Vol 17, "Insulation*" found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15) has extensive building science and code conformance information regarding insulating floors as well as sealing and insulating crawl spaces.

[119] IECC 2012, Table R402.1

[120] U.S. DOE publication "*Building America Best Practices Series, Vol 17, "Insulation*" found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15), p. 58, 1 cfm per every 50 sq. ft. of floor area.

[121] Ibid (p. 59).

Table 95: Floor Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
No insulation under floor	(1) R-19 installed under floor, OR (2) Encapsulated crawl space with air-sealed perimeter having R-13 insulation on the interior side, no floor insulation under the floor above, and moisture-sealed grade under the crawl space

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, according to DEER 2008.

Deemed Savings Values

The deemed savings values listed below are per square foot of first level floor area above the crawl space.

For homes with gas heat and electric air conditioning, the deemed savings include the heating season therm savings plus the heating season (furnace fan) and cooling season kWh savings.

For homes with gas heat and no air conditioning, the deemed savings include the heating season therm savings plus the furnace fan kWh savings.

Floor Insulation Deemed Savings

Table 96: R-19 Floor Insulation – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings/ sq. ft.	kW Savings /sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	-0.139	-0.000031	0.058	0.00036
Gas Heat Only (no AC)	0.044	n/a	0.060	0.00036
Electric AC with Electric Resistance Heat	1.192	-0.000031	n/a	n/a
Electric AC with Heat Pump	0.442	-0.000031	n/a	n/a

Table 97: R-19 Floor Insulation – Deemed Savings Values - Zone 8 Northeast/North Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.[122]
Electric AC with Gas Heat	-0.165	-0.00003	0.050	0.00026
Gas Heat Only (no AC)	0.036	n/a	0.051	0.00026
Electric AC with Electric Resistance Heat	0.985	-0.00003	n/a	n/a
Electric AC with Heat Pump	0.294	-0.00003	n/a	n/a

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[122] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 1.596. For Fort Smith, m = 1.619.

Table 98: R-19 Floor Insulation – Deemed Savings Values - Zone 7 Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	-0.159	-0.00002	0.043	0.00031
Gas Heat Only (no AC)	0.031	n/a	0.044	0.00031
Electric AC with Electric Resistance Heat	0.849	-0.00002	n/a	n/a
Electric AC with Heat Pump	0.237	-0.00002	n/a	n/a

Table 99: R-19 Floor Insulation – Deemed Savings Values - Zone 6 South Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	-0.101	0.00003	0.004	-0.00004
Gas Heat Only (no AC)	0.026	n/a	0.038	-0.00004
Electric AC with Electric Resistance Heat	0.706	0.00003	n/a	n/a
Electric AC with Heat Pump	0.181	0.00003	n/a	n/a

Crawlspace Insulation Deemed Savings

Table 100: Crawlspace Encapsulation – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	0.031	-0.00003	0.082	0.00021
Gas Heat Only (no AC)	0.062	n/a	0.084	0.00021
Electric AC with Electric Resistance Heat	1.922	-0.00003	n/a	n/a
Electric AC with Heat Pump	0.625	-0.00003	n/a	n/a

Table 101: Crawlspace Encapsulation – Deemed Savings Values - Zone 8 Northeast/North Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.[123]
Electric AC with Gas Heat	0.017	-0.00002	0.070	0.00026
Gas Heat Only (no AC)	0.054	n/a	0.076	0.00026
Electric AC with Electric Resistance Heat	1.647	-0.00002	n/a	n/a
Electric AC with Heat Pump	0.448	-0.00002	n/a	n/a

Table 102: Crawlspace Encapsulation – Deemed Savings Values - Zone 7 Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	0.011	-0.00005	0.061	0.00008
Gas Heat Only (no AC)	0.048	n/a	0.067	0.00008
Electric AC with Electric Resistance Heat	1.432	-0.00005	n/a	n/a
Electric AC with Heat Pump	0.397	-0.00005	n/a	n/a

Table 103: Crawlspace Encapsulation – Deemed Savings Values - Zone 6 South Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therms Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	0.122	0.00003	0.068	0.00084
Gas Heat Only (no AC)	0.045	n/a	0.063	0.00084
Electric AC with Electric Resistance Heat	1.353	-0.00003	n/a	n/a
Electric AC with Heat Pump	0.401	-0.00003	n/a	n/a

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones for both options – floor insulation and crawl space encapsulation. BEopt™ was used to estimate energy savings for both options using the same base case model (uninsulated floor, vented crawl space) and the DOE EnergyPlus simulation engine. Savings are sensitive to weather; therefore, available TMY3 weather data specific to each of the four Arkansas weather regions was used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

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[123] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 2.799. For Fort Smith, m = 2.796.

2.2.5 Roof Deck Insulation

Measure Description

This measure consists of installing roof deck insulation underneath the uninsulated roof deck area (no existing insulation). The ceiling insulation at the "floor" of the attic is to be removed in accordance with industry best practice.[124] It is recommended that the top of ceiling be vacuumed to remove insulation fibers and other debris that would otherwise migrate into the living space through openings in the ceiling. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline condition refers to as-found (pre-retrofit) ceiling insulation levels. In existing construction, ceiling insulation levels vary greatly, depending on the age of the home, type of insulation, and attic space utilization. The average pre-retrofit insulation level of the treated area will be determined and documented by the insulation contractor according to the ranges in the Table 104. Degradation of the existing insulation due to age and other factors will need to be considered by the insulation contractor. Baseline conditions include having no existing insulation under the roof deck.

If the existing ceiling insulation level is greater than R-22, it is not eligible for this measure. Additionally, ducts must be predominantly located in the attic to be eligible for this measure.

Insulation will be added to the underside of the roof decking to a total R-values meeting the customer's needs and/or meeting applicable codes for the jurisdiction. Savings are estimated for two levels of final roof deck insulation, R-19 and R-38. For estimating savings between these two final R-values, linear interpolation may be used.

Table 104 Ceiling Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
R-0 to R-1	R-19 and R-38
R-2 to R-4	
R-5 to R-8	
R-9 to R-14	

For this measure, the attic is encapsulated using spray-applied polyurethane foam on the underside of roof decking and on all surfaces separating the attic from unconditioned space (such as gable ends and attic extensions over a porch, garage, etc.), to a minimum insulation value of R-19.[125] The application shall include coating all supporting framing, such as rafters, with a minimum of 1" of foam to mitigate thermal bridging.

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[124] U.S. DOE publication *"Building America Best Practices Series, Vol 17 "Insulation*", found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15), p. 39.

[125] Knee wall insulation retrofits are covered in a separate measure.

The roof deck spray foam insulation can consist of either closed cell foam, which also provides a vapor barrier, or open cell foam which is air permeable. Although not an eligibility issue for this measure, the following is provided from building science literature for consideration by the homeowner when examining options for the project.[126] Literature suggests that a vapor barrier is needed in Zone 9 (not in other zones) to protect the roof deck (wood) surface from attic moisture condensation that may occur due to the colder climate. This vapor barrier can be provided in at least two options; (1) apply closed cell foam as the "first layer" of foam applied to the underside of the deck (the balance of the installation can be open cell), or (2) use all open cell foam applied to the underside of the deck, with a spray-applied vapor retarding paint on the interior side of the cured open cell foam. Both of these options would only pertain to Zone 9.

All installations should comply with applicable versions of the IECC and IRC codes. This includes ensuring that any oil or gas-fueled furnaces or water heaters located in the attic be provided with a dedicated combustion air supply or be sealed-combustion units equipped with a powered combustion system.[127]

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, according to DEER 2008.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space that is being insulated. Savings from insulating a knee wall(s) are defined under a separate measure and are additive to the savings for this measure.

For homes with gas heat and electric air conditioning, the deemed savings include the heating season therm savings plus the heating season (furnace fan) and cooling season kWh savings. For homes with gas heat and no air conditioning, the deemed savings include the heating season therm savings plus the furnace fan kWh savings.

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[126] U.S. DOE publication *"Building America Best Practices Series, Vol 17 "Insulation*", found at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/insulation_guide.pdf (accessed 7-8-15), p. 40.

[127] ibid, page 59

Deemed Savings for Roof Deck Insulation at R-19

Table 105: Roof Deck Insulation (R19) – Deemed Savings Values - Zone 9 Northwest Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	1.703	0.260	0.350	9.507	4.761	0.00151	0.00603
2 to 4	1.006	0.153	0.206	5.554	2.685	0.00098	0.00360
5 to 8	0.640	0.099	0.134	3.570	1.685	0.00069	0.00249
9 to 14	0.426	0.069	0.092	2.418	1.113	0.00052	0.00187
15 to 22	0.242	0.043	0.059	1.473	0.644	0.00034	0.00138

Table 106: Roof Deck Insulation (R19) – Deemed Savings Values - Zone 8: Northeast/North Central Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	1.880	0.228	0.317	8.921	4.315	0.00119	0.00583
2 to 4	1.117	0.135	0.187	5.225	2.484	0.00077	0.00352
5 to 8	0.717	0.089	0.123	3.373	1.580	0.00054	0.00245
9 to 14	0.482	0.062	0.086	2.301	1.055	0.00040	0.00185
15 to 22	0.282	0.040	0.056	1.417	0.620	0.00027	0.00124

Table 107: Roof Deck Insulation (R19) – Deemed Savings Values - Zone 7: Central Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	1.879	0.201	0.281	8.036	3.885	0.00201	0.00532
2 to 4	1.104	0.119	0.166	4.656	2.223	0.00130	0.00323
5 to 8	0.702	0.078	0.109	2.961	1.388	0.00090	0.00227
9 to 14	0.467	0.055	0.076	1.981	0.905	0.00067	0.00173
15 to 22	0.268	0.035	0.049	1.169	0.501	0.00045	0.00129

Table 108: Roof Deck Insulation (R19)– Deemed Savings Values - Zone 6: South Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	2.097	0.178	0.249	7.564	3.743	0.00207	0.00406
2 to 4	1.268	0.105	0.147	4.425	2.193	0.00136	0.00218
5 to 8	0.829	0.069	0.096	2.823	1.392	0.00097	0.00129
9 to 14	0.572	0.047	0.066	1.889	0.922	0.00073	0.00079
15 to 22	0.349	0.030	0.042	1.099	0.522	0.00050	0.00041

Deemed Savings for Roof Deck Insulation at R-38

Table 109: Roof Deck Insulation (R38) – Deemed Savings Values - Zone 9 Northwest Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	1.846	0.272	0.366	10.011	5.038	0.00158	0.00628
2 to 4	1.148	0.164	0.221	6.058	2.962	0.00105	0.00385
5 to 8	0.783	0.111	0.150	4.074	1.962	0.00076	0.00274
9 to 14	0.568	0.080	0.108	2.922	1.390	0.00059	0.00213
15 to 22	0.384	0.055	0.075	1.977	0.920	0.00042	0.00164

Table 110: Roof Deck Insulation (R38) – Deemed Savings Values - Zone 8: Northeast/North Central Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	2.032	0.238	0.331	9.384	4.571	0.00124	0.00609
2 to 4	1.269	0.145	0.201	5.688	2.740	0.00082	0.00378
5 to 8	0.869	0.098	0.137	3.836	1.836	0.00059	0.00271
9 to 14	0.634	0.072	0.100	2.764	1.311	0.00046	0.00211
15 to 22	0.434	0.050	0.070	1.881	0.875	0.00032	0.00150

Table 111: Roof Deck Insulation (R38) – Deemed Savings Values - Zone 7: Central Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	2.031	0.210	0.293	8.463	4.126	0.00212	0.00555
2 to 4	1.256	0.128	0.178	5.084	2.464	0.00141	0.00346
5 to 8	0.854	0.087	0.121	3.389	1.629	0.00102	0.00250
9 to 14	0.619	0.063	0.088	2.408	1.146	0.00078	0.00196
15 to 22	0.420	0.044	0.061	1.596	0.742	0.00056	0.00152

Table 112: Roof Deck Insulation (R38)– Deemed Savings Values - Zone 6: South Region

Ceiling Insulation (Base)	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0 to 1	2.264	0.186	0.260	7.983	3.681	0.00217	0.00500
2 to 4	1.436	0.113	0.158	4.845	2.132	0.00146	0.00312
5 to 8	0.997	0.077	0.107	3.243	1.331	0.00107	0.00223
9 to 14	0.739	0.055	0.077	2.308	0.861	0.00083	0.00173
15 to 22	0.517	0.037	0.052	1.519	0.460	0.00060	0.00135

Calculation of Deemed Savings

BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. All base case model runs assumed ducts located in the attic, and all efficient case model runs had the ducts moved from the attic to the interior. Since envelope insulation savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt ™ building model are outlined in Appendix A.

2.2.6 Radiant Barriers

Measure Description

Radiant barriers are designed to block radiant heat transfer between a building roof and the attic space insulation. They typically consist of a metallic foil material (usually aluminum), and are generally installed on the roof decking or beneath roof sheathing. Radiant barriers are most effective at reducing cooling consumption by reflecting heat away from a home. This measure applies to all residential applications.

Baseline and Efficiency Standards

This measure applies to existing construction that does not have a radiant barrier installed on the roof decking.

The efficiency requirements for radiant barriers must meet the standards set by the Reflective Insulation Manufacturers Association International (RIMA) to include proper attic ventilation. The following table displays the requirements for radiant barriers:

Table 113: Radiant Barriers – Required Substantiation

Required Substantiation		
Physical Property	**Test Method or Standard**	**Requirement**
Surface Emittance	ASTM C 1371	0.1 or less
Water Vapor Transmission	ASTM E 96: Procedure A Desiccant Method	0.02 for Vapor Retarder 0.5 or greater for perforated products
Surface Burning		
Flame Spread	ASTM E 84	25 or less
Smoke Density	ASTM E 84	450 or less
Corrosivity	ASTM D 3310	Corrosion on less than 2% of the affected surface
Tear Resistance	ASTM D 2261	
Adhesive Performance		
Bleeding	Section 10.1 of ASTM C 1313	Bleeding or delamination of less than 2% of the surface area
Pliability	Section 10.2 of ASTM C 1313	No cracking or delamination
Mold and Mildew	ASTM C 1338	No growth when visually examined under 5X magnification

Interior radiation control coatings are not applicable for the deemed savings derived. A study performed by RIMA found that none of the coating-type products currently on the market had an emittance of 0.10 or lower as required by the standards set by ASTM for a product to be considered a radiant barrier.[128] Therefore, all coating materials and spray application materials are ineligible for application of these savings values.

All radiant barriers should be installed according to the RIMA Handbook, Section 7.4.[129] However, horizontal installation is not eligible, due to the likelihood of dust buildup and wear-and-tear damage to the radiant barrier.

A radiant barrier cannot be in contact with any other materials on its underside or else it becomes defective. Therefore, once a radiant barrier is installed on the roof decking, no roof deck insulation can be installed.

Estimated Useful Life (EUL)

The average lifetime of this measure is estimated to be about 25 years for downward facing radiant barriers, based on the US DOE's Radiant Barrier Fact Sheet. http://web.ornl.gov/sci/ees/etsd/btric/RadiantBarrier/RBFactSheet2010.pdf

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space to which the radiant barrier is applied. Gas Heat (no AC) kWh applies to forced air furnace systems only.

Table 114: Radiant Barriers – Deemed Savings Values - Zone 9 Northwest Region

Addition of Radiant Barrier with existing attic insulation level	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic insulation ≤R-19	0.221	0.007	0.009	0.419	0.322	0.0001	0.00019
Attic insulation >R19	0.134	0.003	0.004	0.225	0.187	0.0001	0.00011

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[128] Study by RIMA that found no radiant coating on the market having a low enough emittance to be considered a radiant barrier: www.rimainternational.org/technical/ircc.html

[129] RIMA Handbook available online: www.rimainternational.org/technical/handbook.html

Table 115: Radiant Barriers – Deemed Savings Values - Zone 8 Northeast/North Central Region

Addition of Radiant Barrier with existing attic insulation level	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings[130] Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic insulation ≤R-19	0.240	0.005	0.007	0.401	0.304	0.00015	0.00019
Attic insulation >R19	0.145	0.003	0.003	0.216	0.177	0.00008	0.00011

Table 116: Radiant Barriers – Deemed Savings Values - Zone 7 Central Region

Addition of Radiant Barrier with existing attic insulation level	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic insulation ≤R-19	0.244	0.005	0.007	0.393	0.288	0.00015	0.00016
Attic insulation >R19	0.148	0.002	0.003	0.213	0.166	0.00008	0.00009

Table 117: Radiant Barriers – Deemed Savings Values - Zone 6 South Region

Addition of Radiant Barrier with existing attic insulation level	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic insulation ≤R-19	0.278	0.005	0.007	0.438	0.311	0.00014	0.00016
Attic insulation >R19	0.171	0.003	0.003	0.245	0.183	0.00008	0.00009

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The calculations for deemed savings values are based on the addition of a radiant barrier to the roof decking where a radiant barrier did not previously exist.

BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since radiant barrier savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

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[130] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.734 (≤R-19), 0.722 (>R19). For Fort Smith, m = 0.709 (≤R-19), 0.694 (>R19).

2.2.7 ENERGY STAR® Windows

Measure Description

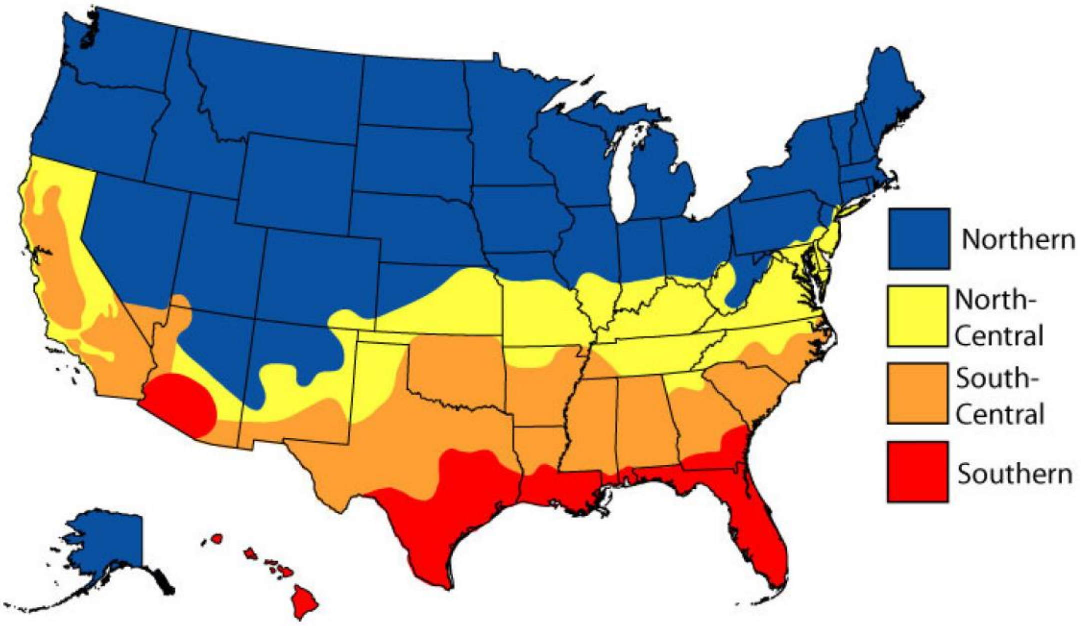
This measure involves the replacement of windows with ENERGY STAR® window(s) in an existing home. This measure applies to all residential applications.

Baseline and Efficiency Standards

For this measure, there are two separate baseline assumptions and two sets of deemed savings values. One set of deemed savings values is applicable where the window being replaced is a single-pane window without a storm window.

The other set of deemed savings values is applicable in instances where the ENERGY STAR® window is replacing a double-glazed or a single-pane window with a storm window.

Effective January 4, 2010, ENERGY STAR® increased the efficiency levels for ENERGY STAR® windows. The updated requirements are specific to climate as shown in the Figure 7.



ENERGY STAR Program Requirements for Windows, Doors, and Skylights: Version 5.0 (April 7, 2009)

Figure 7: ENERGY STAR® Window Program Requirements – Climate Map

In compliance with the climate map, the new efficiency levels are as follows:

Table 118: ENERGY STAR® Windows – Weather Zones

Baseline	Efficiency Levels			
All Zones	**Weather Zone**	**ENERGY STAR® Assigned Climate Zone**	**U-factor**	**SHGC**
Single-pane clear glass aluminum frame, no thermal break, U-factor of 1.12, SHGC of 0.79, air infiltration rate of 0.7 cfm/ft^2.	**Zone 9**	North-Central	0.32	0.40
	Zone 8	South-Central	0.35	0.30
Double-glazed (i.e., double-pane), clear window aluminum frame, U-factor of 0.81, SHGC of 0.64, air infiltration rate of 0.7 cfm/ft^2.	**Zone 7**	South-Central	0.35	0.30
	Zone 6	South-Central	0.35	0.30

Estimated Useful Life (EUL)

The average lifetime of this measure is 20 years, according to DEER 2008.

Deemed Savings Values

Deemed savings are calculated per square foot of window, inclusive of frame and sash. The following table applies to qualified ENERGY STAR® windows replacing single-paned or double-paned, clear glass. Gas Heat (no AC) kWh savings are the reduction in electricity used by the furnace's air handler during the heating season.

Table 119: ENERGY STAR® Replacement for Single-Pane Window – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	4.884	0.0031	0.360	0.0124
Gas Heat Only (no AC)	0.275	n/a	0.368	0.0124
Elec. AC with Resistance Heat	13.050	0.0031	n/a	n/a
Heat Pump	8.509	0.0031	n/a	n/a

Table 120: ENERGY STAR® Replacement for Single-Pane Window – Deemed Savings Values - Zone 8 Northeast/North Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.[131]
Electric AC with Gas Heat	5.800	0.0036	0.253	0.011
Gas Heat Only (no AC)	0.187	n/a	0.256	0.011
Elec. AC with Resistance Heat	11.485	0.0036	n/a	n/a
Heat Pump	7.768	0.0036	n/a	n/a

Table 121: ENERGY STAR® Replacement for Single-Pane Window – Deemed Savings Values - Zone 7 Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	5.889	0.0035	0.216	0.0085
Gas Heat Only (no AC)	0.160	n/a	0.219	0.0085
Elec. AC with Resistance Heat	10.719	0.0035	n/a	n/a
Heat Pump	7.278	0.0035	n/a	n/a

Table 122: ENERGY STAR® Replacement for Single-Pane Window – Deemed Savings Values - Zone 6 South Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	6.864	0.0037	0.174	0.0083
Gas Heat Only (no AC)	0.127	n/a	0.173	0.0083
Elec. AC with Resistance Heat	10.771	0.0037	n/a	n/a
Heat Pump	7.526	0.0037	n/a	n/a

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[131] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.629. For Fort Smith, m = 0.597.

Table 123: ENERGY STAR® Replacement for Double-Pane Window – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	3.028	0.0019	0.317	0.0091
Gas Heat Only (no AC)	0.243	n/a	0.326	0.0091
Elec. AC with Resistance Heat	10.241	0.0019	n/a	n/a
Heat Pump	6.303	0.0019	n/a	n/a

Table 124: ENERGY STAR® Replacement for Double-Pane Window – Deemed Savings Values - Zone 8 Northeast/North Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.[132]
Electric AC with Gas Heat	3.730	0.0037	0.210	0.0077
Gas Heat Only (no AC)	0.156	n/a	0.214	0.0077
Elec. AC with Resistance Heat	8.476	0.0037	n/a	n/a
Heat Pump	5.484	0.0031	n/a	n/a

Table 125: ENERGY STAR® Replacement for Double-Pane Window – Deemed Savings Values - Zone 7 Central Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	3.785	0.0036	0.179	0.0062
Gas Heat Only (no AC)	0.134	n/a	0.185	0.0062
Elec. AC with Resistance Heat	7.820	0.0035	n/a	n/a
Heat Pump	5.072	0.0031	n/a	n/a

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[132] Data in table is for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.660. For Fort Smith, m = 0.627.

Table 126: ENERGY STAR® Replacement for Double-Pane Window – Deemed Savings Values - Zone 6 South Region

Equipment Type	kWh Savings / sq. ft.	kW Savings / sq. ft.	Therm Savings / sq. ft.	Peak Therm Savings / sq. ft.
Electric AC with Gas Heat	4.449	0.0042	0.1478	0.0061
Gas Heat Only (no AC)	0.109	n/a	0.1493	0.0061
Elec. AC with Resistance Heat	7.787	0.0042	n/a	n/a
Heat Pump	5.198	0.0035	n/a	n/a

Calculation of Deemed Savings

The deemed savings are dependent on the U-factor and SHGC of the pre- and post-retrofit glazing as displayed Table A3.g of Appendix A in Arkansas TRM Volume 3. BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since ENERGY STAR® window savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt building model are outlined in Appendix A.

2.2.8 Window Film

Measure Description

This measure consists of adding solar film to east and west facing windows. This measure applies to all residential applications.

Baseline and Efficiency Standards

This measure is applicable to existing homes only. Low E windows and tinted windows are not applicable for this measure. In order to qualify for deemed savings, solar film should be applied to east and west facing glass.

Table 127: Window Film – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Single- or double-pane window with no existing solar films, solar screens, or low-e coating	Solar Film with SHGC <0.50

Estimated Useful Life (EUL)

The average lifetime of this measure is 10 years, according to DEER 2008.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the window area to which the films are being added. Gas Heat (no AC) kWh applies to forced air furnace systems only.

Table 128: Window Film – Deemed Savings Values - Zone 9 Northwest Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	2.883	-0.229	-0.312	-3.946	-0.320	0.002	-0.00152
Double Pane	0.943	-0.079	-0.107	-1.405	-0.152	0.000	-0.00052

Table 129: Window Film – Deemed Savings Values - Zone 8 Northeast/North Central Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.167	-0.196	-0.276	-2.850	0.324	0.0016	-0.00239
Double Pane	1.029	-0.067	-0.095	-1.037	0.060	0.0005	-0.00083

Table 130: Window Film – Deemed Savings Values - Zone 7 Central Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.273	-0.171	-0.243	-1.989	0.733	0.0016	-0.00245
Double Pane	1.069	-0.059	-0.084	-0.739	0.204	0.0005	-0.00085

Table 131: Window Film – Deemed Savings Values - Zone 6 South Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.668	-0.141	-0.201	-0.617	1.507	0.0015	-0.00189
Double Pane	1.202	-0.048	-0.069	-0.258	0.473	0.0005	-0.00066

Calculation of Deemed Savings

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent on the SHGC of pre- and post-retrofit glazing. BEopt™ was used to estimate energy savings for a series of models using the DOE EnergyPlus simulation engine. Since window film savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt building model are outlined in Appendix A.

2.2.9 Air Infiltration

Measure Description

This measure reduces air infiltration into the residence, using pre- and post-treatment blower door air pressure readings to quantify the air leakage reduction. There is no post-retrofit minimum infiltration requirement, however, installations must comply with the prevailing Arkansas mechanical or ventilation code. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline for this measure is the existing leakage rate of the residence to be treated. The existing leakage rate should be capped to account for the fact that the deemed savings values per CFM_{50} leakage reduction are only applicable up to a point where the existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.

Baseline assumptions used in the development of these deemed savings are based on the *2013 ASHRAE Handbook of Fundamentals, Chapter 16*, which provides typical infiltration rates for residential structures. In a study of low income homes reported in ASHRAE, approximately 95 percent of the home infiltration rates were below 3.0 $ACH_{Nat.}$[133] Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or improperly conducted blower door tests, these savings should only be applied starting at a baseline ACH_{Nat} of 3.0 or lower.

To calculate the maximum allowable $CFM_{50,\ pre}$ value for a particular house, use the following equation:

$$CFM_{50,pre}/ft^2 = \frac{ACH_{Nat,pre} \times h \times N}{60}$$

(74)

Where:

$CFM_{50,pre}/ft^2$ = Per square foot pre-installation infiltration rate (CFM_{50}/ft^2)

$ACH_{Nat,pre}$ = Maximum pre-installation air change rate (ACH_{Nat}) = 3.0

60 = Constant to convert from minutes to hours

h = Ceiling height (ft.) = 8.5 (default)[134]

N = N factor (Table132)

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[133] 2013 ASHRAE *Handbook of Fundamentals, Chapter 16,* pp. 16.18, Figure 12.

[134] Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

Table 132: Air Infiltration – N Factor[135]

Wind Shielding	Number of Stories		
	Single Story	**Two Story**	**Three + Story**
Well Shielded	25.8	20.6	18.1
Normal	21.5	17.2	15.1
Exposed	19.4	15.5	13.5

Well Shielded is defined as urban areas with high buildings or sheltered areas, and buildings surrounded by trees, bermed earth, or higher terrain.

Normal is defined as buildings in a residential neighborhood or subdivision setting, with yard space between buildings. Approximately 80-90 percent of houses fall in this category.

Exposed is defined as buildings in an open setting with few buildings or trees around and buildings on top of a hill or ocean front, exposed to winds.

Maximum CFM_{50} per square foot values are available in Table 133. Pre-retrofit leakage rates are limited to a maximum per square foot value specified in the table, as this generally indicates severe structural damage not repairable by typical infiltration reduction techniques.

Table 133: Pre-Retrofit Infiltration Cap (CFM50/ft2)

	Number of Stories		
Wind Shielding	**Single Story**	**Two Story**	**Three + Story**
Well Shielded	11.0	8.8	7.7
Normal	9.1	7.3	6.4
Exposed	8.2	6.6	5.7

Estimated Useful Life (EUL)

According to DEER 2008, the Estimated Useful Life for air infiltration is 11 years.

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[135] Krigger, J. & Dorsi, C. 2005, *Residential Energy: Cost Savings and Comfort for Existing Buildings, 4th Edition. Version RE. Appendix A-11: Zone 3 Building Tightness Limits*, p. 284., December 20. www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf.

Deemed Savings Values

The following formulas shall be used to calculate deemed savings for infiltration efficiency improvements. The formulas apply to all building heights and shielding factors.

$$kWh_{savings} = CFM_{50} \times ESF \tag{75}$$

$$kW_{savings} = CFM_{50} \times DSF \tag{76}$$

$$therms_{savings} = CFM_{50} \times GSF \tag{77}$$

$$peak\ therms_{savings} = CFM_{50} \times GPSF \tag{78}$$

Where:

CFM_{50} = Air infiltration reduction in Cubic Feet per Minute at 50 pascals, as measured by the difference between pre- and post-installation blower door air leakage tests

ESF = corresponding energy savings factor (Table 134 through Table 137)

DSF = corresponding demand savings factor (Table 134 through Table 137)

GSF = corresponding gas savings factor (Table 134 through Table 137)

$GPSF$ = corresponding gas peak savings factor (Table 134 through Table 137)

Electrical energy savings for Gas Heat (no AC) are the reduction in electricity used by the furnace's air handler during the heating season.

Table 134: Air Infiltration Reduction – Deemed Savings Values - Zone 9 Northwest Region

Equipment Type	kWh Savings / CFM_{50} (ESF)	kW Savings / CFM_{50} (DSF)	Therm Savings / CFM_{50} (GSF)	Peak Therms / CFM_{50} (GPSF)
Electric AC with Gas Heat	0.166	0.000098	0.095	0.002529
Gas Heat Only (no AC)	0.073	n/a	0.099	0.002529
Elec. AC with Resistance Heat	2.344	0.000098	n/a	n/a
Heat Pump	1.099	0.000098	n/a	n/a

Table 135: Air Infiltration Reduction – Deemed Savings Values - Zone 8 Northeast/North Central Region

Equipment Type	kWh Savings / CFM_{50} (ESF)	kW Savings / CFM_{50} (DSF)	Therm Savings / CFM_{50} (GSF)	Peak Therms / CFM_{50} [136] (GPSF)
Electric AC with Gas Heat	0.188	0.00014	0.0825	0.002325
Gas Heat Only (no AC)	0.062	n/a	0.0863	0.002325
Elec. AC with Resistance Heat	2.079	0.00014	n/a	n/a
Heat Pump	0.942	0.00014	n/a	n/a

Table 136: Air Infiltration Reduction – Deemed Savings Values - Zone 7 Central Region

Equipment Type	kWh Savings / CFM_{50} (ESF)	kW Savings / CFM_{50} (DSF)	Therm Savings / CFM_{50} (GSF)	Peak Therms / CFM_{50} (GPSF)
Electric AC with Gas Heat	0.190	0.00016	0.0707	0.002181
Gas Heat Only (no AC)	0.053	n/a	0.0747	0.002181
Elec. AC with Resistance Heat	1.812	0.00016	n/a	n/a
Heat Pump	0.818	0.00016	n/a	n/a

Table 137: Air Infiltration Reduction – Deemed Savings Values - Zone 6 South Region

Equipment Type	kWh Savings / CFM_{50} (ESF)	kW Savings / CFM_{50} (DSF)	Therm Savings / CFM_{50} (GSF)	Peak Therms / CFM_{50} (GPSF)
Electric AC with Gas Heat	0.255	0.00017	0.0604	0.001812
Gas Heat Only (no AC)	0.046	n/a	0.0639	0.001812
Elec. AC with Resistance Heat	1.641	0.00017	n/a	n/a
Heat Pump	0.756	0.00017	n/a	n/a

Calculation of Deemed Savings

BEopt™ was used to estimate energy savings for a series of models using the US DOE EnergyPlus simulation engine. Since infiltration savings are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype home characteristics used in the BEopt™ building model are outlined in Appendix A.

Deemed savings values have been calculated for each of the four weather zones. The deemed savings are dependent on the pre- and post-CFM_{50} leakage rates of the home and are presented as annual savings / CFM_{50} reduction. A series of model runs was completed in order to establish the relationship between various CFM_{50} leakage rates and heating and cooling energy consumption. The resulting analysis of model outputs was used to create the deemed savings tables of kWh, kW, and therm savings per CFM_{50} of air infiltration reduction.

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[136] Data in table are for Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.792. For Fort Smith, m = 0.752.

2.3 Domestic Hot Water Measures

2.3.1 Water Heater Replacement

Measure Description

This measure involves:

- The replacement of electric storage water heaters by either high efficiency electric storage tank water heaters or electric tankless water heaters
- The replacement of electric water heaters by heat pump water heaters (HPWH)
- The replacement of gas water heaters by more efficient gas storage tank water heaters or gas tankless (instantaneous) water heaters
- The replacement of either electric or gas water heaters by ENERGY STAR® certified solar water heaters

Water heating deemed savings values are measured on an annual per-unit basis. Deemed savings variables include tank volume, estimated water usage, weather zone, and rated energy factor. Fuel substitution is not eligible for deemed savings. This measure applies to all residential applications.

Baseline and Efficiency Standards

The current baseline for electric and gas water heaters is the US DOE energy efficiency standard (10 CFR Part 430), which is consistent with the IECC 2009. Residential water heaters manufactured on or after April 16, 2015 must comply with the amended standards found in the Code of Federal Regulations, 10 CFR 430.32(d), as found in Table 138.

Table 138: Title 10: 430.32 (d) Water Heater Standards[137]

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor (EF)[138]
Gas-fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 − (0.0020 × Vr)
		Low	0.5982 − (0.0019 × Vr)
		Medium	0.6483 − (0.0017 × Vr)
		High	0.6920 − (0.0013 × Vr)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 − (0.0006 × Vr)
		Low	0.7689 − (0.0005 × Vr)
		Medium	0.7897 − (0.0004 × Vr)
		High	0.8072 − (0.0003 × Vr)
	≤ 50 gal	Very Small	0.2509 − (0.0012 × Vr)

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[137] https://energy.gov/energysaver/sizing-new-water-heater. Accessed August 7, 2017

[138] Vr presented in this table is the rated storage volume (in gallons) of the water heater determined pursuant to 10 CFR 429.17.

Product class	**Rated storage volume and input rating (if applicable)**	**Draw pattern**	**Uniform energy factor (EF)[138]**
Oil-fired Storage Water Heater		Low	0.5330 − (0.0016 × Vr)
		Medium	0.6078 − (0.0016 × Vr)
		High	0.6815 − (0.0014 × Vr)
Electric Storage Water Heaters	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 − (0.0008 × Vr)
		Low	0.9254 − (0.0003 × Vr)
		Medium	0.9307 − (0.0002 × Vr)
		High	0.9349 − (0.0001 × Vr)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 − (0.0011 × Vr)
		Low	2.0440 − (0.0011 × Vr)
		Medium	2.1171 − (0.0011 × Vr)
		High	2.2418 − (0.0011 × Vr)
Tabletop Water Heater	≥ 20 gal and ≤ 120	Very Small	0.6323 − (0.0058 × Vr)
		Low	0.9188 − (0.0031 × Vr)
		Medium	0.9577 − (0.0023 × Vr)
		High	0.9884 − (0.0016 × Vr)
Instantaneous Gas-fired Water Heater	< 2 gal and > 50,000 Btu/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92
Grid-Enabled Water Heater	>75 gal	Very Small	1.0136 − (0.0028 × Vr)
		Low	0.9984 − (0.0014 × Vr)
		Medium	0.9853 − (0.0010 × Vr)
		High	0.9720 − (0.0007 × Vr)

The new code requires that a draw pattern be determined in order to calculate the correct energy factor. The draw pattern is calculated based on the first hour rating (FHR) of the installed water heater, and is defined as the number of gallons of hot water the heater can supply per hour. [139] Table 139, Table 140, and Table 141 provide the FHR ranges and corresponding draw pattern designation.

Table 139: Tank Water Heater Draw Pattern[140]

New FHR greater than or equal to:	and new FHR less than:	Draw pattern
0 gallons	18 gallons	Very Small
18 gallons	51 gallons	Low
51 gallons	75 gallons	Medium
75 gallons	No upper limit	High

Table 140: Instantaneous Water Heater Draw Pattern[141]

New max GPM greater than or equal to:	And new max GPM rating less than:	Draw pattern
0 gallons/minute	1.7 gallons/minute	Very Small
1.7 gallons/minute	2.8 gallons/minute	Low
2.8 gallons/minute	4 gallons/minute	Medium
4 gallons/minute	No upper limit	High

Table 141: Heat Pump Water Heater Draw Pattern[142]

Draw pattern	DV
Very Small	10 gallons
Low	38 gallons
Medium	55 gallons
High	84 gallons

Estimated Useful Life (EUL)

The average lifetime of this measure is dependent on the type of water heating. According to DEER 2008, the following measure lifetimes should be applied:

- 13 years for electric storage tank water heaters

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[139] https://energy.gov/energysaver/sizing-new-water-heater. Accessed August 7, 2017

[140] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

[141] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

[142] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

- 20 years for tankless gas or electric water heaters
- 10 years for HPWH
- 11 years for gas storage tank water heaters
- 15 years for solar water heaters

Calculation of Deemed Savings – Electric Water Heating

Energy Savings – Electric Storage Tank Water Heater Replacement

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{3{,}412\ Btu/kWh}$$

(79)

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal) from Table 142

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

$\boldsymbol{T_{Supply}}$ = Average supply water temperature from Table 143

EF_{pre} = Baseline Energy Factor, Calculated from Table 138. If draw pattern is unknown, assume medium

EF_{post} = Energy Factor of new water heater

$Conversion\ Factor$ = 3,412 Btu/kWh

Table 142: Estimated Annual Hot Water Use (gal)

Weather Zone	**Tank Size (gal) of Replaced Water Heater**			
	40	**50**	**65**	**80**
9 Fayetteville	18,401	20,911	25,093	30,111
8 Fort Smith	18,331	20,831	24,997	29,996
7 Little Rock	18,267	20,758	24,910	2,9892
6 El Dorado	17,815	20,245	24,293	2,9152

The values in Table 142 are calculated according to guidance in the Building America Research Benchmark Definition,[143] December 2009, using tank size as a proxy for the number of bedrooms, and incorporating average water main temperatures per weather zone (Table 143). Average water main temperature affects the ratio of hot water (120°F) and "cold water" needed to achieve the end-use water temperature, estimated to be 105°F.

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[143] Available at: www.nrel.gov/docs/fy10osti/47246.pdf.

Table 143: Average Water Main Temperature

Weather Zone	Average Water Main Temperature (°F)
9 Fayetteville	65.6
8 Forth Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

As an example for the current year, the following deemed electricity savings are applicable for a 50-gallon electric storage tank high-efficiency water heater replacement using a model with an EF of 0.95 for a household in weather zone 9 and a medium draw pattern:

$$kWh_{savings} = \frac{8.33 \times 1 \ \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.92} - \frac{1}{0.95}\right)}{3{,}412} = 95.3\ kWh/yr$$

(80)

Demand Savings - Electric Storage Tank Water Heater Replacement

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(81)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.0000877

Demand savings were calculated using the US DOE's *"Building America Performance Analysis Procedures for Existing Homes"* combined domestic hot water use profile.[144] Based on this profile, the ratio of Peak kW to Annual kWh for domestic hot water usage was estimated to be 0.0000877 kW per annual kWh savings.

For the above example, peak demand savings are 95.3 kWh × 0.0000877 = 0.008 kW.

Energy Savings - Electric Tankless Water Heater Replacement

The following deemed savings apply to electric instantaneous (tankless) water heating systems for residential applications. To qualify for deemed savings, a tankless electric water heater must be the sole source of hot water and designed to serve the entire household.

Deemed savings apply to the household, not the unit(s), and are based on the estimated water usage from Table 142 and baseline storage tank Energy Factor from Table 138. In the case of multiple tankless systems being installed, the deemed savings will be based on the least efficient tankless system installed. The Energy Factor accepted as readily available for the best performing tankless electric water heaters is 0.99.[145]

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[144] U.S. DOE *"Building America Performance Analysis Procedures for Existing Homes"* combined domestic hot water use profile.

[145] AHRI Directory: www.ahridirectory.org.

If a tankless water heater (EF = 0.99) were used in the previous example, annual deemed savings would be 280.5 kWh/yr.

$$kWh_{savings} = \frac{8.33 \times 1 \ \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.91} - \frac{1}{0.99}\right)}{3{,}412} = 246.6\ kWh/yr$$

(82)

Demand Savings - Tankless Electric Water Heater Replacement

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(83)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.0000877

For the above tankless water heater example, peak demand savings is 246.6 kWh × 0.0000877 = 0.022 kW.

Calculation of Deemed Savings – Heat Pump Water Heater (HPWH)

Energy Savings – HPWH

The residential heat pump water heater measure involves the installation of an integrated ENERGY STAR® HPWH. The HPWHs available through the ENERGY STAR® product finder[146] have an average EF of 2.75.

The variables affecting deemed savings are: storage tank volume, HPWH Energy Factor (EF), HPWH installation location (in conditioned or unconditioned space), and weather zone. This measure takes into account an air-conditioning energy savings ("Cooling Bonus") and an additional space heating energy requirement ("Heating Penalty") associated with the HPWH when it is installed inside conditioned space.

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \left(\frac{1}{(EF_{post} \times (1 + PA\%)} \times Adj\right)\right)}{3{,}412\ Btu/kWh}$$

(84)

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[146] www.energystar.gov/productfinder/product/certified-water-heaters/ accessed on 6/27/2015.

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal) from Table 142

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average supply water temperature from Table 143

EF_{pre} = Baseline Energy Factor from Table 138

EF_{post} = Energy Factor of new HPWH

$PA\%$ = Performance Adjustment to adjust the HPWH EF relative to ambient air temperature per DOE guidance [147] $= 0.00008 \times T_{amb}^3 + 0.0011 \times T_{amb}^2 - 0.4833 \times T_{amb} + 0.0857$

T_{amb}= Ambient temperature dependent on location of HPWH (Conditioned or Unconditioned Space) and Weather Zone from Table 144

Adj =HPWH-specific adjustment factor to account for Cooling Bonus and Heating Penalty on an annual basis, as well as backup electrical resistance heating which is estimated at 0.92 EF. Adjustment factors are listed in Table 145

$Conversion\ Factor$ = 3,412 Btu/kWh

The average air ambient temperatures listed in Table 144 are applicable to the installation locations for the HPWH. Unconditioned space is considered to be an unheated garage-like environment. This data is based on local ambient temperatures for each weather zone calculated from TMY3 weather data. The conditioned space temperatures assume thermostat settings of 78F (cooling season) and 70F (heating season), and a “balance point temperature”[148] of 65F. Unconditioned space ambient temperatures are adjusted from the local temperatures by seasonal factors[149] to account for a garage-like setting.

Table 144: Average Ambient Temperatures by Installation Location

Weather Zone	Conditioned Space	Unconditioned Space
9 Fayetteville	72.2	69.1
8 Fort Smith	73.4	69.4
7 Little Rock	73.4	71.1
6 El Dorado	72.9	73.3

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[147] Kelso, J. 2003. *Incorporating Water Heater Replacement into The Weatherization Assistance Program*, May. D&R International, Ltd. Information Tool Kit.

[148] “Average daily outside temperature at which a building maintains a comfortable indoor temperature without heating or cooling”; www.weatherdatadepot.com/faq#.USPZwKWvN8E

[149] ASHRAE: Standard 152-2004 Table 6.1b and 6.2b

Table 145: HPWH Adjustment[150]

<table>
<tr><th colspan="6">Weather Zone 9 Fayetteville</th></tr>
<tr><th rowspan="2">Water Heater Location</th><th rowspan="2">Furnace Type</th><th colspan="4">HPWH Tank Size Range (gal)</th></tr>
<tr><th>40</th><th>50</th><th>65</th><th>80</th></tr>
<tr><td rowspan="3">Conditioned Space</td><td>Gas</td><td>1.02</td><td>1.02</td><td>1.03</td><td>1.04</td></tr>
<tr><td>Heat Pump</td><td>1.46</td><td>1.42</td><td>1.37</td><td>1.33</td></tr>
<tr><td>Elec. Resistance</td><td>2.04</td><td>1.94</td><td>1.82</td><td>1.71</td></tr>
<tr><td>Unconditioned Space</td><td>N/A</td><td>1.06</td><td>1.06</td><td>1.06</td><td>1.06</td></tr>
<tr><th colspan="6">Weather Zone 8 Fort Smith</th></tr>
<tr><th rowspan="2">Water Heater Location</th><th rowspan="2">Furnace Type</th><th colspan="4">HPWH Tank Size Range (gal)</th></tr>
<tr><th>40</th><th>50</th><th>65</th><th>80</th></tr>
<tr><td rowspan="3">Conditioned Space</td><td>Gas</td><td>1.02</td><td>1.03</td><td>1.03</td><td>1.04</td></tr>
<tr><td>Heat Pump</td><td>1.43</td><td>1.39</td><td>1.35</td><td>1.31</td></tr>
<tr><td>Elec. Resistance</td><td>1.95</td><td>1.86</td><td>1.75</td><td>1.66</td></tr>
<tr><td>Unconditioned Space</td><td>N/A</td><td>1.06</td><td>1.06</td><td>1.06</td><td>1.06</td></tr>
<tr><th colspan="6">Weather Zone 7 Little Rock</th></tr>
<tr><th rowspan="2">Water Heater Location</th><th rowspan="2">Furnace Type</th><th colspan="4">HPWH Tank Size Range (gal)</th></tr>
<tr><th>40</th><th>50</th><th>65</th><th>80</th></tr>
<tr><td rowspan="3">Conditioned Space</td><td>Gas</td><td>0.99</td><td>1.00</td><td>1.01</td><td>1.02</td></tr>
<tr><td>Heat Pump</td><td>1.41</td><td>1.38</td><td>1.34</td><td>1.30</td></tr>
<tr><td>Elec. Resistance</td><td>1.96</td><td>1.87</td><td>1.76</td><td>1.66</td></tr>
<tr><td>Unconditioned Space</td><td>N/A</td><td>1.07</td><td>1.07</td><td>1.07</td><td>1.07</td></tr>
<tr><th colspan="6">Weather Zone 6 El Dorado</th></tr>
<tr><th rowspan="2">Water Heater Location</th><th rowspan="2">Furnace Type</th><th colspan="4">HPWH Tank Size Range (gal)</th></tr>
<tr><th>40</th><th>50</th><th>65</th><th>80</th></tr>
<tr><td rowspan="3">Conditioned Space</td><td>Gas</td><td>0.95</td><td>0.96</td><td>0.98</td><td>0.99</td></tr>
<tr><td>Heat Pump</td><td>1.34</td><td>1.31</td><td>1.28</td><td>1.25</td></tr>
<tr><td>Elec. Resistance</td><td>1.84</td><td>1.76</td><td>1.66</td><td>1.58</td></tr>
<tr><td>Unconditioned Space</td><td>N/A</td><td>1.07</td><td>1.07</td><td>1.07</td><td>1.07</td></tr>
</table>

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[150] In order to facilitate an algorithmic approach: a spreadsheet model was created which modeled savings accounting for Cooling Bonus and Heating Penalty on an annual basis, as well as backup electrical resistance heating; HPWH Adjustment factors were derived to equate the results of this more extensive model to a simpler algorithm.

As an example, the following deemed electricity savings are applicable for the replacement of a 50-gallon electric storage tank water heater and a medium draw pattern with a 50-gallon heat pump water heater using a model with an EF of 2.75 in conditioned space for a household using a gas furnace in weather zone 9:

$$kWh_{Savings} = \frac{8.33 \times 1 \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.92} - \left(\frac{1}{2.75 \times (1 + 0.01035)} \times 1.02\right)\right)}{3{,}412}$$
$$= 1{,}996.9\ kWh$$

(85)

Demand Savings – HPWH

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(86)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.0000877

For the HPWH example shown in Equation above, peak demand savings is 1,996.9 kWh × 0.0000877 = 0.175 kW.

Calculation of Deemed Savings – Gas Water Heating

Energy Savings – Gas Storage Tank Water Heater Replacement

$$Annual\ Therms_{Savings} = \frac{\rho \times C_p \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{100{,}000\ Btu/therm}$$

(87)

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal per year) from Table 142

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average supply water temperature from Table 143
EF_{pre} = Baseline Energy Factor from Table 138

EF_{post} = Energy Factor of new water heater

For example, deemed savings for replacement of a 50-gallon gas water heater and a medium flow pattern with a high-efficiency gas water heater with EF = 0.70 for a household in weather zone 9 (e.g., Fayetteville) would be:

$$Annual\ Therms_{savings} = \frac{8.33 \times 1\ \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.58} - \frac{1}{0.70}\right)}{100{,}000}$$
$$= 28.0\ therms/yr$$

(88)

Peak Day Therm Savings – Gas Storage Tank Water Heater Replacement

$$Peak\ Therms_{savings} = Annual\ Therm_{savings} * Ratio^{Peak\ Therms}_{Annual\ Therms}$$

(89)

Where:

$Ratio^{Peak\ Therms}_{Annual\ Therms}$ = 0.0024

The ratio of Peak Day Therms to Annual Therms was calculated using the U.S. DOE's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile.[151]

For the example above, peak day therm savings would be 28.0 therms × 0.0024 = 0.067 therms.

Annual Therm Savings - Gas Tankless Water Heater Replacement

The following deemed savings calculation method applies to gas tankless water heating systems for residential applications. To qualify for tankless water heating system deemed savings, the tankless system(s) must be the sole source of hot water and designed to serve the entire household.

Deemed savings apply to the household, not the unit(s), and are based on the assumed water usage and baseline storage tank EFs indicated in the table. In the case of multiple tankless systems being installed, the deemed savings will be based on the least efficient tankless system installed. Indicated Energy Factors correspond to currently available systems listed in the AHRI directory.

$$Annual\ Therms_{Savings} = \frac{\rho \times C_P \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{100{,}000\ Btu/therm}$$

(90)

Where:

ρ = Water density = 8.33 lb/gal

C_P = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal per year) from Table 142

$T_{SetPoint}$ = Water heater set point (default value is 120°F)

T_{Supply} = Average supply water temperature from Tabel 143

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[151] U.S. DOE's *"Building America Performance Analysis Procedures for Existing Homes"* combined domestic hot water use profile. http://www.nrel.gov/docs/fy06osti/38238.pdf.

EF_{pre} = Baseline Energy Factor from Table 138

EF_{post} = Energy Factor of new water heater

The deemed savings for replacement of a 50-gallon gas storage tank water heater by a tankless gas water heater with an EF = 0.82 for a household in weather zone 9 (e.g. Fayetteville) would be:

$$Annual\ Therms_{savings} = \frac{8.33 \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.56} - \frac{1}{0.82}\right)}{100{,}000} = 52.7\ therms/yr$$

(91)

Peak Day Therm Savings – Gas Tankless Water Heater Replacement

$$Peak\ Therms_{savings} = Annual\ Therms_{savings} \times Ratio_{Annual\ Therms}^{Peak\ Therms}$$

(92)

Where:

$Ratio_{Annual\ Therms}^{Peak\ Therms}$ = 0.0024

For the example above, peak day therm savings would be 52.7 therms x 0.0024 = 0.126 therms.

Calculation of Deemed Savings – Solar Water Heating with Gas or Electric Backup

Energy Savings – Solar Water Heating Systems with Electric Backup

The residential solar water heater measure involves the installation of an ENERGY STAR® certified solar water heater rated by the Solar Rating and Certification Corporation (SRCC). Solar water heaters available through the ENERGY STAR® product finder[152] have an average Solar Energy Factor (SEF) of 8.7 for electric backup and 1.9 for gas backup.

The variables affecting deemed savings are: SEF and weather zone.

The SRCC determines SEF based on standardized 1,500 Btu/ft^2-day solar radiation profile across the U.S. As solar insolation varies widely depending on geographic location, in order to derive more accurate estimates for a given locale, Localization Factors (LF) are used to adjust the SEF. LFs for the four Arkansas weather zones have been calculated. The LFs (Table 147) are based on the daily total insolation (Table 146), averaged annually, per a Satellite Solar Radiation model developed by the State University of New York (SUNY).

$$kWh_{Savings} = \frac{\rho \times C_p \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{SEF\ x\ LF}\right)}{3412\ Btu/kWh}$$

(93)

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[152] www.energystar.gov/productfinder/product/certified-water-heaters/results

Where:

ρ = Water density = 8.33 lb/gal

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal) from Table 142

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average supply water temperature from Table 143

EF_{pre} = Baseline Energy Factor from Table 138

SEF = Solar Energy Factor of new water heater

LF = Localization Factor for SEF of new water heater Table 147

Table 146: Annual Average Daily Total Insolation[153]

Weather Zone	Daily Total Insolation (BTU/ft2/day)
9 Fayetteville	1,591
8 Forth Smith	1,597
7 Little Rock	1,579
6 El Dorado	1,601

Table 147: AR Weather Zone Localization Factor (LF) for SEF

Weather Zone	LF for SEF
9 Fayetteville	1.06
8 Forth Smith	1.06
7 Little Rock	1.05
6 El Dorado	1.07

As an example, the following deemed electricity savings are applicable for replacement of a 50-gallon electric storage tank water heater and medium draw pattern with a 50-gallon solar water heater with electric backup using a model with an EF of 8.7 for a household in weather zone 9:

$$kWh_{Savings} = \frac{8.33 \times 1 \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.92} - \frac{1}{(8.7\ \times\ 1.06)}\right)}{3{,}412\ Btu/kWh}$$
$$= 2{,}715.3\ kWh/yr$$

(94)

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[153] SUNY Satellite Solar Radiation model (Perez, et. al., 2002).

Demand Savings – Solar Water Heating Systems with Electric Backup

$$kW_{savings} = kWh_{savings} \times Ratio \frac{Peak\ kW}{Annual\ kWh}$$

(95)

Where:

$Ratio \frac{Peak\ kW}{Annual\ kWh}$ = 0.0000877

For the above example, peak demand savings is 2,715.3 kWh x 0.0000877 = 0.238 kW.

Energy Savings –Solar Water Heating Systems with Gas Backup

$$Therm_{Savings} = \frac{\rho \times C_P \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{SEF\ x\ LF}\right)}{100{,}000\ Btu/therm}$$

(96)

Where:

ρ = Water density = 8.33 lb/gal.

C_p = Specific heat of water = 1 BTU/lb·°F

V = Estimated annual hot water use (gal) from Table 142

$T_{SetPoint}$ = Water heater set point (default value = 120°F)

T_{Supply} = Average supply water temperature from Table 143

EF_{pre} = Baseline Energy Factor from Table 138

SEF = Solar Energy Factor of new water heater

LF = Localization Factor for SEF of new water heater Table 147

The deemed gas savings applicable for replacement of a 50-gallon gas storage tank water heater and a medium draw pattern with a 50-gallon solar water heater with gas backup using a model with an EF of 1.9 for a household in weather zone 9:

$$Annual\ Therms_{Savings} = \frac{8.33 \times 1 \times 20{,}911 \times (120 - 65.6) \times \left(\frac{1}{0.56} - \frac{1}{(1.9\ \times\ 1.06)}\right)}{100{,}000\ Btu/therm}$$
$$= 121.2\ therms/yr$$

(97)

Demand Savings – Solar Water Heating Systems with Gas Backup

$$Peak\ Therms_{savings} = Annual\ Therms_{savings} \times Ratio_{Annual\ Therms}^{Peak\ Therms}$$

(98)

Where:

$Ratio_{Annual\ Therms}^{Peak\ Therms}$ = 0.0024

The ratio of Peak Day Therms to Annual Therms was calculated using the same method described for electricity demand savings and calculated to be 0.0024 peak day therm savings per annual therm savings.

For the example above, peak day therm savings would be 121.2 therms x 0.0024 = 0.291 therms.

2.3.2 Water Heater Jackets

Measure Description

This measure involves water heater jackets (WHJ) installed on water heaters located in an unconditioned space. These estimates apply to all weather regions. This measure applies to all residential applications.

Baseline and Efficiency Standards

Baseline is assumed to be the post-1991, storage-type water heater.

WHJ must be installed on storage water heaters having a capacity of 30 gallons or greater. The manufacturer's instructions on the WHJ and the water heater itself should be followed. If electric, thermostat and heating element access panels must be left uncovered. If gas, follow WHJ installation instructions regarding combustion air and flue access.

Table 148: Water Heater Jackets – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Uninsulated water heater	Minimum insulation of R-6.7

Estimated Useful Life (EUL)

The average lifetime of this measure is 13 years, according to NEAT v. 8.6.

Deemed Savings Values

Deemed savings are per installed jacket based on the jacket thickness, the type of water heating and the tank size.

Table 149: Water Heater Jackets – Electric Heating Deemed Savings Values

	Electric Water Heating					
Approximate Tank Size (gal)	kWh Savings			kW Savings		
	40	52	80	40	52	80
2" WHJ savings kWh	68	76	101	0.005	0.006	0.008
3" WHJ savings kWh	94	104	139	0.007	0.008	0.011

Table 150: Water Heater Jackets – Gas Heating Deemed Savings Values

	Gas Water Heating					
Approximate Tank Size (gal)	Therms Savings			Peak Therms		
	30	40	50	30	40	50
2" WHJ savings Therms	3.38	3.96	4.41	0.006	0.007	0.008
3" WHJ savings Therms	4.67	5.46	6.09	0.009	0.010	0.011

Calculation of Deemed Savings

Energy consumption for baseline units, with and without insulation jackets, was calculated using industry-standard energy-use calculation methodologies for residential domestic water heating. Variables in the calculations include the following:

- Water heater fuel type (electric or gas/propane)
- Baseline EF
- Estimated U-value of baseline unit
- Ambient temperature
- Tank volume
- Tank surface area
- Tank temperature
- Estimated hot water consumption

To estimate peak energy consumption, a load profile for residential water heating was developed from individual load profiles for the following end-uses:

- Clothes washer
- Dishwasher
- Faucet
- Shower
- Sink-filling
- Bath
- Miscellaneous

This end-use load shape data was calibrated using metered end-used data obtained from several utility end-use metering studies.

2.3.3 Water Heater Pipe Insulation

Measure Description

This measure requires water heater pipe insulation. Water heaters plumbed with heat traps are not eligible to receive incentives for this measure. New construction and water heater retrofits are not eligible for this measure, because they must meet current code requirements. This measure applies to all residential applications.

Baseline and Efficiency Standards

Baseline is assumed to be the typical gas or electric water heater with no heat.

All hot and cold vertical lengths of pipe should be insulated, plus the initial length of horizontal hot and cold water pipe, up to three feet from the transition, or until wall penetration, whichever is less.

Table 151: Water Heater Pipe Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Uninsulated hot water pipes	Minimum insulation thickness of ½”

Estimated Useful Life (EUL)

The average lifetime of this measure is dependent on the type of water heater it is applied to. According to DEER 2008, the following measure lifetimes should be applied:

- 13 years for electric storage water heating
- 11 years for gas storage water heating
- 10 years for heat pump water heaters

Calculation of Deemed Savings

Energy Savings – Water Heater Pipe Insulation for Electric, Gas, or Heat Pump Water Heater (HPWH)

$$\begin{aligned} &Annual\ Energy\ Savings \\ &= \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient}\right) \times \left(\frac{1}{RE}\right) \times \frac{Hours_{Total}}{Conversion\ Factor} \end{aligned}$$

(99)

Where:

U_{pre}= 1/(2.03[154]) = 0.49 BTU/h sq. ft. degree F

U_{post}= 1/(2.03+$R_{Insulation}$)

$R_{Insulation}$= R-value of installed insulation

A = Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

T_{Pipe}(°F) = Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambient}$(°F) = See Table 152; use 78°F if installed in conditioned space

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 0.79 for natural gas water heaters, or 2.2 for heat pump water heaters[155]

$Hours_{Total}$ = 8,760 hr per year[156,157]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

Table 152: Average Ambient Temperature by Weather Zone

Weather Zone	Average Ambient Temperature (°F)
9 Fayetteville	59.6
8 Forth Smith	60.1
7 Little Rock	61.8
6 El Dorado	64.1

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[154] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe and between the surface and air. Mark's Standard Handbook for Mechanical Engineers, 8th edition.

[155] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

[156] Ontario Energy's Measures and Assumptions for Demand Side Management (DSM) Planning www.ontarioenergyboard.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[157] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Residential, Multi-Family, and Commercial/Industrial Measures http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/06f2fee55575bd8a852576e4006f9af7/$FILE/TechManualNYRevised10-15-10.pdf

For example, deemed savings for water heater pipe insulation with an R-value of 3 installed on an electric water heater in Zone 8 would be:

$$kWh_{savings} = (0.49 - 0.20) \times 2.1 \times (90 - 60.1) \times \left(\frac{1}{0.98}\right) \times \frac{8{,}760}{3{,}412} = 48\ kWh/yr$$

(100)

Demand Savings

Peak demand savings for hot water heaters installed in conditioned space can be calculated using the following formula for electric:

$$kW_{savings} = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambientMAX}\right) \times \left(\frac{1}{RE}\right) \times \frac{1}{3{,}412\ Btu/kWh}$$

(101)

Where:

U_{pre} = 1/(2.03) =0.49 BTU/h sq ft degree F

U_{post} = 1/(2.03+$R_{Insulation}$)

$R_{Insulation}$ = R-value of installed insulation

A = Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

T_{Pipe}(°F) = Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambientMAX}$(°F) =For water heaters installed in unconditioned basements, use an average ambient temperature of 75°F; for water heaters inside the thermal envelope, use an average ambient temperature of 78 °F

RE = Recovery efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance or 2.2 for heat pump water heaters

Table 153: Maximum and Minimum Temperatures per Weather Zone

Weather Zone	Ambient Temperature (°F)			
	$T_{ambientMAX}$ (Electric)		$T_{ambientMIN}$ (Gas)	
	Conditioned Space	Unconditioned Basement[158]	Conditioned Space	Unconditioned Space
9 Fayetteville	78	75	70	4.3
8 Fort Smith	78		70	13.5
7 Little Rock	78		70	12.1
6 El Dorado	78		70	27.8

For gas, peak day demand savings can be calculated using the following formula:

$$Peak\ Therms_{savings} = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient,MIN}\right) \times \left(\frac{1}{RE_t}\right) \times \frac{1}{100{,}000\ Btu/therm} \times 24\ hrs/day \tag{102}$$

Where:

U_{pre} = 1/(2.03) = 0.49

U_{post} = 1/(2.03+$R_{Insulation}$)

$R_{Insulation}$= R-value of installed insulation

A = Surface Area in square feet (for a length of pipe = $2\pi rL$) with L and r in feet

T_{Pipe}(°F) =Average temperature of the pipe; default value = 90°F (average temperature of pipe between water heater and the wall)

$T_{ambientMIN}$(°F) =For water heaters not installed in conditioned space, use the minimum annual ambient temperatures in Table 153; for water heaters inside the building envelope, use the conditioned space temperature of 70°F

RE = Recovery efficiency; if unknown, use 0.77 as a default

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[158] Unconditioned basement temperature calculated from ground temperature data for Arkansas using data from the National Resource Conservation Service http://www.wcc.nrcs.usda.gov/scan/. We took an average of the last 30 Day Daily Table at a depth of 40inches for the representative sites in Arkansas.

2.3.4 Faucet Aerators

Measure Description

This measure involves retrofitting aerators on kitchen and bathroom water faucets. The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable. This measure applies to all residential applications.

Baseline and Efficiency Standards

The 2.2 gpm baseline faucet flow rate[159] is based upon a settlement agreement among the parties in the energy efficiency project before the Arkansas Public Service Commission, Docket 10-100-R, submitted February 22, 2012. The US EPA WaterSense® specification for faucet aerators is 1.5 gallons per minute (gpm).[160]

Table 154: Faucet Aerators – Baseline and Efficiency Standards

Baseline	Efficiency Standard
2.2 gpm	1.5 gpm maximum

The deemed savings values are for residential, retrofit-only installation of kitchen and bathroom faucet aerators.

Additional Requirement for Contractor-Installed Aerators

Aerators that have been defaced so as to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Estimated Useful Life (EUL)

The average lifetime of this measure is 10 years, according to DEER 2008.

Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the four Arkansas weather zones are shown in Table 155. The water main temperature data was approximated using the following formula.[161]

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb} \tag{103}$$

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[159] Maximum flow rate federal standard for lavatories and aerators set in Federal Energy Policy Act of 1992 and codified at 2.2 GPM at 60 psi in 10CFR430.32

[160] "High-Efficiency Lavatory Faucet Specification." WaterSense. EPA. October 1, 2007. http://www.epa.gov/watersense/partners/faucets_final.html

[161] Burch, J & Christensen, C. 2007. "*Towards Development of an Algorithm for Mains Water Temperature.*" Proceedings of the 2007 ASES Annual Conference, Cleveland, OH.

Where:

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature

$R = 0.05$

ΔT_{amb} = the average of maximum and minimum ambient air dry bulb temperature for the month $(T_{max} + T_{min})/2$ where T_{max} = maximum ambient dry bulb temperature for the month, and T_{min} = minimum ambient dry bulb temperature for the month

Table 155: Average Water Main Temperature by Weather Zone

Weather Zone	Average Ambient Temperature (°F)
9 Fayetteville	65.6
8 Forth Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.[162, 163, 164]

Estimated Hot Water Usage Reduction

$$Water\ consumption = \frac{\frac{Faucet\ Use\ per\ Person}{Day} \times Occupants\ per\ Home \times \frac{365\ Days}{Year}}{Faucets\ per\ Home}$$

(104)

Applying the formula to the values used for Arkansas from Table 156 returns the following values for baseline and post water consumption.

Baseline (2.2 gpm): 9.7 x 2.69 x 365 / 3.86 = 2,467

Post (1.5 gpm): 8.2 x 2.69 x 365 / 3.86 = 2,086

Post (1.0 gpm): 7.2 x 2.69 x 365 / 3.86 = 1,831

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[162] Seattle Home Water Conservation Study, 2000. *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes."* December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle%20Home%20Water%20Conservation%20Study

[163] Residential Indoor Water Conservation Study, 2003 "*Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area.*" July. www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868

[164] Tampa Water Department Residential Water Conservation Study, 2004, *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes."* January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

Gallons of water saved per year can be found by subtracting the post consumption in gallons per year per aerator from the baseline consumption.

Gallons of water saved per year (1.5 gpm): 2,467 – 2,086 = 381

Gallons of water saved per year (1.0 gpm): 2,467 – 1,831 = 636

Table 156: Estimated Aerator Hot Water Usage Reduction

Assumption Type	Seattle Study[165]	Tampa Study[166]	East Bay Study	Average	Value used for Arkansas
Faucet use gallons/person/day (baseline)	9.2	9.4	10.5	9.7	9.7
Faucet use gallons/person/day (1.5 gpm)	8.0	6.2	10.5	8.2	8.2
Faucet use gallons/person/day (1.0 gpm)[167]	--	--	--	--	7.2
Occupants per home[168][2]	2.54	2.92	2.56	2.67	2.69
Faucets per home[169][3]	--	--	--	--	3.86
Gal./yr./faucet (baseline)	--	--	--	--	2,467
Gal./yr./faucet (1.5 gpm)	--	--	--	--	2,086
Gal./yr./faucet (1.0 gpm)	--	--	--	--	1,831
Percent hot water	76.10%[4]	Not listed	57.60%[5]	66.90%	66.9%
Water gallons saved/yr./faucet (1.5 gpm)	--	--	--	--	381
Water gallons saved/yr./faucet (1.0 gpm)	--	--	--	--	636

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[165] Average of pre-retrofit percent faucet hot water 72.7% on page 35, and post-retrofit percent faucet hot water 79.5% on page 53.

[166] Average of pre-retrofit percent faucet hot water 65.2% on page 31 and post-retrofit faucet hot water percentage 50.0% on page 54.

[167] This value is a linear extrapolation of gallons per person per day from the baseline (2.2 gpm) and the 1.5 gpm case.

[168] Occupants per home for Arkansas from 2009 Residential Conservation Survey, Table HC9.10.

[169] Faucets per home assumed to be equal to one plus the number half bathrooms and full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Based on the average percentage hot water shown in Table 156, the average mixed water temperature across all weather zones was determined. The hot water temperature was assumed to be 120°F.[170] The mixed water temperature used in the energy savings calculation can be seen in Table 157.

Table 157: Mixed Water Temperature Calculation

Weather Zone	Average Water Main Temperature (°F)	Percent Hot Water	Mixed Water Temperature (°F)
9 Fayetteville	65.6	66.9%	102.0
8 Fort Smith	66.1	66.9%	102.2
7 Little Rock	67.8	66.9%	102.7
6 El Dorado	70.1	66.9%	103.5
Average for Arkansas (T_{Mixed})			**102.6**

Calculation of Deemed Savings

Energy Savings – Faucet Aerators

$$Annual\ Energy\ Savings = \frac{\rho \times C_P \times V \times (T_{Mixed} - T_{Supply}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor} \tag{105}$$

Where:

ρ = Water density = 8.33 lb/gal

C_P = Specific heat of water = 1 BTU/lb·°F

V = gallons of water saved per year per faucet from Table 156

T_{Mixed} = Mixed water temperature, 102.6°F, from Table 157 (average for Arkansas)

T_{Supply} = Average supply water temperature (Water Main Temperature from Table 155)

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters[171]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

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[170] Review of water heater information from Rheem and GE shows that most water heaters are usually at the factory setting of 120°F. Note that the temperature of the water at faucet is likely to be lower, due to thermal losses in the water pipe system within the home, and tempering of the water temperature by the user.

[171] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/rwh/defaultSearch.aspx

Demand Savings – Faucet Aerators

Demand savings for homes with electric water heating were calculated using the following formula:

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(106)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.000104

This value is taken from the DOE domestic hot water use study.[172] The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower bath, and sink hot water use. An average was calculated using peak hours of 3 PM to 6 PM to generate an average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.

For homes with gas water heaters, peak day therm savings were calculated as follows:

$$Peak\ Therms_{savings} = Annual\ Therm\ _{savings} \times Ratio_{Annual\ Therms}^{Peak\ Therms}$$

(107)

Where:

$Ratio_{Annual\ Therms}^{Peak\ Therms}$= 0.003

This value is based on DOE's Domestic Hot Water Event Schedules.[173] The ratio was developed by identifying the coldest average water main temperature day for the year. Then the corresponding hot water consumption for that day was used to calculate a ratio related to annual therms consumption.

As an example, the expected energy savings for an aerator replacement in Weather Zone 9 (e.g., Fayetteville) are shown in Table 158.

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[172] U.S. DOE's 2006. "*Building America Performance Analysis Procedures for Existing Homes". National Renewable Energy Laboratory*. May. http://www.nrel.gov/docs/fy06osti/38238.pdf (See Figure 3, page 17.) This TRM looked at hourly share of daily water use at 3pm 4pm, 5pm, and 6pm in Figure 3. The fractions of hourly use derived were 0.022 for 3pm, 0.03 for 4pm, 0.04 for 5pm, and 0.06 for 6pm. The average of these fractions is 0.038, which is the average share of daily water use that falls on a peak hour per day. Dividing that value by 365 days calculates a ratio of 0.000104 as the ratio of peak share to annual use.

[173] Burch, J. & Hendron, R. 2007, U.S. DOE "*Development of Standardized Domestic Hot Water Event Schedules for Residential Builders*, June. www.nrel.gov/docs/fy08osti/40874.pdf

Example Calculation of Deemed Savings Values

Deemed savings values are per faucet aerator installed.

Table 158: Example, Replacing 2.2 gpm with 1.5 gpm Faucet Aerator - Deemed Energy and Demand Savings

Faucet Aerator, Fayetteville Weather Zone			
Water Usage Reduction (gal)	381		
T_{Supply}	65.6°F		
T_{Mixed}	102.6°F		
Water heater RE (excluding standby losses)	0.98 (Electric) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 35 kWh	Heat Pump: 14 kWh	Gas: 1.46 Therms
Demand Savings	Electric: 0.004 kW	Heat Pump: 0.001 kW	Gas: 0.004 Peak Day Therms

2.3.5 Low-Flow Showerheads

Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline average flow rate of the existing stock of showerheads is based on the current US DOE standard.

The incentive is for replacement of an existing showerhead with a new showerhead rated at 2.0, 1.75 or 1.5 gallons per minute (gpm). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

Additional Requirement for Contractor-Installed Showerheads

Existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Table 159: Low-Flow Showerhead – Baseline and Efficiency Standards

Measure	New Showerhead Flow Rate[174] (gpm)	Existing Showerhead Baseline Flow Rate (gpm)
2.0 gpm showerhead	2.0	2.5
1.75 gpm showerhead	1.75	2.5
1.5 gpm showerhead	1.5	2.5

The U.S. Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 gpm. http://www1.eere.energy.gov/femp/program/waterefficiency_bmp7.html

Estimated Useful Life (EUL)

The average lifetime of this measure is 10 years, according to DEER 2008.

Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the four Arkansas weather zones are shown in Table 160. The water main temperature data was approximated using the following formula.[175]

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

(108)

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[174] All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

[175] Burch, J. & Christensen, C. 2007. *"Towards Development of an Algorithm for Mains Water Temperature"* Proceedings of the 2007 ASES Annual Conference, Cleveland, OH.

Where:

$R = 0.05$

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature

ΔT_{amb} = the average of maximum and minimum ambient air dry bulb temperature for the month $(T_{max} + T_{min})/2$ where T_{max} = maximum ambient dry bulb temperature for the month and T_{min} = minimum ambient dry bulb temperature for the month

Table 160: Average Water Main Temperature by Weather Zone

Weather Zone	Average Water Main Temperature (°F)
9 Fayetteville	65.6
8 Fort Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

Estimated Hot Water Usage Reduction

Baseline and efficiency standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.[176,177,178] See Table 156 for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\frac{Gallons}{Shower} \times \frac{Showers\ per\ Person}{Day} \times \frac{365\ Days}{Year} \times \frac{Occupants\ per\ Home}{Showerheads\ per\ Home}$$

(109)

Applying the formula to the values for Arkansas from Table 156 returns the following baseline and post water consumption.

Baseline (2.5 gpm): 20.7 x 0.69 x 365 x 2.69 / 1.62 = 8,657

Post (2.0 gpm): 16.5 x 0.72 x 365 x 2.69 / 1.62 = 7,200

Post (1.5 gpm): 12.4 x 0.72 x 365 x 2.69 / 1.62 = 5,411

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[176] Seattle Home Water Conservation Study, 2000. *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes."* December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle Home Water Conservation Study

[177] Residential Indoor Water Conservation Study, 2003. "*Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area."* July. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868

[178] Tampa Water Department Residential Water Conservation Study, 2004, *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes,"* January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

Although the referenced studies do not provide data on 1.75 gpm showerheads, the consumption values for 2.5, 2.0, and 1.5 gpm roughly follow a linear pattern. Taking a simple average of the consumption for 2.0 and 1.5 gpm showerheads returns a value for a 1.75 gpm showerhead:

$$\text{Post (1.75 gpm)}: (7{,}200 + 5{,}411) / 2 = 6{,}306$$

Gallons of water saved per year can be found by subtracting the post consumption in gallons per year per showerhead from the baseline consumption. These values are also in Table 161.

Gallons of water saved per year (2.0 gpm): (8,657 – 7,200) = 1,457

Gallons of water saved per year (1.75 gpm): (8,657 – 6,306) = 2,351

Gallons of water saved per year (1.5 gpm): (8,657 – 5,411) = 3,246

Table 161: Estimated Showerhead Hot Water Usage Reduction

Assumption Type	Seattle Study[179]	Tampa Study	East Bay Study[180]	Average	Value used for Arkansas
Gallons/shower @ 2.5 gpm (baseline)	19.8	20.0	22.3	20.7	20.7
Gallons/shower @ 2.0 gpm	15.8	16.0	17.8	16.5	16.5
Gallons/shower @ 1.5 gpm	11.9	12.0	13.4	12.4	12.4
Showers/person/day (baseline)	0.51	0.92	0.65	0.69	0.69
Showers/person/day (post)	0.59	0.82	0.74	0.72	0.72
Occupants per home[181]	2.54	2.92	2.56	2.67	2.69
Showerheads per home[182]	not listed	not listed	not listed	not listed	1.62
Water gal./yr./showerhead @ 2.0 gpm saved	not listed	not listed	not listed	not listed	1,457
Water gal./yr./showerhead @ 1.75 gpm saved	not listed	not listed	not listed	not listed	2,351
Water gal./yr./showerhead @ 1.5 gpm saved	not listed	not listed	not listed	not listed	3,246
Percent hot water	74.3%[3]	not listed	66%[4]	70.1%	70.1%

Based on the average percentage hot water shown in Table 161, the average mixed water temperature across all weather zones was determined. The hot water temperature was assumed to be 120°F.[183] The mixed water temperature used in the energy savings calculation can be seen in Table 162.

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[179] Seattle Study: Average of pre-retrofit percent shower hot water 73.1% on page 35, and post-retrofit percent shower hot water 75.5% on p. 53.

[180] East Bay Study: Average of pre-retrofit percent shower hot water 71.9% on page 31 and post-retrofit shower hot water percentage 60.0% on p. 54.

[181] Occupants per home for Arkansas from 2009 Residential Conservation Survey, Table HC9.10

[182] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

[183] Review of water heater information from Rheem and GE shows that most water heaters are usually at the factory setting of 120°F. Note that the temperature of the water at faucet is likely to be lower, due to thermal losses in the water pipe system within the home, and tempering of the water temperature by the user.

Table 162: Mixed Water Temperature Calculation

Weather Zone	Average Water Main Temperature (°F)	Percent Hot Water	Mixed Water Temperature (°F)
9 Fayetteville	65.6	70.1%	103.7
8 Fort Smith	66.1	70.1%	103.9
7 Little Rock	67.8	70.1%	104.4
6 El Dorado	70.1	70.1%	105.1
Average for Arkansas (T_{Mixed})			**104.3**

Calculation of Deemed Savings

Energy Savings

$$Annual\ Energy\ Savings = \frac{\rho \times C_P \times V \times \left(T_{Mixed} - T_{Supply}\right) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor}$$

(110)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 BTU/lb·°F

V = 2.0, 1.75, or 1.5 gpm showerhead water gallons saved per year (from Table 161)

T_{Mixed} = Mixed water temperature, 104.3°F, from Table 162 (average for Arkansas)

T_{Supply} = Average supply water temperature (water main temperature), see Table 160

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters[184]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

Demand Savings

Demand savings were calculated using the US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes"[185] combined domestic hot water use profile which resulted in a ratio of 0.000104 Peak kW to Annual kWh. The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower, bath, and sink hot water use. An average was calculated using peak hours of 3pm to 6pm to generate an

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[184] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH

[185] U.S. DOE's 2006, *"Building America Performance Analysis Procedures for Existing Homes"*. National Renewable Energy Laboratory. May. www.nrel.gov/docs/fy06osti/38238.pdf

average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.[186]

$$kW_{savings} = kWh_{\ savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(111)

Peak Day Therm Savings

The peak day therm ratio was calculated using the US Department of Energy Domestic Hot Water Event Schedules.[187] The ratio was developed by identifying the coldest average water main temperature day for the year. Then the corresponding hot water consumption for that day (0.361 therms) was used to calculate a ratio related to annual therm consumption (105 therms). The resulting ratio was 0.003 Peak Day Therms to Annual Therms (0.361 coldest main temperature therms ÷ 105 annual therms = 0.003 therms savings ratio).

$$Peak\ Therms_{savings} = Annual\ Therms_{savings} \times Ratio_{Annual\ Therms}^{Peak\ Therms}$$

(112)

The expected energy and demand savings for a showerhead replacement in Weather Zone 9 (e.g. Fayetteville) is shown below. This table is provided merely as an *example*.

Example Calculation of Deemed Savings Values

Table 163: Example, 2.0, 1.75, and 1.5 GPM Showerhead Retrofit Deemed Energy Savings

2.0 GPM Showerhead, Fayetteville Weather Zone			
Water gal. saved /year/showerhead @ 2.0 gpm	1,457		
T_{Supply}	65.6°F		
T_{Mixed}	104.3°F		
Water heater RE	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 140 kWh	Heat Pump: 57 kWh	Gas: 5.9 Therms
Demand Savings	Electric: 0.015kW	Heat Pump: 0.006 kW	Gas: 0.018 Day Therms
1.75 GPM Showerhead, Fayetteville Weather Zone			
Water gal. saved /year/showerhead @ 1.75 gpm	2,351		
T_{Supply}	65.6°F		
T_{Mixed}	104.3°F		

---

[186] At 3pm, the hourly share of daily water use is 0.022, at 4pm is 0.03, at 5pm is 0.04, and at 6pm is 0.06. The average of these values is 0.038. Divided by 365 days, the result is a 0.000104 ratio of peak share to annual use.

[187] Burch, J. & Hendron, R. 2007, U.S. DOE, 2007. *Development of Standardized Domestic Hot Water Event Schedules for Residential Builders*. June. www.nrel.gov/docs/fy08osti/40874.pdf

1.75 GPM Showerhead, Fayetteville Weather Zone			
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 227 kWh	Heat Pump: 93 kWh	Gas: 9.6 Therms
Demand Savings	Electric: 0.024 kW	Heat Pump: 0.010 kW	Gas: 0.029 Peak Therms
1. 5 GPM Showerhead, Fayetteville Weather Zone			
Water gal. saved /year/showerhead @ 1.5 gpm	3,246		
T_{Supply}	65.6°F		
T_{Mixed}	104.3°F		
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 313 kWh	Heat Pump: 128 kWh	Gas: 13.2 Therms
Demand Savings	Electric: 0.033 kW	Heat Pump: 0.013 kW	Gas: 0.040 Peak Therms

2.3.6 Showerhead Thermostatic Restrictor Valve

Measure Description

This measure consists of installing a thermostatic restrictor valve (TRV) between the existing shower arm and showerhead. The valve will reduce behavioral water waste by restricting water flow when the water reaches a set temperature (generally 95˚F). Restricting the flow when the water reaches the temperature set point, reduces the amount of water that goes down the drain prior to the user entering the shower.

Baseline and Efficiency Standards

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a thermostatic restrictor valve installed.

To qualify for thermostatic restrictor valve deemed savings, the installed equipment must be a thermostatic restrictor valve installed on a residential showerarm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-Flow Showerheads measure and claim additional savings as outlined in that measure.

Estimated Useful Life (EUL)

The average lifetime of this measure is 10 years, according to DEER 2008.

This value is consistent with the EUL reported for a low-flow showerhead in the DEER 2014.[188]

Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the four Arkansas weather zones are shown in Table 164. Table 160 The water main temperature data was approximated using the following formula.[189]

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

(113)

Where:

$R = 0.05$

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature

ΔT_{amb} = the average of maximum and minimum ambient air dry bulb temperature for the month $(T_{max} + T_{min})/2$ where T_{max} = maximum ambient dry bulb temperature for the month and T_{min} = minimum ambient dry bulb temperature for the month

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[188] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

[189] Burch, J. & Christensen, C. 2007. *"Towards Development of an Algorithm for Mains Water Temperature"* Proceedings of the 2007 ASES Annual Conference, Cleveland, OH.

Table 164: Average Water Main Temperature by Weather Zone

Weather Zone	Average Water Main Temperature (°F)
9 Fayetteville	65.6
8 Fort Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

Estimated Hot Water Usage Reduction

Baseline and efficiency standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.[190,191,192]

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

(114)

Where:

SHFR = Showerhead flow rate, gallons per minute (gpm) (see Table 165)

BW = Behavioral waste, minutes per shower (see Table 165)

n_S = Number of showers per person per day (see Table 165)

365 = Constant to convert days to years (see Table 165)

n_O = Number of occupants per home (see Table 165)

n_{SH} = Number of showerheads per home (see Table 165)

Applying the formula to the values used for Arkansas from Table 165 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM): 2.5 \times\ 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 742\ gal$$

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[190] Seattle Home Water Conservation Study, 2000. *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes."* December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle Home Water Conservation Study

[191] Residential Indoor Water Conservation Study, 2003. "*Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area."* July. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868

[192] Tampa Water Department Residential Water Conservation Study, 2004, *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes,"* January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

$$Showerhead\ (2.0\ GPM): 2.0 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 594\ gal$$

$$Showerhead\ (1.75\ GPM): 1.75 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 520\ gal$$

$$Showerhead\ (1.5\ GPM): 1.5 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 445\ gal$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 165.

$$Gallons\ of\ hot\ water\ saved\ per\ year = Annual\ Behavioral\ Waste \times HW\% \tag{115}$$

Where:

HW% = Hot water percentage (see Table 165)

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 742 \times 0.825 = 613\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 594 \times 0.825 = 490\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 520 \times 0.825 = 429\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 445 \times 0.825 = 368\ gal$$

Table 165: Estimated Showerhead with TRV Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower)[193]	0.783	0.783	0.783	0.783
Showers/person/day[194]	0.69	0.69	0.69	0.69
Occupants per home[195]	2.53	2.53	2.53	2.53
Showerheads per home[196]	1.68	1.68	1.68	1.68
Gallons behavioral waste per showerhead per year	**742**	**594**	**520**	**445**
Percent hot water[197]	82.5%	82.5%	82.5%	82.5%
Gallons hot water saved per year	**613**	**490**	**429**	**368**

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[193] Average behavioral waste from Lutz (2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and Sherman (2014) Disaggregating Residential Shower Warm-Up Waste. Derived by dividing 47 seconds by 60 seconds.

[194] Derivation of value for showers per person per day defined in the Low Flow Showerhead measure, Table 156: Estimated Showerhead Hot Water Usage Reduction

[195] Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2011-2015." Accessed June 2017. https://www.census.gov/quickfacts/fact/map/AR,US#viewtop

[196] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

[197] Average percent hot water from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

Calculation of Deemed Savings

Energy Savings

$$Annual\ Energy\ Savings = \frac{\rho \times C_P \times V \times \left(T_{Setpoint} - T_{SupplyAverage}\right)}{\mathrm{RE} \times Conversion\ Factor}$$

(116)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 BTU/lb·°F

V = Gallons of hot water saved per year per shower head, see Table 165

$\mathrm{T}_{\mathrm{SetPoint}}$ = Hot water temperature, assumed to be 120°F

$T_{SupplyAverage}$ = Average supply water temperature (Water main temperature), see Table 160

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters[198]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

Demand Savings

Demand savings were calculated using the US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes"[199] combined domestic hot water use profile which resulted in a ratio of 0.000104 Peak kW to Annual kWh. The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower, bath, and sink hot water use. An average was calculated using peak hours of 3pm to 6pm to generate an average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.[200] Note: peak gas saving are not calculated for this measure.

$$kW_{savings} = kWh_{\ savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(117)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.000104[201]

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[198] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH

[199] U.S. DOE's 2006, *"Building America Performance Analysis Procedures for Existing Homes"*. National Renewable Energy Laboratory. May. www.nrel.gov/docs/fy06osti/38238.pdf

[200] At 3pm, the hourly share of daily water use is 0.022, at 4pm is 0.03, at 5pm is 0.04, and at 6pm is 0.06. The average of these values is 0.038. Divided by 365 days, the result is a 0.000104 ratio of peak share to annual use.

[201] US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The expected energy and demand savings for installing a showerhead TRV in Weather Zone 7 (e.g. Little Rock) are shown. This table is provided merely as an *example*.

Example Calculation of Deemed Savings Values

Table 166: Example, 2.0, 1.75, and 1.5 GPM Showerhead TRV Deemed Energy Savings

2.0 GPM Showerhead, Little Rock Weather Zone			
Behavioral Water gal. saved /year/showerhead @ 2.0 gpm	490		
$T_{SupplyAverage}$	67.8°F		
$T_{SetPoint}$	120°F		
Water heater RE	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 63.7 kWh	Heat Pump: 28.4 kWh	Gas: 2.7 Therms
Demand Savings	Electric: 0.007 kW	Heat Pump: 0.003 kW	Gas: N/A
1.75 GPM Showerhead, Little Rock Weather Zone			
Behavioral Water gal. saved /year/showerhead @ 1.75 gpm	429		
$T_{SupplyAverage}$	67.8°F		
$T_{SetPoint}$	120°F		
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 55.8 kWh	Heat Pump: 24.8 kWh	Gas: 2.4 Therms
Demand Savings	Electric: 0.006 kW	Heat Pump: 0.003 kW	Gas: N/A
1. 5 GPM Showerhead, Little Rock Weather Zone			
Behavioral Water gal. saved /year/showerhead @ 1.5 gpm	368		
$T_{SupplyAverage}$	67.8°F		
$T_{SetPoint}$	120°F		
Water heater EF (excluding standby losses)	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 47.8 kWh	Heat Pump: 21.3 kWh	Gas: 2.0 Therms
Demand Savings	Electric: 0.002 kW	Heat Pump: 0.002 kW	Gas: N/A

2.3.7 Tub Spout and Showerhead Thermostatic Restrictor Valve

Measure Description

This measure consists of replacing existing tub spouts and shower heads with an automatically diverting tub spout and showerhead system with a thermostatic restrictor valve (TRV) between the existing shower arm and showerhead. When the water temperature reaches a set point (generally 95˚F), the thermostatic restrictor valve will engage the anti-leak diverter. The water will divert from the spout to a showerhead with a closed valve, which prevents the hot water from flowing down the drain prior to use.

Baseline and Efficiency Standards

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a thermostatic restrictor valve installed.

To qualify for tub spout and showerhead system with thermostatic restrictor technology deemed savings, the installed equipment must be an anti-leak, automatically diverting tub spout system with thermostatic restrictor technology installed on a residential showerarm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-Flow Showerheads measure and claim additional savings as outlined in that measure.

Estimated Useful Life (EUL)

The average lifetime of this measure is 10 years, according to DEER 2008.

This value is consistent with the EUL reported for a low-flow showerhead in the DEER 2014.[202]

Effect of Weather Zones on Water Usage and Water Main Temperature

Average water main temperatures for the four Arkansas weather zones are shown Table 167. The water main temperature data was approximated using the following formula.[203]

$$T\ of\ water\ main = T_{avg\ ambient} + R \times \Delta T_{amb}$$

(118)

Where:

R= 0.05

$T_{avg\ ambient}$ = the average annual ambient dry bulb temperature

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[202] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

[203] Burch, J. & Christensen, C. 2007. *"Towards Development of an Algorithm for Mains Water Temperature"* Proceedings of the 2007 ASES Annual Conference, Cleveland, OH.

ΔT_{amb} = the average of maximum and minimum ambient air dry bulb temperature for the month $(T_{max} + T_{min})/2$ where T_{max} = maximum ambient dry bulb temperature for the month and T_{min} = minimum ambient dry bulb temperature for the month

Table 167: Average Water Main Temperature by Weather Zone

Weather Zone	Average Water Main Temperature (°F)
9 Fayetteville	65.6
8 Fort Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

Estimated Hot Water Usage Reduction

Baseline and efficiency standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA.; the East Bay Municipal Utility District (CA); and Tampa, FL.[204],[205],[206]

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage.

Part 1:To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = \%WHUE_{SH} \times SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}} \tag{119}$$

$$Annual\ Showerhead\ Behavioral\ Waste = \%WHUE_{TS} \times SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}} \tag{120}$$

Where:

$\%WUE_{SH}$ = Showerhead percentage of warm-up events (see Table 165)

$\%WUE_{TS}$ = Tub spout percentage of warm-up events (see Table 165)

SHFR = Showerhead flow rate, gallons per minute (gpm) (see Table 165)

TSFR = Tub spout flow rate, gallons per minute (gpm) (see Table 165)

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[204] Seattle Home Water Conservation Study, 2000. *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes."* December. http://www.allianceforwaterefficiency.org/mainsearch.aspx?searchtext=Seattle Home Water Conservation Study

[205] Residential Indoor Water Conservation Study, 2003. "*Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area."* July. http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=868

[206] Tampa Water Department Residential Water Conservation Study, 2004, *"The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes,"* January 8. https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/End%20Use%20Studies%20-%20Multiple%20Technologies/Tampa-Residential-Water-Conservation-Final-Report.pdf

BW = Behavioral waste, minutes per shower (see Table 165)

n_S = Number of showers per person per day (see Table 165)

365 = Constant to convert days to years (see Table 165)

n_O = Number of occupants per home (see Table 165)

n_{SH} = Number of showerheads per home (see Table 165)

Applying the formula to the values used for Arkansas from Table 165 returns the following values for baseline behavioral waste in gallons per showerhead and tub spout per year:

$$Showerhead\ (2.5\ GPM): 0.6 \times 2.5 \times\ 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 267\ gal$$

$$Showerhead\ (2.0\ GPM): 0.6 \times 2.0 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 312\ gal$$

$$Showerhead\ (1.75\ GPM): 0.6 \times 1.75 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 356\ gal$$

$$Showerhead\ (1.5\ GPM): 0.6 \times 1.5 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 455\ gal$$

$$Tub\ Spout\ (5.0\ GPM): 0.4 \times 5.0 \times 0.783 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 594\ gal$$

Part 2: To determine the baseline gallons of diverted leakage per year, the following formula was used:

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

(121)

Where:

DLR = Diverter leakage rate (gpm) (see Table 168)

t_S = Shower time (min/shower) (see Table 165)

Applying the values used for Arkansas from Table 165 returns the following values:

$$Diverter\ (0.8\ GPM): 0.8 \times 5.68 \times 0.69 \times 365 \times \frac{2.53}{1.68} = 1{,}723$$

Part 3: Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 165.

$$Gallons\ of\ hot\ water\ saved = (SHBW + TSBW) \times HW\%_{SH,TS} + DW \times HW\%_D$$

(122)

Where:

SHBW = Showerhead behavioral waste (gallons per year)

TSBW = Tub spout behavioral waste (gallons per year)

DW = Diverter waste (gallons per year)

$HW\%_{SH,TS}$ = Showerheads and tub spout hot water percentage (see Table 168)

$HW\%_{D}$ = Diverter hot water percentage (see Table 168)

$$Total\ Gallons\ Saved\ Per\ Year\ (1.5\ gpm): (267 + 594) \times 0.825 + 1{,}723 \times 0.737 = 1{,}981$$

$$Total\ Gallons\ Saved\ Per\ Year\ \ (1.75\ gpm): (312 + 594) \times 0.825 + 1{,}723 \times 0.737 = 2{,}017$$

$$Total\ Gallons\ Saved\ Per\ Year\ \ (2.0\ gpm): (356 + 594) \times 0.825 + 1{,}723 \times 0.737 = 2{,}054$$

$$Total\ Gallons\ Saved\ Per\ Year\ (2.5\ gpm): (445 + 594) \times 0.825 + 1{,}723 \times 0.737 = 2{,}128$$

Table 168: Estimated Tub Spout/Showerhead System with TRV Hot Water Usage Reduction

Description	**Part 1- Behavioral Waste**		**Part 2 – Diverter Leakage**	**Part 3 – Total**
	Showerhead Warm-up	**Tub spout Warm-up**		
Baseline showerhead flow rate (gpm)	1.5, 1.75,2.0, or 2.5	**N/A**		
Tub spout flow rate (gpm)[207]	**N/A**	5.0	**N/A**	
Percent of warm up events[208]	60	40	**N/A**	
Average behavioral waste (minutes per shower)[209]	0.783	0.783	**N/A**	
Average diverter leak rate (gpm)[210]	**N/A**		0.80	**N/A**
Average shower time (minutes)[211]	**N/A**		5.68	**N/A**
Showers/person/day[212]	0.69	0.69	0.69	0.69
Occupants per home[213]	2.53	2.53	2.53	2.53
Showerheads per home[214]	1.68	1.68	1.68	1.68
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	267	594	1,723	2,585
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	312	594	1,723	2,629

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[207] Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[208] Percent of warm up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

[209] Average behavioral waste from Lutz (2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and Sherman (2014) Disaggregating Residential Shower Warm-Up Waste. Derived by dividing 47 seconds by 60 seconds.

[210] Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.

[211] Average shower time from (REUWS 1999) Residential End Uses of Water Study and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[212] Derivation of value for showers per person per day defined in the Low Flow Showerhead measure, Table 156: Estimated Showerhead Hot Water Usage Reduction

[213] Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2011-2015." Accessed June 2017. https://www.census.gov/quickfacts/fact/map/AR,US#viewtop.

[214] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Description	**Part 1- Behavioral Waste**		**Part 2 – Diverter Leakage**	**Part 3 – Total**
	Showerhead Warm-up	**Tub spout Warm-up**		
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	356	594	1,723	2,674
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	445	594	1,723	2,763
Percent hot water[215]	82.5%	82.5%	73.7%	N/A
Gallons hot water saved per year (1.5 gpm)	**N/A**			**1,981**
Gallons hot water saved per year (1.75 gpm)	**N/A**			**2,017**
Gallons hot water saved per year (2.0 gpm)	**N/A**			**2,054**
Gallons hot water saved per year (2.5 gpm)	**N/A**			**2,128**

Calculation of Deemed Savings

Energy Savings

$$Annual\ Energy\ Savings = \frac{\rho \times C_P \times V \times \left(T_{Setpoint} - T_{SupplyAverage}\right)}{\mathrm{RE} \times Conversion\ Factor}$$

(123)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 BTU/lb·°F

V = Gallons of hot water saved per year per shower head (from Table 168), if unknown use the values for a showerhead system with 2.0 gpm

$\mathrm{T_{SetPoint}}$ = Hot water temperature, assumed to be 120°F

$T_{SupplyAverage}$= Average supply water temperature (Water main temperature), see Table 167

RE = Recovery Efficiency (or in the case of HPWH, EF); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters[216]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/Therm for gas water heating

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[215] Average percent hot water for warm up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[216] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH

Demand Savings

Demand savings were calculated using the US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes"[217] combined domestic hot water use profile which resulted in a ratio of 0.000104 Peak kW to Annual kWh. The DOE domestic hot water use study provided values for the share of daily water use per hour in a profile for shower, bath, and sink hot water use. An average was calculated using peak hours of 3pm to 6pm to generate an average hourly share of daily water use during peak hours. That value was divided by 365 to generate a ratio of peak share to annual use.[218] Note: peak gas saving are not calculated for this measure.

$$kW_{savings} = kWh_{\ savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

(124)

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.000104[219]

The expected energy and demand savings for installing a tub spout/showerhead TRV in Weather Zone 7 (e.g. Little Rock) are shown in Table 169. This table is provided merely as an example.

Example Calculation of Deemed Savings Values

Table 169: Example, 2.5 GPM Showerhead and 5.0 GPM Tub Spout TRV Deemed Energy Savings

2.5 GPM Showerhead and 5.0 GPM Tub Spout System, Little Rock Weather Zone			
Behavioral Water gal. saved /year/showerhead @ 2.5 gpm	858		
Behavioral Water gal. saved /year/Tub Spout @ 5.0 gpm	1,270		
Total behavioral Water gal. saved /year	2,128		
$T_{SupplyAverage}$	67.8°F		
$T_{Setpoint}$	120°F		
Water heater RE	0.98 (Electric Resistance) / 2.2 (Heat Pump) / 0.79 (Gas)		
Energy Savings	Electric: 276.7 kWh	Heat Pump: 123.3 kWh	Gas: 11.7 Therms
Demand Savings	Electric: 0.029 kW	Heat Pump: 0.013 kW	N/A

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[217] U.S. DOE's 2006, *"Building America Performance Analysis Procedures for Existing Homes"*. National Renewable Energy Laboratory. May. www.nrel.gov/docs/fy06osti/38238.pdf

[218] At 3pm, the hourly share of daily water use is 0.022, at 4pm is 0.03, at 5pm is 0.04, and at 6pm is 0.06. The average of these values is 0.038. Divided by 365 days, the result is a 0.000104 ratio of peak share to annual use.

[219] US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

2.4 Appliances

2.4.1 ENERGY STAR® Clothes Washers

Measure Description

This measure involves the installation of a residential ENERGY STAR® clothes washer > 2.5 ft^3 in a new construction or replacement-on-burnout application. This measure applies to all residential applications.

Baseline and Efficiency Standards[220]

The baseline standard for deriving savings from this measure is the current federal minimum efficiency levels.

The efficiency standard is the ENERGY STAR® requirements for clothes washers.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

Efficiency performance for clothes washers are characterized by Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF). The units for IMEF are ft^3/kWh/cycle. Units with higher IMEF values are more efficient. The units for IWF are gallons/cycle/ft^3. Units with lower IWF values will use less water and are therefore more efficient.

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[220] Current federal standards for clothes washers can be found on the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Current ENERGY STAR® criteria for clothes washers can be found on the ENERGY STAR® website at: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers.

ENERGY STAR® Most Efficient criteria for clothes washers can be found at: http://www.energystar.gov/ia/partners/downloads/most_efficient/2015/Final_ENERGY_STAR_Most_Efficient_2015_Recognition_Criteria_Clothes_Washers.pdf.

Table 170: ENERGY STAR® Clothes Washer – Baseline and Efficiency Levels

Clothes Washer Configuration	Baseline Efficiency Prior to 3/7/2015	ENERGY STAR® Efficiency Level Prior to 3/7/2015	Baseline Efficiency Effective 3/7/2015	ENERGY STAR® Efficiency Level Effective 3/7/2015
Top Loading	MEF $\geq$ 1.26 WF $\leq$ 9.5	MEF $\geq$ 2.0 WF $\leq$ 6.0	MEF $\geq$ 1.29 WF $\leq$ 8.4	MEF $\geq$ 2.06 WF $\leq$ 4.3
Front Loading			MEF $\geq$ 1.84 WF $\leq$ 4.7	MEF $\geq$ 2.38 WF $\leq$ 3.7

Estimated Useful Life (EUL)

The average lifetime of this measure is 14 years, according to the US DOE.[221]

Deemed Savings Values

Prior to March 7, 2015, deemed savings are per installed unit based on the water heating and dryer fuel type. After March 7, 2015, for retrofit situations, baseline and efficiency case energy consumption is based on the configuration of the replaced unit and new unit (top loading or front loading). For new construction applications, a top loading clothes washer is assumed as the baseline and the efficient equipment is either top loading or front loading.

Table 171: ENERGY STAR® Clothes Washer – Deemed Savings (Prior to 3/7/2015)

Water Heater Fuel Type	Dryer Fuel Type	kW Savings	kWh Savings	Therms Savings
Gas	Gas	0.006	35	9.6
Gas	Electric	0.022	129	6.3
Electric	Gas	0.029	174	3.2
Electric	Electric	0.046	269	0.0

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[221] U.S. DOE "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers" Section 8.2.3 Product Lifetimes. April 2012. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Table 172: ENERGY STAR® Clothes Washer – Deemed Savings in Retrofit Applications (Effective 3/7/2015)

Baseline Configuration	Efficient Configuration	Water Heater Fuel Type	Dryer Fuel Type	kW Savings	kWh Savings	Therms Savings
Top Loading	Top Loading	Gas	Gas	0.005	23	9.9
		Gas	Electric	0.045	192	4.1
		Electric	Gas	0.027	114	5.8
		Electric	Electric	0.067	282	0.0
Top Loading	Front Loading	Gas	Gas	0.009	38	12.4
		Gas	Electric	0.047	198	7.0
		Electric	Gas	0.045	191	5.4
		Electric	Electric	0.083	351	0.0
Front Loading	Front Loading	Gas	Gas	0.002	6	4.1
		Gas	Electric	0.022	93	1.2
		Electric	Gas	0.008	32	3.0
		Electric	Electric	0.028	119	0.0

Table 173: ENERGY STAR® Clothes Washer – Deemed Savings in New Construction Applications (Effective 3/7/2015)

Baseline Configuration	Efficient Configuration	Water Heater Fuel Type	Dryer Fuel Type	kW Savings	kWh Savings	Therms Savings
Top Loading	Top Loading	Gas	Gas	0.005	23	9.9
		Gas	Electric	0.045	192	4.1
		Electric	Gas	0.027	114	5.8
		Electric	Electric	0.067	282	0.0
Top Loading	Front Loading	Gas	Gas	0.009	38	12.4
		Gas	Electric	0.047	198	7.0
		Electric	Gas	0.045	191	5.4
		Electric	Electric	0.083	351	0.0

Calculation of Deemed Savings

Energy savings for this measure were derived using the ENERGY STAR® Clothes Washer Savings Calculator.[222] Unless otherwise specified, all savings assumptions are extracted from the ENERGY STAR® calculator. The baseline and ENERGY STAR® efficiency levels are set to those matching Table 170. The ENERGY STAR® calculator determines savings based on whether or not an electric or gas water heater is used. Calculations are also conducted based on whether or not the dryer is electric or gas.

For applications using an electric water heater and an electric dryer, the savings are calculated as follows:

$$kWh_{savings} = \left(E_{conv,machine} + E_{conv,WH} + E_{conv,dryer}\right) - \left(E_{ES,machine} + E_{ES,WH} + E_{ES,dryer}\right)$$

(125)

Where:

$E_{conv,machine}$= Conventional machine energy (kWh)

$E_{conv,WH}$= Conventional water heating energy (kWh)

$E_{conv,dryer}$= Conventional dryer energy (kWh)

$E_{ES,machine}$= ENERGY STAR® machine energy (kWh)

$E_{ES,WH}$= ENERGY STAR® water heating energy (kWh)

$E_{ES,dryer}$=ENERGY STAR® dryer energy (kWh)

Energy consumption for the above factors can be determined using the following algorithms.

$$E_{conv,machine} = \frac{MCF \times RUEC_{conv} \times LPY}{RLPY}$$

(126)

$$E_{conv,WH} = \frac{WHCF \times RUEC_{conv} \times LPY}{RLPY}$$

(127)

$$E_{conv,dryer} = \left(\frac{CAP \times LPY}{IMEF_{FS}} - \frac{RUEC_{conv} \times LPY}{RLPY}\right) \times DUF$$

(128)

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[222] The ENERGY STAR® Clothes Washer Savings Calculator can be found on the ENERGY STAR® website on the right hand side of the page at:www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CW.

$$E_{ES,machine} = \frac{MCF \times RUEC_{ES} \times LPY}{RLPY}$$

(129)

$$E_{ES,WH} = \frac{WHCF \times RUEC_{ES} \times LPY}{RLPY}$$

(130)

$$E_{ES,dryer} = \left(\frac{CAP \times LPY}{IMEF_{ES}} - \frac{RUEC_{ES} \times LPY}{RLPY}\right) \times DUF$$

(131)

If the water heater is gas, the following equation is used to determine therms savings from water heating.

$$therms_{savings,WH} = \left(\frac{WHCF \times LPY}{RLPY \times \eta_{gas\ WH}}\right) \times \frac{0.03412\ therms}{kWh} \times (RUEC_{conv} - RUEC_{ES})$$

(132)

If the dryer is gas, then the following equation is used to determine therms saved from reduced time for drying.

$$\begin{aligned} therms_{savings,dryer} \\ &= \left(\frac{CAP \times LPY}{IMEF_{FS}} - \frac{RUEC_{FS} \times LPY}{RLPY}\right) \\ &- \left(\frac{CAP \times LPY}{IMEF_{ES}} - \frac{RUEC_{ES} \times LPY}{RLPY}\right) \times \frac{0.03412\ therms}{kWh} \times DUF \end{aligned}$$

(133)

Demand savings are calculated using the following equation:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

(134)

Where:

MCF= Machine electricity consumption factor = 20%

$WHCF$= Water heating electricity consumption factor = 80%

$RUEC_{conv}$= Rated unit electricity consumption (kWh/year) = 381 (Top Loading); 169 (Front Loading)

$RUEC_{ES}$ = Rated unit electricity consumption (kWh/year) = 230 (Top Loading); 127 (Front Loading)

CAP= Clothes washer capacity = 3.5 (ft^3)

$IMEF_{FS}$= Federal Standard Integrated Modified Energy Factor (ft^3/kWh/cycle)

$IMEF_{ES}$= ENERGY STAR® Integrated Modified Energy Factor (ft^3/kWh/cycle)

LPY = Loads per year = 295

$RLPY$= Reference loads per year = 392

DUF= Dryer use factor = 91%

d= Average wash cycle duration = 1 hour[223,224]

AOH= Annual operating hours = LPY × d = 295 hours

CF= Coincidence factor = 0.07[225]

$\eta_{gas\ WH}$= Gas water heater efficiency = 75%

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[223] Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers. www.consumerreports.org/cro/washing-machines.htm. Information available for subscribers only.

[224] Consumer Reports. "Top-loading washers remain more popular with Americans". April 13, 2010. Weighted average of 75% Top-Loading Clothes Washers and 25% Front-Loading Clothes Washers. www.consumerreports.org/cro/news/2010/04/top-loading-washers-remain-more-popular-with-americans/index.htm.

[225] Value from Clothes Washer Measure, Mid Atlantic TRM 2014. Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, p. 36.

2.4.2 ENERGY STAR® Dishwashers

Measure Description

This measure involves the installation of an ENERGY STAR® DISHWASHER in a new construction or replacement-on-burnout situation. This measure applies to all residential applications.

Baseline and Efficiency Standards

The baseline for this measure is the current federal standard as displayed in the table below.

Table 174: ENERGY STAR® Dishwasher – Federal Standard Efficiency[226]

	Federal Standard as of May 30, 2013		
	Capacity	**kWh/Year**	**Gallons/Cycle**
Standard Model Size	= 8 place settings	≤ 307	≤ 5.0
Compact Model Size	< 8 place settings	≤ 222	≤ 3.5

ENERGY STAR® eligible standard and compact dishwashers must meet the criteria displayed in the table below.

Table 175: ENERGY STAR® Criteria for Dishwashers[227]

	ENERGY STAR® Criteria		
	Capacity	**Annual Energy Consumption (AEC) kWh/Year**	**Gallons/Cycle**
Standard Model Size	≥ 8 place settings + 6 serving pieces	$AEC_{base} + AEC_{adderconnected}$ AEC_{base}: 270 $AEC_{adderconnected}$: $0.05 \times AEC_{base}$	≤ 3.5
Compact Model Size	< 8 place settings + 6 serving pieces	≤ 203	≤ 3.1

Estimated Useful Life (EUL)

The average lifetime of this measure is 15 years, according to the US DOE.[228]

Deemed Savings Values

Deemed savings are per installed unit based on the water heating fuel type.

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[226] Current federal standards for dishwashers can be found on the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67.

[227] ENERGY STAR® criteria for dishwashers can be found on the ENERGY STAR® website at: www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers.

[228] U.S. DOE, *Technical Support Document: "Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment: Residential Dishwashers, Section 8.2.3 Product Lifetimes."* May 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0007.

Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0007.

Table 176: ENERGY STAR® Dishwashers – Deemed Savings Values

	Water Heater Fuel Type	kW Savings	kWh Savings	Therms Savings
Standard Model Size	Gas	0.0021	16.3	0.89
Standard Model Size	Electric	0.0047	37	0.0
Compact Model Size	Gas	0.0011	8.4	0.46
Compact Model Size	Electric	0.0024	19	0.0

Calculation of Deemed Savings

Energy savings for this measure were derived using the ENERGY STAR® DISHWASHER Savings Calculator.[229] The baseline and ENERGY STAR® efficiency levels are set to those matching Table 174 and Table 175.

$$kWh_{Savings} = \left(E_{conv,machine} + E_{conv,WH}\right) - \left(E_{ES,machine} + E_{ES,WH}\right)$$

(135)

Where:

$E_{conv,machine}$ = Conventional machine energy (kWh)

$E_{conv,WH}$ = Conventional water heating energy (kWh)

$E_{ES,machine}$ = ENERGY STAR® machine energy (kWh)

$E_{ES,WH}$ = ENERGY STAR® water heating energy (kWh)

Algorithms to calculate the above parameters are defined as:

$$E_{conv,machine} = MCF \times RUEC_{conv}$$

(136)

$$E_{conv,WH} = WHCF \times RUEC_{conv}$$

(137)

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[229] The ENERGY STAR® Dishwasher Savings Calculator, updated January 29, 2016, can be found on the ENERGY STAR® website.

$$E_{ES,machine} = MCF \times RUEC_{ES}$$

(138)

$$E_{ES,WH} = WHCF \times RUEC_{ES}$$

(139)

For gas water heating applications, therms can be calculated as:

$$therms_{Savings,WH} = \frac{(RUEC_{conv} - RUEC_{ES}) \times WHCF}{\eta_{gas\ WH}} \times \frac{0.03412\ therms}{kWh}$$

(140)

Demand savings can be derived using the following:

$$kW_{Savings} = \frac{kWh_{Savings}}{AOH} \times CF$$

(141)

Where:

MCF= Machine electricity consumption factor = 44%

$WHCF$= Water heating electricity consumption factor = 56%

$RUEC_{conv}$= Rated unit electricity consumption (kWh/year) = 307 (Standard), 222 (Compact)

$RUEC_{ES}$ = Rated unit electricity consumption (kWh/yr) = 270 (Standard), 203 kWh/year (Compact)

CPY = Cycles per year = 142[230]

d = Average wash cycle duration = 2 hours[231]

AOH = Annual operating hours = CPY × d = 284 hours

CF = Coincidence factor = 0.036[232]

$\eta_{gas\ WH}$= Gas water heater efficiency = 75%

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[230] Assuming 142 cycles per year based on a weighted average of dishwasher use in AR, LA, OK from the Residential Energy Consumption 2015 Survey, accessed August 3, 2017.

[231] Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/dishwashers.htm. Information available for subscribers only.

[232] Hendron, R. & Engebrecht, C. 2010, , National Renewable Energy Laboratory (NREL). "Building America Research Benchmark Definition: Updated December" US U.S. DOE. January 2010. p. 14 (peak hour of 4 PM was applied). http://www.nrel.gov/docs/fy10osti/47246.pdf

2.4.3 ENERGY STAR® Refrigerators

Measure Description

This measure involves replace-on-burnout or early retirement of an existing refrigerator and installation of a new, full-size (7.75 ft^3 or greater) ENERGY STAR® refrigerator. This measure applies to all residential or small commercial applications.

To qualify for early retirement, the ENERGY STAR® unit must replace an existing, full-size, working unit that is at least six years old. For early retirement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Baseline and Efficiency Standards[233]

For ROB, the baseline for refrigerators is the DOE minimum efficiency standards for refrigerators, effective September 15, 2014.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

For an individual refrigerator early retirement program, the baseline for refrigerators is assumed to be the annual unit energy consumption of the refrigerator being replaced, as reported by the Association of Home Appliance Manufacturers (AHAM) refrigerator database[234], adjusted for age according to the formula in the Measure Savings Calculations section. AHAM energy use data includes the average manufacturer-reported annual kilowatt hour usage, by year of production. This data dates back to the 1970s.

Alternatively, the baseline annual kilowatt hour usage of the refrigerator being replaced may be estimated by metering for a period of at least three hours using the measurement protocol specified in the US DOE report, *"Incorporating Refrigerator Replacement into the Weatherization Assistance Program."*[235]

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[233] Current federal standards for refrigerators can be found on the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Current ENERGY STAR® criteria for refrigerators can be found on the ENERGY STAR® website at: www.energystar.gov/index.cfm?c=refrig.pr_crit_refrigerators

[234] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx

[235] Moore, A. 2001, D&R International, Ltd. *"Incorporating Refrigerator Replacement into the Weatherization Assistance Program: Information Tool Kit."* U.S. DOE. November 19. http://www.waptac.org/data/files/website_docs/training/standardized_curricula/curricula_resources/refrigerator_info_toolkit.pdf

To determine annual kWh of the refrigerator being replaced, use the formula:

$$kWh/yr = \frac{WH \times 8{,}760}{h \times 1{,}000}$$

(142)

Where:

WH = the watt-hours metered during a time period

h = measurement time period (hours)

$8{,}760$ = hours in a year

$1{,}000$ watt-hours = 1 kWh

For the early retirement application, all new refrigerators must replace refrigerators currently in use, and all replaced refrigerators must be dismantled in an environmentally-safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators.

Newly-installed refrigerators must meet current ENERGY STAR® efficiency levels. All newly-installed refrigerators must be connected to an adequately-sized electrical receptacle and be grounded in accordance to the National Electric Code (NEC).

Minimum efficiency requirements for ENERGY STAR® refrigerators are set at ten percent more efficient than required by the minimum federal government standard. The standard varies depending on the size and configuration of the refrigerator. See Table 177.

Configuration Codes

- BF: Bottom Freezer
- SD: Refrigerator Only – Single Door
- SR: Refrigerator/Freezer – Single Door
- SS: Side-by-Side
- TF: Top Freezer
- TTD: Through the Door (Ice Maker)
- A: Automatic Defrost
- M: Manual Defrost
- P: Partial Automatic Defrost
- AV[236] = Adjusted Volume

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[236] Adjusted Volume (AV) can be found for ENERGY STAR® certified refrigerators on their website under the “advanced view” option. https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Residential-Refrigerators/p5st-her9. Scroll to the right until you reach the column named “Adjusted Volume”.

Table 177: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume (Effective September 15, 2014)[237]

Product Category	Federal Standard as of Sept 15, 2014 Standard (kWh/year)	Maximum ENERGY STAR® Energy Usage (kWh/year)[238]	Configuration(s)	Ice (Y/N)	Defrost
Refrigerator-only—manual defrost	6.79 × AV + 193.6	6.111 × AV + 174.24	SD	Y, N	M
Refrigerator-freezers—manual or partial automatic defrost	7.99 × AV + 225.0	7.191 × AV + 202.5	SS, TF, BF, SR	Y, N	M, P
Refrigerator-only—automatic defrost	7.07 × AV + 201.6	6.363 × AV + 181.44	SD	Y, N	A
Built-in refrigerator-only—automatic defrost	8.02 × AV + 228.5	7.218 × AV + 205.65	SD	Y, N	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.965 × AV + 285.3	BF	N	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	8.46 × AV + 378.81	BF	N	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	7.965 × AV + 360.9	BF	N	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	9.40 × AV + 420.9	8.46 × AV + 378.81	BF	N	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.25 × AV + 475.4	8.325× AV + 427.86	BF	Y	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.83 × AV + 499.9	8.847 × AV + 449.91	BF	Y	A
Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	8.51 × AV + 297.8	7.659 × AV + 268.02	SS	N	A

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[237] Available for download at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[238] Ten percent more efficient than baseline, as specified in the ENERGY STAR® appliance calculator.

Product Category	Federal Standard as of Sept 15, 2014 Standard (kWh/year)	Maximum ENERGY STAR® Energy Usage (kWh/year)[238]	Configuration(s)	Ice (Y/N)	Defrost
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	9.198 × AV + 321.66	SS	N	A
Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	7.659 × AV + 343.62	SS	N	A
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	9.198 × AV + 397.26	SS	N	A
Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.686 × AV + 389.52	SS	Y	A
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	10.25 × AV + 502.6	9.225 × AV + 452.34	SS	Y	A
Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.263 × AV + 210.33	TF	N	A
Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	9.15 × AV + 264.9	8.235 × AV + 238.41	TF	N	A
Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	8.07 × AV + 317.7	7.263 × AV + 285.93	TF	N	A
Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic ice maker with TTD ice service	9.15 × AV + 348.9	8.235 × AV + 238.41	TF	N	A
Refrigerator-freezers—automatic defrost with top-mounted freezer with TTD ice service	8.40 × AV + 385.4	7.56 × AV + 346.86	TF	Y	A

Estimated Useful Life (EUL)

According to the Department of Energy Technical Support Document,[239] the Estimated Useful Life of High Efficiency Refrigerators is 17 years.

Measure Savings Calculations

Deemed peak demand and annual energy savings should be calculated as shown below. Note that these savings calculations are different depending on whether the measure is replace-on-burnout or early retirement.

Replace-on-Burnout

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

(143)

Where:

$kWh_{baseline}$ = Federal standard baseline average energy usage (Table 177)

kWh_{ES}= ENERGY STAR® average energy usage (Table 177)

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (17 – RUL)

For the RUL (Table 178):

$$kWh_{savings} = kWh_{pre} - kWh_{ES}$$

(144)

kWh_{pre} refers to manufacturer data or a measured consumption that is adjusted using applicable degradation factors.

$$kWh_{pre} = kWh_{manf} \times (1 + \mathrm{PDF})^{n}\ x\ SLF$$

(145)

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[239] U.S. DOE 2011, Technical Support Document: "Residential Refrigerators, Refrigerator-Freezers, and Freezers, 8.2.3 Product Lifetimes." September 15. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

For the remaining time in the EUL period:

Calculate annual savings as you would for a replace-on-burnout project using Equation (143). Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kwh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(146)

Where:

kWh_{NAECA}= NAECA baseline average energy usage (Table 177)

kWh_{pre} = Adjusted manufacturer energy usage Equation (145)

kWh_{ES} = ENERGY STAR® average energy usage (Table 177)

kWh_{manf} = annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database[240] (or from metering, using Equation (142)

PDF = Performance Degradation Factor 0.0125/year. Refrigerator energy use is expected to increase at a rate of 1.25% per year as performance degrades over time[241]

n = age of replaced refrigerator (years)

SLF = Site/Lab Factor = 0.81 to account for the difference between DOE laboratory testing and actual conditions[242]

RUL = Remaining Useful Life (Table 178)

EUL = Estimated Useful Life = 17 years

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[240] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

[241] *2009 Second Refrigerator Recycling Program NV Energy – Northern Nevada Program Year 2009*; M&V, ADM, Feb 2010, referencing Cadmus data on a California program, February 2010.

[242] Peterson, J, et. al., 2007, "*Gross Savings Estimation for Appliance Recycling Programs: The Lab Versus In Situ Measurement Imbroglio and Related Issues"* International Energy Program Evaluation Conference (IEPEC). Cadmus, et. al. "Residential Retrofit High Impact Measure Evaluation Report." February 8, 2010.

Table 178: Remaining Useful Life (RUL) of Replaced Refrigerator[243]

Age of Replaced Refrigerator (years)	RUL (years)
6	10.3
7	9.6
8	8.9
9	8.3
10	7.8
11	7.4
12	7.0
13	6.6
14	6.3
15	6.0
16	5.8
17	5.5
18	5.3
19	5.1
20	4.9
21	4.8
22	4.6
23 +	0.0

Average Demand Savings

Since refrigerators operate around the clock, average kW reduction is equal to annual kWh divided by 8,760 hours per year. As shown below, this average kW reduction is multiplied by temperature and load shape adjustment factors to derive peak period kW reduction.

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760\ hrs} \times \mathrm{TAF} \times \mathrm{LSAF}$$

(147)

Where:

TAF = Temperature Adjustment Factor[244] = 1.188

LSAF = Load Shape Adjustment Factor[245] = 1.074

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[243] Use of the early retirement baseline is capped at 22 years, representing the age at which 75 percent of existing equipment is expected to have failed. Equipment older than 22 years should use the ROB baseline.

[244] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group, 2004, *"Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study"*. July 29. Factor to adjust for varying temperature based on site conditions, p. 47.

[245] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group, 2004, "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29. Used load shape adjustment for "hot days" during the 4PM hour, pp. 45-48.

Derivation of RULs

ENERGY STAR® Refrigerators have an estimated useful life of 17 years. This estimate is consistent with the age at which 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 8.

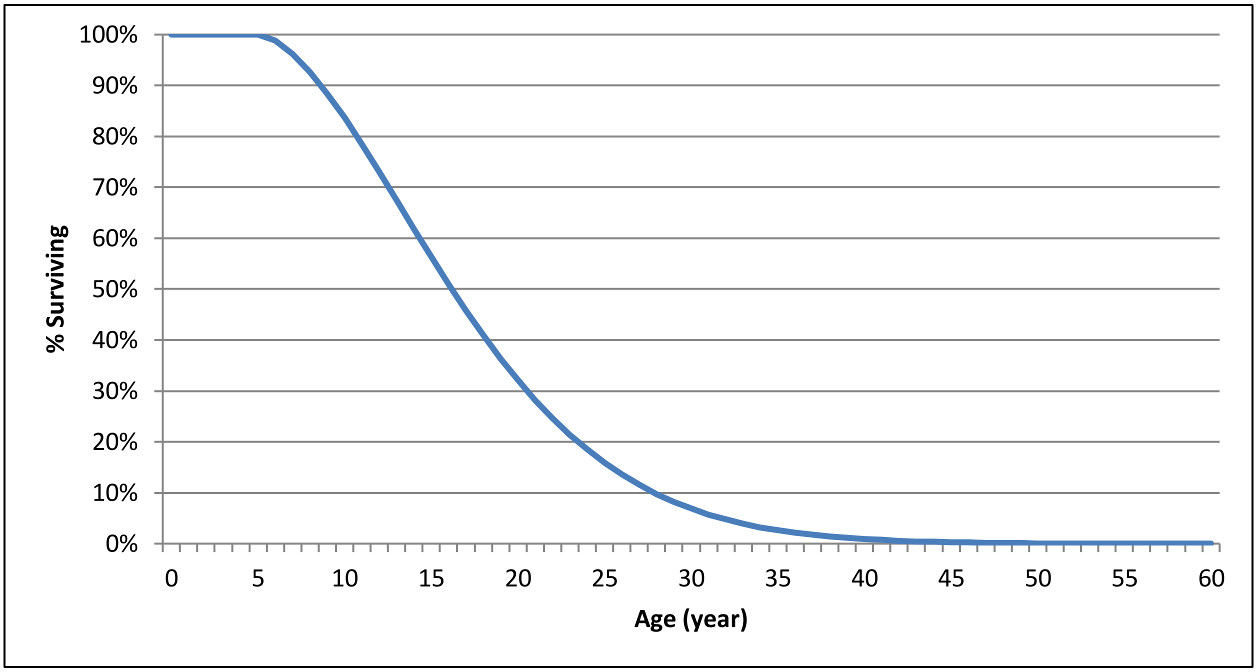

Figure 8: Survival Function for ENERGY STAR® Refrigerators[246]

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 8. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[246] U.S. DOE, Technical Support Document, 2011, "Residential Refrigerators, Refrigerator-Freezers, and Freezers, 8.2.3 Product Lifetimes." September 15. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

2.4.4 Advanced Power Strips

Measure Description

This measure involves the installation of a multi-plug Advanced Power Strip (APS) that has the ability to automatically disconnect specific loads depending on the power draw of a specified or “master” load.

In the case of Tier 1 APS, a load sensor in the strip disconnects power from the control outlets when the master power draw is below a certain threshold. This feature allows for a reduction of power draw from peripheral consumer electronics, which usually maintain some load even when in the off or standby position. Thus when the master device (i.e. television) is turned off, power supply is cut to other related equipment (i.e., set top boxes, speakers, video game consoles, etc.).

Tier 2 APS use an external sensor paired with a configurable countdown timer to manage both active and standby power loads for controlled devices in a complete system. Tier 2 APS may operate either with or without a master control socket. Those without a master control socket sense power of all devices connected to the controlled sockets; those with a master control socket sense power for the device connected to the control socket. The external sensor of a Tier 2 APS may utilize an infrared-only sensor, or it may utilize a “multi-sensor” which detects both infrared (IR) remote control signals and motion to determine device inactivity and deliver additional savings as compared to a Tier 1 APS device. Both versions of external sensor use IR filtering to prevent inappropriate switching events which may have otherwise resulted from natural interference such as sunlight or CFL light bulbs. Residential deemed savings were developed based on reported plug load electricity consumption and hourly use data. A set of home office and home entertainment system peripheral equipment and related performance data are presented in the following table. “Daily Standby Hours” and “Daily Off Hours” represent the average number of hours the device is left in standby or off mode. For each device, a weighted watt per hour value is calculated based on projected watts consumed in either standby or off mode.

There are three deemed savings paths available for Tier 1: Savings can be estimated 1) by complete system type (Home Entertainment or Home Office), 2) per APS for an average complete system if the type is unknown, or 3) by individual peripheral device(s). Tier 2 deemed savings are determined using the average component uses for a complete system and an energy reduction percentage.

This measure applies to all residential applications.

Table 179: Peripheral Watt Consumption Breakdown[247]

System Type	Peripheral Device	Daily Standby Hours	Daily Off Hours	Standby Power (W)	Off Power (W)	Weighted W/hr.	Annual APS Hours
Home Entertainment	Audio Equipment: AV Receiver	0.0	18.0	19.2	3.1	3.1	6,570.0
Home Entertainment	Audio Equipment: Speakers	0.0	18.0	3.0	0.0	0.0	6,570.0
Home Entertainment	Audio Equipment: Subwoofer	0.0	18.0	7.8	0.6	0.6	6,570.0
Home Entertainment	Media Player: Blu-Ray	2.5	20.8	7.0	0.1	0.8	8,504.5
Home Entertainment	Media Player: DVD	2.5	20.8	5.0	2.0	2.3	8,504.5
Home Entertainment	Media Player: DVD-R	2.5	20.8	7.0	3.0	3.4	8,504.5
Home Entertainment	Media Player: DVD/VCR	2.5	20.4	8.0	4.0	4.4	8,358.5
Home Entertainment	Media Player: VCR	2.2	21.4	6.0	3.0	3.3	8,614.0
Home Entertainment	Set-Top Box: Cable	0.0	16.5	25.0	16.0	16.0	6,022.5
Home Entertainment	Set-Top Box: Cable with DVR	0.0	16.5	45.0	43.0	43.0	6,022.5
Home Entertainment	Set-Top Box: Satellite	0.0	15.1	10.0	15.0	15.0	5,511.5
Home Entertainment	Set-Top Box: Satellite with DVR	0.0	15.1	27.0	28.0	28.0	5,511.5
Home Entertainment	Set-Top Box: Stand Alone DVR	0.0	18.3	27.0	27.0	27.0	6,679.5
Home Entertainment	Television: CRT	0.0	18.7	5.3	1.6	1.6	6,825.5
Home Entertainment	Television: LCD	0.0	18.7	2.2	0.5	0.5	6,825.5
Home Entertainment	Television: Plasma	0.0	18.7	0.9	0.6	0.6	6,825.5
Home Entertainment	Television: Projection	0.0	18.7	4.4	7.0	7.0	6,825.5
Home Entertainment	Video Game Console: Nintendo Wii	1.5	21.4	10.5	1.9	2.5	8,358.5

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[247] Hours Standby, Hours Off, and Watt Consumption derived from: New York State Energy Research and Development Authority (NYSERDA), "*Advanced Power Strip Research Report*, "August 2011.

System Type	Peripheral Device	Daily Standby Hours	Daily Off Hours	Standby Power (W)	Off Power (W)	Weighted W/hr.	Annual APS Hours
Home Entertainment	Video Game Console: PlayStation 2	1.5	21.4	17.0	0.2	1.3	8,358.5
Home Entertainment	Video Game Console: PlayStation 3	1.5	21.4	152.9	1.1	11.0	8,358.5
Home Entertainment	Video Game Console: XBOX	1.5	21.4	68.0	2.0	6.3	8,358.5
Home Entertainment	Video Game Console: XBOX 360	1.5	21.4	117.5	3.1	10.6	8,358.5
Home Office	Computer: Desktop	4.1	16.7	11.6	3.3	4.9	7,592.0
Home Office	Computer: Laptop	4.1	16.7	7.6	4.4	5.0	7,592.0
Home Office	Computer Monitor: CRT	2.4	16.5	7.6	1.5	2.3	6,898.5
Home Office	Computer Monitor: LCD	2.4	16.5	1.9	1.1	1.2	6,898.5
Home Office	Computer Speakers	0.0	18.7	3.7	2.3	2.3	6,825.5
Home Office	Copier	0.0	23.5	2.8	1.5	1.5	8,577.5
Home Office	Fax Machine: Inkjet	0.5	23.3	6.0	5.3	5.3	8,687.0
Home Office	Fax Machine: Laser	0.5	23.3	5.3	2.2	2.3	8,687.0
Home Office	Printer: Inkjet	4.4	19.5	2.5	1.3	1.5	8,723.5
Home Office	Printer: Laser	4.4	19.5	9.0	3.3	4.3	8,723.5
Home Office	Scanner	0.0	23.5	3.6	2.1	2.1	8,577.5

Baseline & Efficiency Standard

For both Tier 1 and Tier 2 APS, the baseline case is the absence of an APS, where peripherals are plugged in to a traditional surge protector or wall outlet.

The efficiency standard case for Tier 1 is the presence of an APS, with all peripherals plugged into the APS. The efficiency standard case for Tier 2 APS in a residential environment includes control of at least 2 audio visual devices.

Estimated Useful Life (EUL)

For Tier 1 advanced power strips, the measure life is 10 years according to the NYSERDA Advanced Power Strip Research Report from August 2011.[248]

For Tier 2 advanced power strips, the measure life is assumed to be 10 years.[249]

Calculation of Deemed Savings

Energy Savings

Tier 1

Energy and demand savings for a 5-plug APS in use in a home office or for a home entertainment system are calculated using the following algorithm, where kWh saved are calculated and summed for all peripheral devices:

$$\Delta kWh = \sum \frac{(W_i * H_i)}{1{,}000}$$

(148)

Where:

$W =$ Weighted watts per hour consumed in standby/off mode for each peripheral device (Table 179)

$H =$ Annual hours per year controlled by APS (Table 179)

$1{,}000 =$ Constant to convert watts to kilowatts

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[248] New York State Energy Research and Development Authority (NYSERDA) 2011, *Advanced Power Strip Research Report*, p. 30. August.

[249] There is little evaluation to upon which to base a lifetime estimate. Based on review of assumptions from other jurisdictions and the relative treatment of In Service Rates and persistence, an estimate of 10 years was used.

Tier 2

The energy and demand savings for Tier 2 APS are obtained using the average household entertainment center and home office component usages, multiplied by an energy reduction percentage.

$$\Delta kWh_{Entertainment\ Center} = kWh_{TV} \times ERP \times ISR \tag{149}$$

$$\Delta kWh_{Computer\ System} = kWh_{Comp} \times ERP \times ISR \tag{150}$$

$$\Delta kWh_{Unspecified\ Use} = \frac{kWh_{TV} + kWh_{Comp}}{2} \times ERP \times ISR \tag{151}$$

Where:

kWh_{TV}= Average annualized energy consumption of Tier 2 qualifying TV systems, default value of 602.8[250]

kWh_{Comp}= Average annualized energy consumption of Tier 2 qualifying computer systems, default value of 197.9[251]

ISR = In Service Rate, the percentage of units rebated that are installed, default value of 1.0[252]

ERP = Energy Reduction Percentage of qualifying Tier 2 APS product range, estimated at an average of 51%[253]

Demand Savings

Tier 1

$$\Delta kW = \sum \frac{\Delta kWh_i}{H_i} \times CF \tag{152}$$

Where:

ΔkWh = Annual energy savings (kWh) for each peripheral device (Table 179)

H= Annual hours per year controlled by Tier 1 APS

CF= Coincidence Factor [254] = 0.80

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[250] New York State Energy Research and Development Authority (NYSERDA) 2011, *Advanced Power Strip Research Report*, p. 30. August.

[251] ibid.

[252] In-service rates are set to 100% based on the assumption that all purchased units are installed, from Illinois TRM

[253] Average of ERP from NEEP *Case Study: Tier 2 Advanced Power Strips and Efficiency Programs*

[254] Given an absence of empirical data sources, this assumption was based on typical TV/PC use patterns during the peak hour.

Tier 2

$$\Delta kW = \sum \frac{\Delta kWh}{H} \times CF \tag{153}$$

Where:

ΔkWh = Annual energy savings (kWh) for each system as calculated above

H = Annual number of hours during which the Tier 2 APS provides savings = 4,380[255]

CF = Coincidence Factor [256] = 0.80

Deemed Savings Values

Table 180: Deemed Savings for Tier 1 Residential APS

System Type	Peripheral Device	kW Savings	kWh Savings
Home Entertainment	Audio Equipment: AV Receiver	0.002	20.4
Home Entertainment	Audio Equipment: Speakers	0.000	0.0
Home Entertainment	Audio Equipment: Subwoofer	0.000	3.9
Home Entertainment	Media Player: Blu-Ray	0.001	7.1
Home Entertainment	Media Player: DVD	0.002	19.7
Home Entertainment	Media Player: DVD-R	0.003	29.2
Home Entertainment	Media Player: DVD/VCR	0.004	37.1
Home Entertainment	Media Player: VCR	0.003	28.3
Home Entertainment	Set-Top Box: Cable	0.013	96.4
Home Entertainment	Set-Top Box: Cable with DVR	0.034	259.0
Home Entertainment	Set-Top Box: Satellite	0.012	82.7
Home Entertainment	Set-Top Box: Satellite with DVR	0.022	154.3
Home Entertainment	Set-Top Box: Stand Alone DVR	0.022	180.3
Home Entertainment	Television: CRT	0.001	10.9
Home Entertainment	Television: LCD	0.000	3.4
Home Entertainment	Television: Plasma	0.000	4.1
Home Entertainment	Television: Projection	0.006	47.8

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[255] Estimate based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hrs/day, 1936 per year (NYSERDA 2011. "*Advanced Power Strip Research Report*")) and half during standby hours (8760-1936 = 6824 hours). The weighted average is 4380.

[256] Given an absence of empirical data sources, this assumption was based on typical television and computer use patterns in the home.

System Type	**Peripheral Device**	**kW Savings**	**kWh Savings**
Home Entertainment	Video Game Console: Nintendo Wii	0.002	20.6
Home Entertainment	Video Game Console: PlayStation 2	0.001	10.9
Home Entertainment	Video Game Console: PlayStation 3	0.009	92.3
Home Entertainment	Video Game Console: XBOX	0.005	52.9
Home Entertainment	Video Game Console: XBOX 360	0.008	88.5
Home Office	Computer: Desktop	0.004	37.5
Home Office	Computer: Laptop	0.004	38.2
Home Office	Computer Monitor: CRT	0.002	15.7
Home Office	Computer Monitor: LCD	0.001	8.3
Home Office	Computer Speakers	0.002	15.7
Home Office	Copier	0.001	12.9
Home Office	Fax Machine: Inkjet	0.004	46.2
Home Office	Fax Machine: Laser	0.002	19.7
Home Office	Printer: Inkjet	0.001	13.3
Home Office	Printer: Laser	0.003	37.9
Home Office	Scanner	0.002	18.0
Home Entertainment	Whole System Average[257]	0.030	252.2
Home Office	Whole System Average[258]	0.008	82.5
Average APS	Whole System Average[259]	0.019	167.4

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[257] Assuming Audio Equipment: AV Receiver, Media Player: Average, Set-Top Box: Average, and Video Game Console: Average. kW savings = 0.002 + [(0.001 + 0.002 + 0.003 + 0.004 + 0.003) ÷ 5] + [(0.013 + 0.034 + 0.012 + 0.022 + 0.022) ÷ 5] + [(0.002 + 0.001 + 0.009 + 0.005 + 0.008) ÷ 5] = 0.030 kW; kWh savings = 20.4 + [(7.1 + 19.7 + 29.2 + 37.1 + 28.3) ÷ 5] + [(96.4 + 259.0 + 82.7 + 154.3 + 180.3) ÷ 5] + [(20.6 + 10.9 + 92.3 + 52.9 + 88.5) ÷ 5] = 252.2 kWh.

[258] Assuming Computer Monitor: LCD, Computer Speakers, Fax Machine: Average, and Printer: Average. kW savings = 0.001 + 0.002 + [(0.004 + 0.002) ÷ 2] + [(0.001 + 0.003) ÷ 2] = 0.008 kW; kWh savings = 8.3 + 15.7 + [(46.2 + 19.7) ÷ 2] + [(13.3 + 37.9) ÷ 2] = 82.5 kWh.

[259] Average of Home Entertainment System and Home Office system averages. kW savings = (0.030 + 0.008) ÷ 2 = 0.019 kW; kWh savings = (252.2 + 82.5) ÷ 2 = 167.4 kWh.

Example Calculation for Tier 2 Power Strip

$$\Delta kWh_{Entertainment\ Center} = kWh_{TV} \times ERP \times ISR = 602.8\ kWh \times 0.51 \times 1.0 = 307.4\ kWh$$

$$\Delta kW = \sum \frac{\Delta kWh}{H} \times CF = \frac{307.4\ kWh}{4{,}380\ hours} \times 0.80 = 0.056\ kW$$

Table 181: Deemed Savings for Tier 2 Residential APS

System Type	kW Savings	kWh Savings
Entertainment Center	0.056	307.4
Computer System	0.018	100.9
Unspecified Usage	0.037	204.2

2.4.5 ENERGY STAR® Pool Pumps

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable speed or multi-speed pool pump. This measure applies to all residential applications; however, pools that serve multiple tenants in a common area are not eligible for this measure.

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that is basically two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[260] Therefore, multi-speed pumps must have a minimum size of 1 horsepower (HP) to be eligible for this measure.

Baseline and Efficiency Standards

The baseline condition is a 0.5-3 horsepower (HP) standard efficiency single-speed pool pump.

The high efficiency condition is a 0.5-3 HP ENERGY STAR® certified variable speed or multi-speed pool pump.

Estimated Useful Life (EUL)

According to DEER 2014, the estimated useful life for this measure is 10 years.[261]

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[260] Hunt, A. & Easley, S., 2012, "*Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.*" Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

[261] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Deemed Savings Values

Deemed savings are per installed unit based on the pump horsepower.

Table 182: ENERGY STAR® Variable Speed Pool Pumps – Deemed Savings Values

Pump HP	kW Savings	kWh Savings
0.5	0.24	1,713
0.75	0.28	1,860
1	0.36	2,063
1.5	0.47	2,465
2	0.52	2,718
2.5	0.57	2,838
3	0.72	3,364

Table 183: ENERGY STAR® Multi-Speed Pool Pumps – Deemed Savings Values

Pump HP	kW Savings	kWh Savings
1	0.30	1,629
1.5	0.40	1,945
2	0.41	1,994
2.5	0.46	2,086
3	0.54	2,292

Calculation of Deemed Savings

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator.[262]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

(154)

Where:

kWh_{conv}= Conventional single-speed pool pump energy (kWh)

kWh_{ES}= ENERGY STAR® variable speed pool pump energy (kWh)

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours_{conv} \times days}{EF_{conv} \times 1000}$$

(155)

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[262] The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

$$hours_{conv} = \frac{V_{pool} \times PT}{PFR_{conv} \times 60}$$

(156)

$$kWh_{ES} = kWh_{HS} + kWh_{LS}$$

(157)

$$kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$$

(158)

$$kWh_{LS} = \frac{PFR_{LS} \times 60 \times hours_{LS} \times days}{EF_{LS} \times 1000}$$

(159)

$$PFR_{LS} = \frac{V_{pool}}{t_{turnover} \times 60}$$

(160)

Where:

kWh_{HS} = ENERGY STAR® variable speed pool pump energy at high speed (kWh)

kWh_{LS} = ENERGY STAR® variable speed pool pump energy at low speed (kWh)

$hours_{conv}$ = Conventional single-speed pump daily operating hours (Table 184)

$hours_{HS,VS}$ = ENERGY STAR® variable speed pump high speed daily operating hours = 2 hours

$hours_{LS,VS}$ = ENERGY STAR® variable speed pump low speed daily operating hours = 10 hours

$hours_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed daily operating hours = 2 hours

$hours_{LS,VS}$ = ENERGY STAR® multi-speed pump low speed daily operating hours (Table 185)

$days$ = Operating days per year = 7 months x 30.4 days/month = 212.8 days (default)

PFR_{conv} = Conventional single-speed pump flow rate (gal/min) (Table 184)

$PFR_{HS,VS}$ = ENERGY STAR® variable speed pump high speed flow rate = 50 gal/min (default)

$PFR_{LS,VS}$ = ENERGY STAR® variable speed pump low speed flow rate (gal/min) = 30.6 (default)

$PFR_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed flow rate (gal/min) (Table 185)

$PFR_{LS,MS}$ = ENERGY STAR® multi-speed pump low speed flow rate (gal/min) (Table 185)

EF_{conv} = Conventional single-speed pump energy factor (gal/W·hr) (Table 184)

$EF_{HS,VS}$ = ENERGY STAR® variable speed pump high speed energy factor = 3.75 gal/W·hr (default)

$EF_{LS,VS}$ = ENERGY STAR® variable speed pump low speed energy factor = 7.26 gal/W·hr (default)

$EF_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed energy factor (gal/W·hr) (Table 185)

$EF_{LS,MS}$ = ENERGY STAR® multi-speed pump low speed energy factor (gal/W·hr) (Table 185)

V_{pool} = Pool volume = 22,000 gal (default)

$PT =$ Pool turnovers per day = 1.5 (default)

$t_{turnover,VS}$ = Variable speed pump time to complete 1 turnover = 12 hours (default)

$t_{turnover,MS}$ = Multi-speed pump time to complete 1 turnover (Table 185)

60 = Constant to convert between minutes and hours

1000 = Constant to convert W to kW

Table 184: Conventional Pool Pumps Assumptions

Pump HP	hours$_{conv}$	PFR$_{conv}$(gal/min)	EF$_{conv}$ (gal/W·h)
0.5	11.0	50.0	2.71
0.75	10.4	53.0	2.57
1	9.2	60.1	2.40
1.5	8.6	64.4	2.09
2	8.5	65.4	1.95
2.5	8.1	68.4	1.88
3	7.5	73.1	1.65

Table 185: ENERGY STAR® Multi-Speed Pool Pumps Assumptions

Pump HP	t$_{,turnover,MS}$	hours$_{MS,LS}$	PFR$_{HS,MS}$ (gal/min)	EF$_{HS,MS}$ (gal/W·h)	PFR$_{LS,MS}$ (gal/min)	EF$_{LS,MS}$ (gal/W·h)
1	11.8	9.8	56.0	2.40	31.0	5.41
1.5	11.5	9.5	61.0	2.27	31.9	5.43
2	11.0	9.0	66.4	1.95	33.3	5.22
2.5	10.8	8.8	66.0	2.02	34.0	4.80
3	9.9	7.9	74.0	1.62	37.0	4.76

Demand savings can be derived using the following:

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \left(\frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right)\right] \times \frac{CF}{days}$$

(161)

Where:

CF = Coincidence factor[263] = 0.31

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[263] Southern California Edison (SCE) Design & Engineering Services, 2008., *"Pool Pump Demand Response Potential, DR 07.01 Report."* June 2008. Derived from Table 16 assuming a peak period of 2-6 PM.

2.4.6 ENERGY STAR® Dehumidifer

Measure Description

This measure includes installing a dehumidifier meeting the minimum qualifying efficiency standard set forth by the current ENERGY STAR® Version 4.0 (effective 10/25/2016) in place of a unit that meets the minimum federal standard efficiency.

Baseline and Efficiency Standards

The baseline condition for this measure is a new dehumidifier that meets the Federal Standard efficiency standards. Table 186 provides the Federal Standards for Dehumidifiers as of August 2017.

Table 186: Federal Standard for Dehumidifiers

Capacity (pints/day)	Federal Standard Criteria (L/kWh)
> 35	≥ 1.35
> 35 to ≤ 45	≥ 1.50
> 45 to ≤ 54	≥ 1.60
> 54 to ≤ 75	≥ 1.70
> 75 to ≤ 185	≥ 2.50

The efficient humidifier must meet the ENERGY STAR® standards as defined in Table 187.

Table 187: ENERGY STAR® Dehumidifier Standards

Capacity (pints/day)	Energy Factor (L/kWh)[264]
< 75	≥ 2.00
75 to ≤ 185	≥ 2.80

Estimated Useful Life (EUL)

The assumed lifetime of the measure is 12 years.[265]

Calculation of Deemed Savings

Energy Savings

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[264] ENERGY STAR Dehumidifiers Key Efficiency Criteria. https://www.energystar.gov/products/appliances/dehumidifiers/key_efficiency_criteria

[265] EPA Research, 2012; ENERGY STAR Dehumidifier Calculator

$$Annual\ Energy\ Savings = \left[\left(\frac{Avg\ Cap\ x\ 0.473}{24}\right)\ x\ Hours\right] * \left[\left(\frac{1}{L/kWh_{Base}}\right) - \left(\frac{1}{L/kWh_{Eff}}\right)\right]$$

(162)

Where:

Avg Cap = Average capacity of unit (pints/day)

= Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average

0.473 = Constant to covert Pints to Liters

24 = Constant to convert Liters/day to Liters/hour

Hours = run hours per year

= 1,632[266]

L/kWh_{Base} = Liters of water per kWh consumed (see Table 186)

L/kWh_{Eff} = Liters of water per kWh consumed (see Table 187)

Annual energy consumption and savings for each capacity class are shown in Table 188.

Table 188: Annual Energy Savings by Capacity Range

Capacity Range (pints/day)	Capacity Used (pints/day)	Federal Standard (≥ L/kWh)	ENERGY STAR (≥ L/kWh)	Federal Standard (kWh)	ENERGY STAR (kWh)	Savings (kWh)
≤ 25	20	1.35	2.0	477	322	155
> 25 to ≤ 35	30	1.35	2.0	715	482	232
> 35 to ≤ 45	40	1.5	2.0	858	643	214
> 45 to ≤ 54	50	1.6	2.0	1,005	804	201
> 54 to ≤ 75	65	1.7	2.0	1,230	1,045	184
> 75 to ≤ 185	130	2.5	2.8	1,673	1,493	179

Demand Savings

$$kW_{savings} = \left(\frac{kWh_{Savings}}{Hours}\right)\ x\ CF$$

(163)

Where:

Hours = Annual operating hours

= 1,632[267]

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[266] ENERGY STAR® calculator; 24 hour operation over 68 days of the year. Effective October 25, 2016

[267] ENERGY STAR® calculator; 24 hour operation over 68 days of the year. Effective October 25, 2016

CF = Summer Peak Coincidence Factor for measure

= 0.37[268]

Summer coincident peak demand savings for each capacity class is shown in Table 189.

Table 189: Summer Peak Coincident Demand Savings

Capacity Range (pints/day)	Annual Summer Peak Demand Savings (kW)
≤ 25	0.035
> 25 to ≤ 35	0.053
> 35 to ≤ 45	0.049
> 45 to ≤ 54	0.046
> 54 to ≤ 75	0.042
> 75 to ≤ 185	0.041

The expected energy and demand savings for installing an ENERGY STAR® Dehumidifier are shown in the following example table. This table is provided merely as an *example*.

Example Calculation of Deemed Savings Values

Example Table, 50 Pints/Day Capacity ENERGY STAR® Dehumidifier Deemed Energy Savings

50 Pints/Day Dehumidifier	
Capacity (pints/day)	50
L/kWh_{Base}	1.6
L/kWh_{Eff}	2.0
Energy Savings (kWh)	201
Demand Savings (kW)	0.046

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[268] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through September (4,392 possible hours). 1,632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer is therefore 1,632/4,392 = 37.2%.

2.5 Lighting

2.5.1 Lighting Efficiency

These measures apply to all residential applications.

2.5.1.1 ENERGY STAR® Compact Fluorescent Lamps (CFLs)

Measure Description

This measure provides a method for calculating savings for replacing an incandescent lamp with a standard CFL in residential applications.

Baseline

The baseline equipment is assumed to be an incandescent or halogen lamp with adjusted baseline wattages compliant with EISA 2007 regulations dictate higher efficiency baseline lamps.

The first Tier of EISA 2007 regulations were phased in from January 2012 to January 2014. Beginning January 2012, a typical 100W lamp wattage was reduced to comply with a maximum 72W lamp wattage standard for a rated lumen output range of 1,490-2,600 lumens. Beginning January 2013, a typical 75W lamp wattage was reduced to comply with a maximum 53W lamp wattage standard for a rated lumen output range of 1,050-1,489 lumens. Beginning January 2014, typical 60W and 40W lamp wattages were reduced to comply with maximum 43W and 29W lamp wattage standards for rated lumen output ranges of 750-1,049 and 310-749 lumens.

The second Tier of EISA 2007 regulations go into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen per watt efficacy standard.[269] Since the EUL of some lamps in this measure extend beyond that date, the baseline should be adjusted to the second Tier for any years after 2022.[270]

Efficiency Standard

CFLs must be a standard ENERGY STAR® QUALIFIED CFL.

Exceptions to the ENERGY STAR® LABEL are allowed for unlisted lamps, fixtures or other lighting-related devices that have been submitted to ENERGY STAR® FOR approval. If the lamp or fixture does not achieve ENERGY STAR® APPROVAL within the AR DSM program year, however, then the lamp or fixture would have to be immediately withdrawn from the program.

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[269] Note that on January 18, 2017, DOE issued the Final Rules on General Service Lamps for the second Tier of EISA (https://energy.gov/eere/buildings/downloads/two-gsl-final-rules). These rules, in general, expand the definition of GSLs, extending the covered lumen range, base types, and shapes, as well as reduce the types of bulbs exempted. According to the rulings, these expanded bulbs will be subject to GSL efficiency standards, including the 2020 backstop, starting January 1, 2020. Because of political uncertainty over this ruling, particularly regarding enforcement, the IEM will assess the impact of this ruling as part of the PY 2018 TRM.

[270] First tier EISA compliant halogens have a lifetime of 4 years (3,000 hours at 2.17 hours per day). The last year these lamps are available is 2019, and they will need replacement at the end of 2022. Thus, the new standard must be used after 2022.

Estimated Useful Life (EUL)

The average measure life is based upon rated lamp life of the CFL shown in the following table. The measure life assumes an average daily use of 2.17 blended[271] hours for indoor/outdoor applications and applies a 0.688[272] degradation factor to indoor residential CFLs. This table shows the useful life that should be used for the first tier EISA baseline, and the useful life remaining for the increased second tier EISA standard baseline.

Note that the values are in this table are incremented each program year so that the first tier values do not exceed 2023 minus the program year. For PY 2018, the first tier measure life cannot exceed the result of 2023 - 2018, which is equal to 5 years. The remainder of the measure life is applied to the second tier.

Table 190: ENERGY STAR® CFLs – Measure Life[273]

Rated Measure Life (Hours)	First Tier EISA Standard Baseline		Second Tier EISA Standard Baseline	
	CFL Indoor Application – Measure Life (Years)	CFL Outdoor Application – Measure Life (Years)	CFL Indoor Application – Measure Life (Years)	CFL Outdoor Application – Measure Life (Years)
8,000	5	5	2	2
10,000	5	5	4	4
12,000	5	5	5	6
15,000	5	5	8	8

Coincidence Factor

Cadmus performed a residential light logging study in 2013 in Arkansas on behalf of Entergy. This study estimated a mean coincidence factor of 10 percent for non-holiday summer weekdays from 3:00 p.m. to 7:00 p.m.[274]

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[271] Residential light logging study by Cadmus - Entergy Arkansas, Inc. *2013 EM&V Evaluation Report.*

[272] Average of 0.526 and 0.85. Original 0.526 is from Itron, Hirsch and Associates, and Research Into Action, "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life"2008 ACEEE Summer Study on Energy Efficiency in Buildings, p. 2-146; and 0.85 is from ENERGY STAR® CFL THIRD PARTY TESTING AND VERIFICATION Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[273] EUL = Rated Measure Life in Hours * Degradation Factor / (365.25 * Average Hours of Daily Use). Degradation Factor = 0.526 for indoor applications and 1.000 for outdoor applications.

[274] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

Calculation of Deemed Savings

For retail (time of sale) programs, increased savings may be claimed based on sales to nonresidential customers.[275] Based on a review of 23 utility programs across 10 states, 6.7 percent of installed lamps may be allocated to the commercial program. To implement, multiply the total number of fixtures by 6.7 percent and apply the savings methodologies described in the Commercial Lighting Efficiency measure. Since no building type will have been identified, apply the weighted average annual operating hours and coincidence factor based on a review of the building types that participating in commercial lighting programs during the current program year.

Calculate savings for the remaining 93.3 percent of fixtures using the residential savings calculations described below. If it is not possible to apply the commercial allocation strategy described above, a program may calculate savings for all fixtures using the residential savings calculations described below. This will result in a conservative estimate for upstream programs. Note: This strategy should only be applied to retail (time of sale) programs. For all other programs, use the residential savings calculations exclusively.

Energy Savings

$$kWh_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_E$$

(164)

Where:

W_{base} = Based on wattage equivalent of the lumen output of the purchased CFL lamp and the program year purchased/installed

W_{post} = Actual wattage of CFL purchased/installed

$Hours$ = Average hours of use per year

IEF_E = Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed

When the EISA 2007 standard goes into effect for a CFL, the reduced wattage savings should be claimed for the rest of the measure life. For example, up until 2022, a 20W CFL with 1200 lumens may claim a 53W baseline. After 2022, the baseline becomes 27W for the remainder of the measure life.

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[275] Dimetrosky, S., Parkinson, K. & Lieb, N. 2015, “Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.” January.

Table 191: ENERGY STAR® CFLs – EISA Baselines[276]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 (W_{base})	Incand. Equiv. 2nd Tier EISA 2007 (W_{base})[277]	Effective dates for 2nd Tier EISA 2007 Baselines
310	749	29	12	1/1/2020
750	1,049	43	20	1/1/2020
1,050	1,489	53	28	1/1/2020
1,490	2,600	72	45	1/1/2020

Table 192: ENERGY STAR® CFLs – Average Hours of Use Per Year

Installation Location	Hours
Blended Indoor/Outdoor[278]	792.6

Table 193: ENERGY STAR® CFLs – In Service Rates

Program	CFL ISR
Retail (Time of Sale) and Direct Install[279]	0.97

Table 194: ENERGY STAR® CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties

Heating Type	Interactive Effects Factor (IEF_E)[280]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[281]	0.97

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[276] Note that ENERGY STAR® has recently assigned new incandescent equivalent wattage lumen bins for the ENERGY STAR® v2.0 lighting standards (see https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20OCT-2016_1.pdf, page 13)). This TRM maintains the EISA lumen bins for assigning baseline wattage. Future TRM iterations of the AR TRM, however, may incorporate these new lumen bins for baseline wattage estimates.

[277] Wattages developed using the 45 lpw standard that goes into effect in 2020.

[278] Annual Hours of Use= 2.17 Average Daily Hours of Use * 365.25 Days per Year.

[279] Reflects best-available information in Arkansas for first-year installation rates, applying a four-year trajectory of installation and a discounting based on Uniform Methods Project residential lighting protocol. The first year ISR for retail is 92.6% based on 2014 Entergy evaluation for retail CFLs. In 2016, SWEPCO evaluated direct install LEDs and found a 95% first-year ISR, which results in similar result once trajectory and discounting are conducted.

[280] Refer to Appendix I, Arkansas TRM 7.0 Volume 3.

[281] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Summer Peak Demand Savings

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times CF \times ISR \times IEF_D \tag{165}$$

Where:

CF = Summer Peak Coincidence Factor for measure

IEF_D = Interactive Effects Factor to account for cooling demand savings; this factor also applies to outdoor and unconditioned spaces

Table 195: Residential Lighting Efficiency – Summer Peak Coincidence Factor

Lamp Location	CF
Indoor[282]	10%
Outdoor	0%

Table 196: ENERGY STAR® CFLs – Interactive Effects Factor for Cooling Demand Savings

Heating Type	Interactive Effects Factor (IEF_D)[283]
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[284]	1.25

Heating Penalty for Natural Gas Heated Homes

$$Therms_{penalty} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_G \tag{166}$$

Where:

IEF_G = Interactive Effects Factor to account for gas heating penalties (Δtherm/kWh); this factor also applies to outdoor and unconditioned spaces
Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure, including single fuel, electric-only programs.[285]

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[282] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[283] The IEF_G factor was weighted by those lamps installed in and out of conditioned space, and thus should be applied to all lamps. Refer to Appendix I, Arkansas TRM 7.0 Volume 3.

[284] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

[285] Electric-only programs can quantify the value of the increased therm interactive effects, as discussed in Protocol L of the TRM, and treat this as a "negative benefit".

Table 197: ENERGY STAR® CFLs – Interactive Effects Factor for Gas Heating Penalties

Heating Type	Interactive Effects Factor (IEF_G)[286]
Gas Heat with AC	-0.011
Gas Heat with no AC	-0.011
Electric Resistance Heat with AC	0
Electric Resistance Heat with no AC	0
Heat Pump	0
Heating/Cooling Unknown[287]	-0.0063

Annual kW, Annual kWh, and Lifetime kWh Savings Calculation Example

A 5W CFL is installed in program year (PY) 2017. In July 2014 Tier 1 EISA 2007 standards went into effect, and the baseline shifted to 29 watts. In January 2023, due to Tier 2 EISA 2007 standards going into effect, the baseline will shift again to 12 watts. This CFL has a rated life of 15,000 hours. Necessary inputs for calculating the kWh savings include the EUL (13.0 years), IEF_D (1.25 for unknown heating/cooling type), IEF_E (0.97 for unknown cooling/heating type), ISR (0.98), summer coincidence factor (0.1), and Hours of Use per Year (792.6 hours). All kWh values are rounded to the second decimal place.

<u>PY 2018 through PY 2022 Savings:</u> From January 2018 to December 2022, the baseline is 29 watts. 2023 – 2016 is 6 years.

$$2017\ to\ 2022\ kW\ Savings\ (for\ each\ year) = \left(\frac{[29-5]}{1000}\right) \times 0.1 \times 1.25 \times 0.98 = 0.0029\ kW$$

$$Cumulative\ 2017\ to\ 2022\ kWh\ Savings = \left(\frac{[29-5]}{1000}\right) \times 792.6 \times 0.97 \times 0.98 \times 5 = 90.41\ kWh \tag{167}$$

<u>PY 2023 through PY 2029 Savings:</u> In January 2023, the baseline changes to the 2nd Tier EISA 2007 standard. The baseline wattage changes from 29 watts to 12 watts. The remaining measure life is 7 years.

$$2023\ to\ 2029\ kW\ Savings\ (for\ each\ year) = \left(\frac{[12-5]}{1000}\right) \times 0.1 \times 1.25 \times 0.98 = 0.0009\ kW$$

$$Cumulative\ 2023\ to\ 2029\ kWh\ Savings = \left(\frac{[12-5]}{1000}\right) \times 792.6 \times 0.97 \times 0.98 \times 7 = 36.92\ kWh \tag{168}$$

<u>Lifetime kWh Savings:</u>

$90.41 + 36.92 = 127.33\ kWh\ lifetime\ savings$

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[286] Refer to Appendix I, Arkansas TRM 7.0 Volume 3

[287] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

2.5.1.2 ENERGY STAR® Specialty Compact Fluorescent Lamps (CFLs)

Measure Description

This measure provides a method for calculating savings for replacing a specialty incandescent or halogen lamp with an ENERGY STAR® QUALIFIED specialty CFL. These lamps include R, PAR, ER, BR, BPAR, globes G40, decorative globes equal to or less that 60W with candelabra base, and decorative candles equal to or less than 60W with candelabra base.

Baseline

The baseline equipment is a specialty incandescent or halogen lamp.[288]

Efficiency Standard

CFLs must be an ENERGY STAR® SPECIALTY CFL.

Exceptions to the ENERGY STAR® LABEL are allowed for unlisted lamps, fixtures or other lighting-related devices that have been submitted to ENERGY STAR® FOR approval. If the lamp or fixture does not achieve ENERGY STAR® APPROVAL within the Arkansas DSM program year, however, then the lamp or fixture would have to be immediately withdrawn from the program.

Estimated Useful Life (EUL)

The average measure life is based upon rated lamp life of the CFL shown in the following table. The measure life assumes an average daily use of 2.17 blended[289] hours for indoor/outdoor applications and applies a 0.688[290] degradation factor to indoor residential CFLs.

Table 198: ENERGY STAR® Specialty CFLs – Measure Life[291]

Rated Measure Life (Hours)	Indoor Application – Measure Life (Years)	Outdoor Application – Measure Life (Years)
8,000	7	7
10,000	9	9
12,000	10	11
15,000	13	13

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[288] Note that on January 18, 2017, DOE issued the Final Rules on General Service Lamps for the second Tier of EISA (https://energy.gov/eere/buildings/downloads/two-gsl-final-rules). These rules, in general, expand the definition of GSLs, extending the covered lumen range, base types, and shapes, as well as reduce the types of bulbs exempted. According to the rulings, these expanded bulbs will be subject to GSL efficiency standards, including the 2020 backstop, starting January 1, 2020. Because of political uncertainty over this ruling, particularly regarding enforcement, the IEM will assess the impact of this ruling as part of the PY 2018 TRM.

[289] Residential light logging study by Cadmus - Entergy Arkansas, Inc. *2013 EM&V Evaluation Report.*

[290] Average of 0.526 and 0.85. Original 0.526 is from Itron, Hirsch and Associates, and Research Into Action, "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life". 2008 ACEEE Summer Study on Energy Efficiency in Buildings, p. 2-146; and 0.85 is from ENERGY STAR® CFL THIRD PARTY TESTING AND VERIFICATION Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[291] EUL = Rated Measure Life in Hours * Degradation Factor / (365.25 * Average Hours of Daily Use). Degradation Factor = 0.526 for indoor applications and 1.000 for outdoor applications.

Coincidence Factor

Cadmus performed a residential light logging study in 2013 in Arkansas on behalf of EAI. This study estimated a mean coincidence factor of 10 percent for non-holiday summer weekdays from 3:00 p.m. to 7:00 p.m.[292]Residential CFLs installed outdoors are not expected to be on during summer peak demand hours. Outdoor CFLs will have a coincidence factor of 0 percent.

Calculation of Deemed Savings

For retail (time of sale) programs, increased savings may be claimed based on sales to nonresidential customers.[293] Based on a review of 23 utility programs across 10 states, 6.7 percent of installed lamps may be allocated to the commercial program. To implement, multiply the total number of fixtures by 6.7 percent and apply the savings methodologies described in the Commercial Lighting Efficiency measure. Since no building type will have been identified, apply the weighted average annual operating hours and coincidence factor based on a review of the building types that participating in commercial lighting programs during the current program year.

Calculate savings for the remaining 93.3 percent of fixtures using the residential savings calculations described below. If it is not possible to apply the commercial allocation strategy described above, a program may calculate savings for all fixtures using the residential savings calculations described below. This will result in a conservative estimate for upstream programs.

Note: This strategy should only be applied to retail (time of sale) programs. For all other programs, use the residential savings calculations exclusively.

Energy Savings

$$kWh_{savings} = \left((W_{base} - W_{post})/1000\right) \times Hours \times ISR \times IEF_E$$

(169)

Where:

W_{base} = Baseline lamp wattage of equivalent lumens: use nameplate wattage or wattage equivalent to lumen output; for directional (reflector) lamps, use the default baseline wattages (Column C) in Table 199 (exempt reflector lamps should use the manufacturer rated equivalent wattage as the baseline)

W_{post} = Actual wattage of CFL purchased/installed

$Hours$ = Average hours of use per year

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed

IEF_E= Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces

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[292] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[293] Dimetrosky, S. et al., 2015, Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. January.

Table 199: ENERGY STAR® Specialty CFLs - Default Baseline Wattage for Reflector Lamps[294]

Lamp Type (a)	Incandescent Equivalent (Pre-EISA) (b)	$\text{Watts}_{\text{Base}}$ (EISA Tier 1) (c)	$\text{Watts}_{\text{Base}}$ (EISA Tier 2) Effective 1/1/2020[295] (c)
PAR20	50	35	23
PAR30	50	35	23
R20	50	45	29
PAR38	60	55	35
BR30	65	EXEMPT	38
BR40	65	EXEMPT	38
ER40	65	EXEMPT	38
BR40	75	65	42
BR30	75	65	42
PAR30	75	55	35
PAR38	75	55	35
R30	75	65	42
R40	75	65	42
PAR38	90	70	45
PAR38	120	70	45
R20	≤ 45	EXEMPT	23
BR30	≤ 50	EXEMPT	EXEMPT
BR40	≤ 50	EXEMPT	EXEMPT
ER30	≤ 50	EXEMPT	EXEMPT
ER40	≤ 50	EXEMPT	EXEMPT

For other specialty, EISA exempt lamps[296], use the baseline wattage in Table 200. Commonly used EISA exempt lamps include 3-way lamps, globes with ≥ 5” diameter or ≤ 749 lumens, and candelabra base lamps with ≤ 1049 lumens. See EISA legislation for full list of exemptions. If rated lumen values fall above or below these values, use manufacturer rated equivalent incandescent wattage.

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[294] Based on manufacturer available reflector lighting products as available in August 2013.

[295] Developed based on using Tier 1 efficacy for standard lamps and adjusting efficacy to the 45 lum/Watt requirement stated for EISA Tier 2.

[296] A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States U.S. DOE Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET. www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf.

Table 200: Default Baseline Wattage for Specialty, EISA Exempt Lamps[297]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent (W_{base})
310	749	40
750	1,049	60
1,050	1,489	75
1,490	2,600	100

Table 201: ENERGY STAR® Specialty CFLs – Average Hours of Use

Installation Location	Hours
Blended Indoor/Outdoor[298]	792.6

Table 202: ENERGY STAR® Specialty CFLs – In Service Rates

Program	ISR
Retail (Time of Sale) and Direct Install[299]	0.97

Table 203: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Penalties

Heating Type	Interactive Effects Factor (IEF_E)[300]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[301]	0.97

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[297] Note that ENERGY STAR® has recently assigned new incandescent equivalent wattage lumen bins for the ENERGY STAR® v2.0 lighting standards (see https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20OCT-2016_1.pdf, page 13)). This TRM maintains the EISA lumen bins for assigning baseline wattage. Future TRM iterations of the AR TRM, however, may incorporate these new lumen bins for baseline wattage estimates.

[298] Annual Hours of Use = 2.17 Average Daily Hours of Use * 365.25 Days per Year

[299] Reflects best-available information in Arkansas for first-year installation rates, applying a four-year trajectory of installation and a discounting based on Uniform Methods Project residential lighting protocol. The first year ISR for retail is 92.6% based on 2014 Entergy evaluation for retail CFLs. In 2016, SWEPCO evaluated direct install LEDs and found a 95% first-year ISR, which results in similar result once trajectory and discounting are conducted.

[300] Refer to Appendix I, Arkansas TRM 6.0 Volume 3.

[301] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Summer Peak Demand Savings

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times CF \times ISR \times IEF_D$$

(170)

Where:

CF = Summer Peak Coincidence Factor for measure

IEF_D = Interactive Effects Factor to account for cooling demand savings; this factor also applies to outdoor and unconditioned spaces

Table 204: ENERGY STAR® Specialty CFLs – Summer Peak Coincidence Factor

Lamp Location	**CF**
Indoor[302]	10%
Outdoor	0%

Table 205: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Cooling Demand Savings

Heating Type	**Interactive Effects Factor (IEF_D)**[303]
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[304]	1.25

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[302] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[303] Refer to Appendix I, Arkansas TRM 6.0 Volume 3.

[304] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Heating Penalty for Natural Gas Heated Homes

$$Therms_{penalty} = \left((W_{base} - W_{post})/1000\right) \times Hours \times ISR \times IEF_G$$

(171)

Where:

IEF_G = Interactive Effects Factor to account for gas heating penalties (Δtherm/kWh); this factor also applies to outdoor and unconditioned spaces

Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure, including single fuel, electric-only programs.[305]

Table 206: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Gas Heating Penalties

Heating Type	Interactive Effects Factor (IEF_G)[306]
Gas Heat with AC	-0.011
Gas Heat with no AC	-0.011
Electric Resistance Heat with AC	0
Electric Resistance Heat with no AC	0
Heat Pump	0
Heating/Cooling Unknown[307]	-0.0063

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[305] Electric-only programs can quantify the value of the increased therm interactive effects, as discussed in Protocol L of the TRM, and treat this as a “negative benefit”.

[306] The IEF_G factor was weighted by those lamps installed in and out of conditioned space, and thus should be applied to all lamps. Refer to Appendix I, Arkansas TRM Volume 3

[307] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

2.5.1.3 ENERGY STAR® Specialty LEDs

Measure Description

This measure provides a method for calculating savings for replacing an incandescent or halogen reflector or other specialty lamp with an ENERGY STAR® QUALIFIED LED lamp. These lamp shapes include PAR, R, BR, MR, and similar lamp shapes, as well as other specialty lamps such as 3-way lamps, globes and candelabra base lamps.

Baseline

The baseline equipment is assumed to be an incandescent or halogen lamp, and where applicable, with adjusted baseline wattages compliant with EISA 2007 regulations dictate higher efficiency baseline lamps.

Directional and most specialty lamps were not covered under Tier 1 EISA legislation. Directional lamps are currently governed by a 2009 DOE rulemaking for Incandescent Reflector Lamps (IRL)—this ruling went into effect in July 2012. The baselines for these products are from this IRL ruling in July 2012. The first Tier of EISA 2007 regulations, as originally drafted, did not apply to all bulb types. Commonly used pre-2020 EISA-exempt bulbs include: reflectors, three-way bulbs, globes with ≥ 5-in. diameter or ≤ 749 lumens, candelabra base bulbs with ≤ 1049 lumens.[308]

On January 18, 2017, DOE issued the Final Rules on General Service Lamps for the second Tier of EISA.[309] These rules, in general, expand the definition of GSLs, extending the covered lumen range, base types, and shapes, as well as reduce the types of bulbs exempted. According to the rulings, these expanded bulbs will be subject to GSL efficiency standards, including the 2020 backstop, starting January 1, 2020. This ruling covers IRLs and adds them to the provisions for EISA Tier 2.

The ruling includes the following:

- **Reflector exemptions:** Reflector bulbs will no longer be exempt. The following three reflector lamp types (which represent the vast majority of reflectors) are no longer exempt from GSL standards: (A) Lamps rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps; (B) Lamps rated at 65 watts that are BR30, BR40, or ER40 lamps; or (C) R20 incandescent reflector lamps rated 45 watts or less.
- **Lumen maximums:** The lumen maximum subject to the EISA GSL definition has been expanded to 3,300 lumens (previously 2600).
- **Base types exemptions**: All standard bulb bases will be included (small screw base and candelabra).
- **Other exemptions**: 3-way, decorative (including globes <5", flame shapes and candelabra shape), T-lamps (≤40w OR ≥ 10"), vibration service, rough service, and shatter resistant bulb exemptions are to be discontinued. These bulbs will be subject to GSL efficiency regulations starting January 1, 2020

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[308] See EISA legislation for the full list of exemptions.

[309] https://energy.gov/eere/buildings/downloads/two-gsl-final-rules

Efficiency Standard

LEDs must be ENERGY STAR® QUALIFIED for the relevant lamp shape being removed.

Exceptions to the ENERGY STAR® label are allowed for unlisted lamps, fixtures or other lighting-related devices that have been submitted to ENERGY STAR® for approval. If the lamp or fixture does not achieve ENERGY STAR® approval within the Arkansas DSM program year, however, then the lamp or fixture would have to be immediately withdrawn from the program.

Estimated Useful Life (EUL)

The measure life for indoor and outdoor LED reflector is 20 years and decorative and omnidirectional is 19 years.[310]

For those bulbs covered under EISA Second Tier standards, the savings over the useful life will need to be adjusted to account for second tier EISA standards for all years after 2022.

Table 207: ENERGY STAR® LEDs – Measure Life

Rated Measure Life (Hours)	Exempt/First Tier EISA Standard Baseline or Exempt	Second Tier EISA Standard Baseline
≥ 15,000[311] for omnidirectional and decorative LEDs	5	14
≥ 25,000 for diectional LEDs	5	15

Daily Hours of Use

These deemed savings assume an average daily use of 2.17 blended[312] hours for indoor/outdoor applications.

Coincidence Factor

Cadmus performed a residential light logging study in 2013 in Arkansas on behalf of Entergy. This study estimated a mean coincidence factor of 10 percent for non-holiday summer weekdays from 3:00 p.m. to 7:00 p.m.[313]

Residential CFLs installed outdoors are not expected to be on during summer peak demand hours. Outdoor LEDs will have a coincidence factor of 0 percent.

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[310] Emerging Technologies Research Report prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships (NEEP). February 13, 2013.

[311] Minimum requirement from current ENERGY STAR® specification. https://www.energystar.gov/products/lighting_fans/light_bulbs/key_product_criteria.

[312] Residential light logging study by Cadmus - Entergy Arkansas, Inc. *2013 EM&V Evaluation Report*.

[313] Ibid.

Calculation of Deemed Savings

For retail (time of sale) programs, increased savings may be claimed based on sales to nonresidential customers.[314] Based on a review of 23 utility programs across 10 states, 6.7 percent of installed lamps may be allocated to the commercial program. To implement, multiply the total number of fixtures by 6.7 percent and apply the savings methodologies described in the Commercial Lighting Efficiency measure. Since no building type will have been identified, apply the weighted average annual operating hours and coincidence factor based on a review of the building types that participating in commercial lighting programs during the current program year.

Calculate savings for the remaining 93.3% of fixtures using the residential savings calculations described below. If it is not possible to apply the commercial allocation strategy described above, a program may calculate savings for all fixtures using the residential savings calculations described below. This will result in a conservative estimate for upstream programs.

Note: This strategy should only be applied to retail (time of sale) programs. For all other programs, use the residential savings calculations exclusively.

Energy Savings

$$kWh_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_E \tag{172}$$

Where:

W_{base} = Baseline lamp wattage of equivalent lumens; for directional (reflector) lamps, use the default baseline wattages (Column C) in Table 208 (exempt reflector lamps should use the manufacturer rated equivalent wattage as the baseline)

W_{post}= Actual wattage of LED purchased/installed

$Hours$ = Average hours of use per year

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed

IEF_E = Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces

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[314] Dimetrosky, S. et al, 2015. “Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.” January.

Table 208: ENERGY STAR® Directional LEDs – Default Baseline Wattage for Reflector Lamps[315]

Lamp Type (a)	Incandescent Equivalent (Pre-EISA) (b)	$\text{Watts}_{\text{Base}}$ (EISA Tier 1) (c)	$\text{Watts}_{\text{Base}}$ (EISA Tier 2) Effective 1/1/2020[316] (c)
PAR20	50	35	23
PAR30	50	35	23
R20	50	45	29
PAR38	60	55	35
BR30	65	EXEMPT	38
BR40	65	EXEMPT	38
ER40	65	EXEMPT	38
BR40	75	65	42
BR30	75	65	42
PAR30	75	55	35
PAR38	75	55	35
R30	75	65	42
R40	75	65	42
PAR38	90	70	45
PAR38	120	70	45
R20	≤ 45	EXEMPT	23
BR30	≤ 50	EXEMPT	EXEMPT
BR40	≤ 50	EXEMPT	EXEMPT
ER30	≤ 50	EXEMPT	EXEMPT
ER40	≤ 50	EXEMPT	EXEMPT

For other specialty, EISA exempt lamps[317], use the baseline wattage in Table 209. Commonly used EISA exempt lamps include 3-way lamps, globes with ≥ 5” diameter or ≤ 749 lumens, and candelabra base lamps with ≤ 1049 lumens. See EISA legislation for full list of exemptions. If rated lumen values fall above or below these values, use manufacturer rated equivalent incandescent wattage.

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[315] Based on manufacturer available reflector lighting products as available in August 2013.

[316] Developed based on using Tier 1 efficacy for standard lamps and adjusting efficacy to the 45 lum/Watt requirement stated for EISA Tier 2.

[317] A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States U.S. DOE Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET. www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf.

Table 209: ENERGY STAR® Directional LEDs – Default Baseline Wattage for Specialty, EISA Exempt Lamps[318]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent (W_{base})
310	749	40
750	1,049	60
1,050	1,489	75
1,490	2,600	100

Table 210: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps Average Hours of Use

Installation Location	Hours
Blended Indoor/Outdoor[319]	792.6

Table 211: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps In Service Rates

Program	ISR
Retail (Time of Sale) and Direct Install[320]	0.97

Table 212: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps Interactive Effects for Cooling Energy Savings and Heating Energy Penalties

Heating Type	Interactive Effects Factor (IEF_E)[321]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[322]	0.97

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[318] Note that ENERGY STAR® has recently assigned new incandescent equivalent wattage lumen bins for the ENERGY STAR® v2.0 lighting standards (see https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20OCT-2016_1.pdf, page 13). This TRM maintains the EISA lumen bins for assigning baseline wattage. Future TRM iterations of the AR TRM, however, may incorporate these new lumen bins for baseline wattage estimates.

[319] Annual Hours of Use = 2.17 Average Daily Hours of Use * 365.25 Days per Year

[320] Reflects best-available information in Arkansas for first-year installation rates, applying a four-year trajectory of installation and a discounting based on Uniform Methods Project residential lighting protocol. The first year ISR for retail is 92.6% based on 2014 Entergy evaluation for retail CFLs. In 2016, SWEPCO evaluated direct install LEDs and found a 95% first-year ISR, which results in similar result once trajectory and discounting are conducted.

[321] Refer to Appendix I, Arkansas TRM 6.0 Volume 3.

[322] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Summer Peak Demand Savings

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times CF \times ISR \times IEF_D$$

(173)

Where:

CF = Summer Peak Coincidence Factor for measure

IEF_D = Interactive Effects Factor to account for cooling demand savings; this factor also applies to outdoor and unconditioned spaces

Table 213: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps Summer Peak Coincidence Factor

Lamp Location	CF
Indoor[323]	10%
Outdoor	0%

Table 214: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps Interactive Effects Factor for Cooling Demand Savings

Heating Type	Interactive Effects Factor (IEF_D)[324]
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[325]	1.25

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[323] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[324] Refer to Appendix I, Arkansas TRM 6.0 Volume 3.

[325] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Heating Penalty for Natural Gas Heated Homes

$$Therms_{penalty} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_G$$

(174)

Where:

IEF_G = Interactive Effects Factor to account for gas heating penalties (Δtherm/kWh); this factor also applies to outdoor and unconditioned spaces

Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure, including single fuel, electric-only programs.[326]

Table 215: ENERGY STAR® Directional LEDs – Reflector and Decorative Lamps Interactive Effects Factor for Gas Heating

Heating Type	**Interactive Effects Factor (IEF_G)**[327]
Gas Heat with AC	-0.011
Gas Heat with no AC	-0.011
Electric Resistance Heat with AC	0
Electric Resistance Heat with no AC	0
Heat Pump	0
Heating/Cooling Unknown[328]	-0.0063

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[326] Electric-only programs can quantify the value of the increased therm interactive effects, as discussed in Protocol L of the TRM, and treat this as a "negative benefit".

[327] The IEF_G factor was weighted by those lamps installed in and out of conditioned space, and thus should be applied to all lamps Refer to Appendix I, Arkansas TRM 6.0 Volume 3

[328] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

2.5.1.4 ENERGY STAR® Omni-Directional LEDs

Measure Description

This measure provides a method for calculating savings for replacing an incandescent or halogen lamp with an omni-directional LED in residential applications. The applicable lamp types that are omni-directional LEDs are the following shapes, using ANSI C79.1-2002 nomenclature: A, BT, P, PS, S, and T.[329]

Baseline

The baseline equipment is assumed to be an incandescent or halogen lamp with adjusted baseline wattages compliant with EISA 2007 regulations dictate higher efficiency baseline lamps.

The first Tier of EISA 2007 regulations were in from January 2012 to January 2014. Beginning January 2012, a typical 100W lamp wattage was reduced to comply with a maximum 72W lamp wattage standard for a rated lumen output range of 1,490-2,600 lumens. Beginning January 2013, a typical 75W lamp wattage was reduced to comply with a maximum 53W lamp wattage standard for a rated lumen output range of 1,050-1,489 lumens. Beginning January 2014, typical 60W and 40W lamp wattages were reduced to comply with maximum 43W and 29W lamp wattage standards for rated lumen output ranges of 750-1,049 and 310-749 lumens.

The second Tier of EISA 2007 regulations go into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen per watt efficacy standard. Since the EUL of some lamps in this measure extend beyond that date, the baseline should be adjusted to the second Tier for any years after 2022.[330]

Efficiency Standard

Omni-directional LEDs must be a standard ENERGY STAR® qualified omni-directional LED.

Exceptions to the ENERGY STAR® label are allowed for unlisted lamps, fixtures or other lighting-related devices that have been submitted to ENERGY STAR® for approval. If the lamp or fixture does not achieve ENERGY STAR® approval within the Arkansas DSM program year, however, then the lamp or fixture would have to be immediately withdrawn from the program.

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[329] According to ENERGY STAR®, omni-directional LED products "…shall have an even distribution of luminous intensity (candelas) within the 0° to 135° zone (vertically axially symmetrical). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux (lumens) must be emitted in the 135°-180° zone. Distribution shall be vertically symmetrical as measured in three vertical planes at 0°, 45°, and 90°." http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf.

[330] First tier EISA compliant halogens have a lifetime of 4 years (3,000 hours at 2.17 hours per day). The last year these lamps are available is 2019, and they will need replacement at the end of 2022. Thus, the new standard must be used after 2022.

Estimated Useful Life (EUL)

The measure life for indoor and outdoor LED omni-directional lamps is 19 years.[331] Due to the EISA standards, the savings over the useful life will need to be adjusted to account for second tier EISA standards for all years after 2022.

Table 216: ENERGY STAR® Omni-Directional LEDs – Measure Life

Rated Measure Life (Hours)	First Tier EISA Standard Baseline	Second Tier EISA Standard Baseline
$\geq$ 15,000[332]	5	14

Daily Hours of Use

These deemed savings assume an average daily use of 2.17 blended[333] hours for indoor/outdoor applications.

Coincidence Factor

Cadmus performed a residential light logging study in 2013 in Arkansas on behalf of EAI. This study estimated a mean coincidence factor of 10 percent for non-holiday summer weekdays from 3:00 p.m. to 7:00 p.m.[334] Residential omni-directional LEDs installed outdoors are not expected to be on during summer peak demand hours. Outdoor omni-directional LEDs will have a coincidence factor of 0 percent.

Calculation of Savings

For retail (time of sale) programs, increased savings may be claimed based on sales to nonresidential customers.[335] Based on a review of 23 utility programs across 10 states, 6.7 percent of installed lamps may be allocated to the commercial program. To implement, multiply the total number of fixtures by 6.7 percent and apply the savings methodologies described in the Commercial Lighting Efficiency measure. Since no building type will have been identified, apply the weighted average annual operating hours and coincidence factor based on a review of the building types that participating in commercial lighting programs during the current program year.

Calculate savings for the remaining 93.3 percent of fixtures using the residential savings calculations described below. If it is not possible to apply the commercial allocation strategy described above, a program may calculate savings for all fixtures using the residential savings calculations described below. This will result in a conservative estimate for upstream programs.

Note: This strategy should only be applied to retail (time of sale) programs. For all other programs, use the residential savings calculations exclusively.

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[331] Emerging Technologies Research Report prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships (NEEP). February 13, 2013.

[332] Minimum requirement from current ENERGY STAR® specification. https://www.energystar.gov/products/lighting_fans/light_bulbs/key_product_criteria.

[333] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[334] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[335] Dimetrosky, S. et al, 2015, "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January.

Energy Savings

$$kWh_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_E$$

(175)

Where:

W_{base} = Based on wattage equivalent of the lumen output of the purchased LED omni-directional lamp and the program year purchased/installed; for omni-directional LEDs, use the following base and post case wattages

W_{post} = Wattage of LED purchased/installed. Use above table for post-wattages

$Hours$ = Average hours of use per year

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed

IEF_E = Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces. Because of the long estimated life of LEDs, omni-directional LEDs have a shifting baseline as a result of EISA 2007. The Second Tier EISA 2007 baseline goes into effect in 2020, when all general service lamps must meet a 45 lumen per watt (lpw) standard. This new baseline should be applied for all years after 2022. As previously discussed, this is when first tier baseline bulbs will be at the end of their useful life and need to be replaced.

Table 217: ENERGY STAR® Omni-Directional LEDs – EISA Baselines336

Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 (W_{base})	Incandescent Equivalent 2nd Tier EISA 2007 (W_{base})[337]	Effective dates for 2nd Tier EISA 2007 Baselines
310	749	29	12	1/1/2020
750	1,049	43	20	1/1/2020
1,050	1,489	53	28	1/1/2020
1,490	2,600	72	45	1/1/2020

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[336] Note that ENERGY STAR® has recently assigned new incandescent equivalent wattage lumen bins for the ENERGY STAR® v2.0 lighting standards (see https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2_0%20Revised%20OCT-2016_1.pdf, page 13)). This TRM maintains the EISA lumen bins for assigning baseline wattage. Future TRM iterations of the AR TRM, however, may incorporate these new lumen bins for baseline wattage estimates.

[337] Wattages developed using the 45 lpw standard that goes into effect in 2020.

Table 218: ENERGY STAR® Omni-Directional LEDs – Average Hours of Use per Year

Installation Location	Hours
Indoor/Outdoor[338]	792.6

Table 219: ENERGY STAR® Omni-Directional LEDs – In Service Rates

Program	ISR
Retail (Time of Sale) and Direct Install[339]	0.97

Table 220: ENERGY STAR® Omni-Directional LEDs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties

Heating Type	Interactive Effects Factor (IEF_E)[340]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[341]	0.97

Summer Peak Demand Savings

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times CF \times ISR \times IEF_D$$

(176)

Where:

CF = Summer Peak Coincidence Factor for measure

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[338] Annual Hours of Use = 2.17 Average Daily Hours of Use * 365.25 Days per Year

[339] Reflects best-available information in Arkansas for first-year installation rates, applying a four-year trajectory of installation and a discounting based on Uniform Methods Project residential lighting protocol. The first year ISR for retail is 92.6% based on 2014 Entergy evaluation for retail CFLs. In 2016, SWEPCO evaluated direct install LEDs and found a 95% first-year ISR, which results in similar result once trajectory and discounting are conducted.

[340] Refer to Appendix I, Arkansas TRM 6.0 Volume 3.

[341] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Table 221: ENERGY STAR® Omni-Directional LEDs – Summer Peak Coincidence Factor

Lamp Location	CF
Indoor[342]	10%
Outdoor	0%

IEF_D = Interactive Effects Factor to account for cooling demand savings and heating demand penalties; this factor also applies to outdoor and unconditioned spaces

Table 222: ENERGY STAR® Omni-Directional LEDs – Interactive Effects for Cooling Demand Savings and Heating Demand Penalties

Heating Type	Interactive Effects Factor (IEF_D)[343]
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[344]	1.25

Heating Penalty for Natural Gas Heated Homes

$$Therms_{penalty} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_G \tag{177}$$

Where:

IEF_G = Interactive Effects Factor to account for gas heating penalties (Δtherm/kWh); this factor also applies to outdoor and unconditioned spaces

Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure, including single fuel, electric-only programs.[345]

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[342] Residential light logging study by Cadmus - Entergy Arkansas, Inc. *2013 EM&V Evaluation Report.*

[343] Refer to Appendix I, Arkansas Volume 3.

[344] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

[345] Electric-only programs can quantify the value of the increased therm interactive effects, as discussed in Protocol L of the TRM, and treat this as a "negative benefit".

Table 223: ENERGY STAR® Omni-Directional LEDs – Interactive Effects for Gas Heating Penalties

Heating Type	**Interactive Effects Factor (IEF_G)**[346]
Gas Heat with AC	-0.011
Gas Heat with no AC	-0.011
Electric Resistance Heat with AC	0
Electric Resistance Heat with no AC	0
Heat Pump	0
Heating/Cooling Unknown[347]	-0.0063

Annual kW, Annual kWh, and Lifetime kWh Savings Calculation Example

A 12 watt omni-directional LED is installed in program year (PY) 2018. In July 2014, due to First Tier EISA 2007 standards going into effect, the baseline changed to 43 watts. In January 2023, due to Second Tier EISA 2007 standards going into effect, the baseline changes again to 20 watts. Necessary inputs for calculating the kWh savings include the EUL (20 years), IEF_D (1.25 for unknown heating/cooling type), IEF_E (0.97 for unknown heating type), ISR (0.926), summer coincidence factor (0.1), and Hours of Use per Year (792.6 hours). All kWh values are rounded to the second decimal place.

PY 2018 through PY 2022 Savings: From January 2018 to December 2022, the baseline is 43 watts. 2023 – 2018 is 5 years.

$$2018\ to\ 2022\ kW\ Savings\ (for\ each\ year) = \left(\frac{[43-12]}{1000}\right) \times 0.1 \times 1.25 \times 0.98$$

$$= 0.0038\ kW$$

$$Cumulative\ 2018\ to\ 2022\ kWh\ Savings = \left(\frac{[43-12]}{1000}\right) \times 792.6 \times 0.97 \times 0.98 \times 5$$

$$= 116.78\ kWh$$

(178)

PY 2023 through PY 2036 Savings: In January 2023, the baseline changes to the 2nd Tier EISA 2007 standard. The baseline wattage changes from 43 watts to 20 watts. The remaining measure life is 14 years.

$$2023\ to\ 2036\ kW\ Savings\ (for\ each\ year) = \left(\frac{[20-12]}{1000}\right) \times 0.1 \times 1.25 \times 0.98 = 0.0010\ kW$$

$$Cumulative\ 2023\ to\ 2036\ kWh\ Savings = \left(\frac{[20-12]}{1000}\right) \times 792.6 \times 0.97 \times 0.98 \times 14 = 84.39\ kWh$$

(179)

Lifetime kWh Savings:

$$116.78 + 84.39 = 201.17\ kWh\ lifetime\ savings$$

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[346] Refer to Appendix I, current Arkansas TRM Volume 3

[347] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

2.5.1.5 Indoor/Outdoor Linear Fluorescents

Measure Description

This measure provides a method for calculating savings for replacing indoor/outdoor linear fluorescents or outdoor high-intensity discharge (HID) lamps with a T5 or T8 indoor/outdoor linear fluorescent lamp and ballast combination.

Baseline

For indoor/outdoor linear fluorescents, the baseline equipment will be an indoor/outdoor electronic T8 or T12 linear fluorescent or an outdoor HID lamp. As a result of increased federal efficiency standards for general service fluorescent lamps, as published in the Energy Policy Act (EPAct) of 2005, 4-foot and 8-foot T12s and 2-foot U-Shaped T12s are no longer an eligible baseline. If these types of fixtures are replaced, an assumed electronic T8 baseline should be used in place of the existing T12 equipment. T12 fixtures not specified above will remain an eligible baseline technology.

Efficiency Standard

For indoor/outdoor linear fluorescents, the replacement lamp and ballast combination should be a T5 or T8 lamp or ballast combination.

Estimated Useful Life (EUL)

The measure life for indoor/outdoor linear fluorescents is 15 years.[348]

Daily Hours of Use

These deemed savings assume an average daily use of 2.17 blended[349] hours for indoor/outdoor applications.

Coincidence Factor

In California's CFL Metering Study, seasonal and hourly use profiles indicate that during the summer months, an average of 9% of residential CFLs installed indoors may be expected to be operating on summer weekdays between the hours of 1500-1900.[350] This value will be used for linear fluorescents.

Residential linear fluorescent fixtures installed outdoors are not expected to be on during summer peak demand hours and will have a coincidence factor of 0%.

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[348] DEER. "EUL/RUL Values." 2008

[349] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[350] KEMA, *CFL Metering Study*., 2005. Prepared for Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE). February 24,. http://www.calmac.org/publications/2005_Res_CFL_Metering_Study_Final_Report.pdf.

Calculation of Deemed Savings

Energy Savings

$$kWh_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times Hours \times ISR \times IEF_E$$

(180)

Where:

W_{base} = Baseline lamp wattage of equivalent lumens; use wattages specified in Appendix E

W_{post} = Actual wattage of linear fluorescent lamp and ballast combination that is purchased/installed

$Hours$ = Average hours of use per year

ISR = In Service Rate, or percentage of rebate units that get installed, to account for units purchased but not immediately installed = 1.0 (default)[351]

Table 224: Residential Lighting Efficiency – Linear Fluorescents Average Hours of Use

Installation Location	Hours
Indoor/Outdoor[352]	792.6

IEF_E = Interactive Effects Factor to account for cooling energy savings and heating energy penalties; this factor also applies to outdoor and unconditioned spaces

Table 225: Residential Lighting Efficiency – Linear Fluorescents Interactive Effects for Cooling Energy Savings and Heating Energy Penalties

Heating Type	Interactive Effects Factor (IEF_E)[353]
Gas Heat with AC	1.10
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	0.83
Electric Resistance Heat with no AC	0.73
Heat Pump	0.96
Heating/Cooling Unknown[354]	0.97

---

[351] Because this measure requires the installation of a T8 or T5 ballast, assume that 100% of the measure is installed immediately.

[352] Annual Hours of Use = 2.17 Average Daily Hours of Use * 365.25 Days per Year

[353] Refer to Appendix I, Arkansas Volume 3.

[354] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Summer Peak Demand Savings

$$kW_{savings} = \left(\left(W_{base} - W_{post}\right)/1000\right) \times CF \times ISR \times IEF_D$$

(181)

Where:

CF = Summer Peak Coincidence Factor for measure

IEF_D = Interactive Effects Factor to account for cooling demand savings; this factor also applies to outdoor and unconditioned spaces

Table 226: Residential Lighting Efficiency – Linear Fluorescents Summer Peak Coincidence Factor

Bulb Location	CF
Indoor[355]	10%
Outdoor	0%

Table 227: Residential Lighting Efficiency – Linear Fluorescents Interactive Effects Factor for Cooling Demand Savings

Heating Type	Interactive Effects Factor (IEF_D)[356]
Gas Heat with AC	1.29
Gas Heat with no AC	1.00
Electric Resistance Heat with AC	1.29
Electric Resistance Heat with no AC	1.00
Heat Pump	1.29
Heating/Cooling Unknown[357]	1.25

---

[355] Residential light logging study by Cadmus - Entergy Arkansas, Inc. 2013 EM&V Evaluation Report.

[356] Refer to Appendix I, Arkansas Volume 3.

[357] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

Heating Penalty for Natural Gas Heated Homes

$$Therms_{penalty} = \left((W_{base} - W_{post})/1000 \right) \times Hours \times ISR \times IEF_G$$

(182)

Where:

IEF_G = Interactive Effects Factor to account for gas heating penalties (Δtherm/kWh); this factor also applies to outdoor and unconditioned spaces

Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure, including single fuel, electric-only programs.[358]

Table 228: Residential Lighting Efficiency – Linear Fluorescents Interactive Effects for Gas Heating Penalties

Heating Type	**Interactive Effects Factor (IEF_G)**[359]
Gas Heat with AC	-0.011
Gas Heat with no AC	-0.011
Electric Resistance Heat with AC	0
Electric Resistance Heat with no AC	0
Heat Pump	0
Heating/Cooling Unknown[360]	-0.0063

---

[358] Electric-only programs can quantify the value of the increased therm interactive effects, as discussed in Protocol L of the TRM, and treat this as a “negative benefit”.

[359] The IEF_G factor was weighted by those lamps installed in and out of conditioned space, and thus should be applied to all lamps Refer to Appendix I, Arkansas Volume 3

[360] Weighted average based on Residential Energy Consumption Survey (RECS) 2009 data. http://www.eia.gov/consumption/residential/data/2009/.

3. COMMERCIAL & INDUSTRIAL DEEMED SAVINGS MEASURES

3.1 Heating, Ventilation & Air Conditioning (HVAC) Measures

3.1.1 Central AC Tune-Up (Converted Residences)

Measure Description

Retired. Use measure 3.1.7 for all Commercial Central AC Tune-Up measures.

3.1.2 Boiler Cut-Out Controls

Measure Description

This measure involves the installation of boiler cutout controls, which automatically turn off the natural gas boiler and associated heating system when the outside air reaches a preset temperature. The measure could also include a timer to de-energize the boiler heating equipment based on time of day. There are controllers available that combine boiler reset and cutout controls in one controller.

Baseline and Efficiency Standards

An average baseline boiler combustion efficiency (E_c) of 70 percent is assumed for existing units. According to the New York State Energy Research and Development Authority (NYSERDA) Natural Gas Database, a baseline combustion efficiency of 70 percent should be used for this measure.

The minimum efficiency requirements for this measure are clearly defined by the IECC 2003 standard. Refer to the Code Review Section below.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database[31], the estimated useful life (EUL) is 20 years.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about boiler cut-out controls. A summary of the key resources is included in Table 229.

Table 229: Boiler Cut-Out Control – Review of Cut-out Information

Resource	Notes
NYSERDA *[31]*	Combines boiler cut-out controls and supply water temperature reset as one measure. References life of measure used for analysis.

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

Based on review of the IECC 2003 Code, it is assumed the new buildings would have this measure as part of the controls system.

For new construction projects, the IECC 2003 states:

> **803.3.3.7 Hydronic systems controls.** The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 803.3.3.7.1 through 803.3.3.7.3. Hydronic heating systems comprising multiple-packaged boilers and designed to deliver conditioned water or steam into a common distribution system shall include automatic controls capable of sequencing operation of the boilers. Hydronic heating systems comprising a single boiler and greater than 500,000 BTU/hr input design capacity shall include either a multi-staged or modulating burner.
>
> **803.2.4 Hydronic system controls.** Hydronic systems of at least 600,000 British thermal units per hour (BTU/h) design capacity supplying heated water to comfort conditioning systems shall include controls that meet the requirements Section 803.3.3.7.
>
> **803.3.1.1 Equipment and system sizing.** Heating and cooling equipment and system capacity shall not exceed the loads calculated in accordance with Section 803.2.1.
>
> Exceptions: 1. Required standby equipment and systems provided with controls and devices that allow such systems or equipment to operate automatically only when the primary equipment is not operating. 2. Multiple units of the same equipment type with combined capacities exceeding the design load and provided with controls that have the capability to sequence the operation of each unit based on load.
>
> **803.3.3.7.4 Part load controls.** Hydronic systems greater than or equal to 300,000 BTU/h (87,930 W) in design capacity supplying heated or chilled water to comfort conditioning systems shall include controls that have the capability to: 1. Automatically reset the supply water temperatures using zone return water temperature, building return water temperature, or outside air temperature as an indicator of building heating or cooling demand. The temperature shall be capable of being reset by at least 25 percent of the design supply-to-return water temperature difference; or 2. Reduce system pump flow by at least 50 percent of design flow rate, utilizing adjustable speed drive(s) on pump(s), multiple-staged pumps where at least one-half of the total pump horsepower is capable of being automatically turned off, control valves designed to modulate or step down, and close, as a function of load, or other approved means.

Calculation of Deemed Savings

Unit Electrical Measure Savings

Concerning the application of boiler cut-out control for electric boilers, no information was found concerning deemed savings values.

Unit Natural Gas Measure Savings

Most of the information available for this measure combines cut-out control with boiler reset. The available information does not separate boiler cutout and boiler reset, while estimating average annual energy savings. Nexant recommends a 1.7 percent savings of current use for boiler cut-out controls (CenterPoint Energy). As these savings estimates are based on a single reference, it is recommended that Arkansas work with early program participants to conduct actual pre- and post-measurement of energy use to verify the accuracy of these values.

Deemed annual natural gas savings for a boiler cut-out control project should be calculated by the following formula:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}$$

(183)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Ec_{Base} = Combustion efficiency for boiler, if unavailable, estimate efficiency to 70 percent

$\%Savings$ = Percent savings (CenterPoint Energy), 1.7 percent

$Therm\ Conversion\ Factor$ = 100,000BTU/therm (assumed)

3.1.3 Boiler or Furnace Vent Dampers

Measure Description

This measure involves the installation of a vent damper, a mechanical device installed in the flue pipe of a fossil fuel-fired furnace or boiler. Its function is to reduce off-cycle heat loss from the boiler. During normal operation, the damper is open and exhaust gases are vented to atmosphere through the flue pipe or chimney. When the boiler or furnace is satisfied and de-energizes, the vent damper closes to reduce off-cycle loss through the flue. Most vent dampers use electric motor actuators to open and close the damper blade. They are normally designed to fail open in the case where electrical power is interrupted, and then the damper opens automatically. Also, some vent dampers have safety switches that prevent the boiler from energizing prior to the vent damper being fully open to the flue duct.

Baseline and Efficiency Standards

An average baseline boiler combustion efficiency (E_c) of 70 percent is assumed for existing units. According to the NYSERDA[31] Natural Gas Database, a 70 percent baseline combustion efficiency is indicated for this measure.

There are no minimum efficiency requirements for this measure as defined by the IECC 2003 standards.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database, the estimated useful life (EUL) 12 years.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about vent dampers. A summary of the key resources is included in Table 230.

Table 230. Boiler or Furnace Vent Damper – Review of Boiler Vent Damper Information

Resource	Notes
ENERGY STAR®[12]	Wise Rules for Industrial Energy Efficiency, September 2003 -- Wise Rule # 10 indicates that Stack dampers prevent heat from being pulled up the stack and can save 5% to 20% of a boiler's fuel use.
NYSERDA[31]	Indicates a 7% annual natural gas savings, 20 year useful life, 70% combustion baseline efficiency and various reference literature

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

Based on review of the IECC 2003 Code, boiler flue control is not specified for new boilers; therefore, it is applicable to both new and retrofit boilers. The IECC 2003 Code requires units to have either power venting or a flue damper for new furnaces. A vent damper is an acceptable alternative to a flue damper for those furnaces in which combustion air is drawn from the conditioned space. Based on Code recommendation, the vent damper measure would only be applicable to a retrofit application.

Calculation of Deemed Savings

Unit Electrical Measure Savings

Electrical energy savings are not associated with this measure. An electric actuator will add about 3 watts of power to the boiler controls system.

Unit Natural Gas Measure Savings

Deemed annual natural gas savings for a boiler vent damper project should be calculated by the following formula:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}$$

(184)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Ec_{Base} = Combustion efficiency for boiler, if unavailable, estimate efficiency to 70 percent

$\%Savings$ = Percent savings (CenterPoint Energy), 7 percent

$Therm\ Conversion\ Factor$ = 100,000BTU/therm (assumed)

3.1.4 Boiler Reset Controls

Measure Description

When considering fossil fuel-fired boilers, lowering hot water boiler control temperatures can save energy because less heat is stored in the boiler vessel and off-cycle heat losses are reduced. The measure includes installing a controller that changes boiler control temperature in response to outdoor air temperature. As the outdoor air temperature increases, the controller automatically resets the boiler control temperature downward to save energy. Some controllers offer a "heat purging" control that allows the pump to continue to operate when the boiler is cycled off, thus removing most of the available heat and supplying it to the heating system. Often, this measure can be combined with the boiler cutout control, since modern controller equipment is capable of handling both measures through one controller.

Baseline and Efficiency Standards

An average baseline boiler combustion efficiency (E_c) of 70 percent is assumed for existing units. According to the NYSERDA*[31]* Natural Gas Database, a 70 percent baseline combustion efficiency is indicated for this measure. The minimum efficiency requirements for this measure are clearly defined by IECC 2003 standard. Refer to the Code Review Section below.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database,*[31]* the estimated useful life (EUL) is 20 years.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about boiler reset controls. A summary of the key resources is included in Table 231.

Table 231: Boiler Reset Controls – Review of Boiler Reset Control Information

Resource	Notes
Utah Natural Gas DSM Advisory Group*[48]*	Report: The Maximum Achievable Cost Effective Potential for the Questar Gas Company Service Area, June 2004 – report indicates a maximum savings potential of 10% energy savings.
NYSERDA*[31]*	Combines boiler cutout controls and boiler water temperature reset as one measure. References life of measure used for analysis. The combination of both measures indicates a 10% energy savings potential.
American Council for an Energy Efficient Economy (ACEEE)*[6]*	ACEEE Emerging Technologies Report: Advanced Boiler Controls, September 2006 – as much as 10% of fuel used for a conventional boiler (existing system).

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

Based on review of the IECC 2003 Code, it is assumed the new buildings would have this measure as part of the controls system.

For new construction projects, the IECC 2003 states:

> **803.3.3.7 Hydronic systems controls.** The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 803.3.3.7.1 through 803.3.3.7.3. Hydronic heating systems comprising multiple-packaged boilers and designed to deliver conditioned water or steam into a common distribution system shall include automatic controls capable of sequencing operation of the boilers. Hydronic heating systems comprising a single boiler and greater than 500,000 BTU/h input design capacity shall include either a multi-staged or modulating burner.
>
> 803.2.4 Hydronic system controls. Hydronic systems of at least 600,000 BTU/h (175,860 W) in design capacity supplying heated water to comfort conditioning systems shall include controls that meet the requirements Section 803.3.3.7.
>
> **803.3.1.1 Equipment and system sizing.** Heating and cooling equipment and system capacity shall not exceed the loads calculated in accordance with Section 803.2.1.
>
> Exceptions: 1. Required standby equipment and systems provided with controls and devices that allow such systems or equipment to operate automatically only when the primary equipment is not operating. 2. Multiple units of the same equipment type with combined capacities exceeding the design load and provided with controls that have the capability to sequence the operation of each unit based on load.
>
> **803.3.3.7.4 Part load controls.** Hydronic systems greater than or equal to 300,000 BTU/h (87,930W) in design capacity supplying heated or chilled water to comfort conditioning systems shall include controls that have the capability to: 1. Automatically reset the supply water temperatures using zone return water temperature, building return water temperature, or outside air temperature as an indicator of building heating or cooling demand. The temperature shall be capable of being reset by at least 25 percent of the design supply-to-return water temperature difference; or 2. Reduce system pump flow by at least 50 percent of design flow rate utilizing adjustable speed drive(s) on pump(s), multiple staged pumps where at least one-half of the total pump horsepower is capable of being automatically turned off, control valves designed to modulate or step down, and close, as a function of load, or other approved means.

Calculation of Deemed Savings

Unit Electrical Measure Savings

Concerning the application of boiler reset control for electric boilers, no information was found concerning deemed savings values for the reduction of boiler off-cycle losses.

Unit Natural Gas Measure Savings

The majority information available for this measure combines reset control with boiler cutout. The available information does not separate boiler cutout and boiler reset, while estimating average annual energy savings. Nexant recommends a 3.8 percent savings of current use for boiler reset controls (CenterPoint Energy). As these savings estimates are based on a single reference, it is recommended that Arkansas work with early program participants to conduct actual pre- and post-measurement of energy use to verify the accuracy of these values.

Deemed annual natural gas savings for a boiler reset control project should be calculated by the following formula:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}$$

(185)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Ec_{Base} = Combustion efficiency for boiler, if unavailable, estimate efficiency to 70 percent

$\%Savings$ = Percent savings (CenterPoint Energy), 3.8 percent

$Therm\ Conversion\ Factor$ = 100,000BTU/therm (assumed)

3.1.5 Boiler Tune-Up

Measure Description

This measure includes a tune-up for an existing boiler so optimal burner combustion is maintained. The measure may include measuring combustion efficiency, adjusting air flow to reduce excessive stack temperatures, adjusting draft control, checking combustion air intake, cleaning the fire side heat exchanger and water tubes, and calibrating the controls.

Baseline and Efficiency Standards

An average baseline boiler combustion efficiency (E_c) of 70 percent is assumed for existing units. According to the NYSERDA*31* Natural Gas Database, a 70 percent baseline combustion efficiency is indicated for this measure.

There are no minimum efficiency requirements for boiler tune-ups.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database,*31* the estimated useful life (EUL) is two years.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about the boiler tune-up measure. A summary of the key resources is included in Table 232.

Table 232: Boiler Tune-Up – Review of Boiler Tune-Up Information

Resource	Notes
NYSERDA *31*	Life of tune-up 2 years, 70% baseline burner efficiency, 2% overall fuel savings
XCEL Energy*54*	Reports and rebate application show minimum tune-up standards, recommend testing burners annually, report does not indicate minimum burner efficiency standard, tune-up is XCEL's most popular gas rebate
ENERGY STAR®*12*	Report: Wise Rules for Industrial Energy Efficiency, September 2003 – BOILER WISE RULE #4, A comprehensive tune-up with precision testing equipment to detect and correct excess air losses, smoking, unburned fuel losses, sooting, and high stack temperatures, can result in *boiler* fuel savings between 2-20%.

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

No applicable energy efficiency codes were found related to boiler tune-ups.

Calculation of Deemed Savings

Unit Electrical Measure Savings

There are no electrical savings associated with this measure.

Unit Natural Gas Measure Savings

Deemed demand and annual natural gas savings for the boiler tune-up measure should be calculated by the following formulas:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}$$

(186)

$$\boldsymbol{Therm/hr_{savings}} = \frac{\boldsymbol{Capacity} \times \left(\frac{\mathbf{1}}{\boldsymbol{Ec_{Base}}}\right) \times (\%\boldsymbol{Savings})}{\boldsymbol{Therm\ Conversion\ Factor}}$$

(187)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Ec_{Base} = Combustion efficiency for boiler, if unavailable, estimate efficiency to 70 percent

$\%Savings$ = Percent savings (NYSERDA Database), 2 percent

$Therm\ Conversion\ Factor$ = 100,000 BTU/therm (assumed)

3.1.6 Burner Replacement for Commercial Boilers

Measure Description

This measure includes replacing a natural gas burner with a more efficient burner. Replacement units include power burners that mechanically mix oxygen and gas for maximum efficiency. The measure only applies to existing boilers, since efficient burners now come as standard features with new boilers. Emissions standards are not considered in the burner efficiency analysis. Discussions with boiler manufacturers indicated environmental restrictions that could affect boiler efficiency negatively.

Baseline and Efficiency Standards

An average baseline burner combustion efficiency of 70 percent is assumed for existing units. According to the NYSERDA*[31]* Natural Gas Database, a 70 percent baseline combustion efficiency is indicated for a burner replacement project. The savings calculations assume that the minimum burner efficiency is 75 percent as published in the NYSERDA database.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database,[31] the estimated useful life (EUL) is 12 years.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about boilers. A summary of the key resources is included in Table 233.

Table 233: Boiler Replacement for Commercial Boilers – Review of Burner Information

Resource	Notes
NYSERDA*[31]*	Life of burner 12 years, 70% baseline burner efficiency, 75% new burner efficiency, 7% natural gas savings, +5% efficiency increase,
Lawrence Berkeley National Laboratory*[28]*	Report: Establishing an Energy Efficiency Recommendation for Commercial Boilers, Michelle J. Ware; report discusses boiler burner efficiency vs. overall boiler efficiency, reports that overall efficiency (E_t) is approximately 3-5% lower than combustion efficiency (E_c)
CenterPoint Energy, Minnesota*[60]*	Rebate requirements: Equal to or less than 5 MM BTU, fully modulating or 6-step modulation, Percent savings used in rebate not indicated, minimum burner efficiency not specified
ENERGY STAR®*[69]*	Report: Wise Rules for Industrial Energy Efficiency, September 2003
XCEL Energy*[53]*	Reports and rebate application show minimum installation and equipment standards to be eligible for rebate, recommend testing burners annually, report does not indicate minimum burner efficiency standard

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

No applicable energy efficiency codes were found related to burner replacements.

Calculation of Deemed Savings

Unit Electrical Measure Savings

Electrical savings were not considered for this measure. If a new blower motor is installed, the size of the motor and constant vs. variable speed will affect the electrical component of the retrofit.

Unit Natural Gas Measure Savings

Deemed demand and annual natural gas savings for a burner replacement should be calculated by the following formulas:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}$$

(188)

$$\boldsymbol{Therm/hr_{savings} = \frac{Capacity \times \left(\frac{1}{Ec_{Base}}\right) \times (\%Savings)}{Therm\ Conversion\ Factor}}$$

(189)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Ec_{Base} = Combustion efficiency of baseline burner from NYSERDA database, 70 percent

$\%Savings$ = Percent savings from NYSERDA database, 7 percent

$Therm\ Conversion\ Factor$ = 100,000 BTU/therm (assumed)

3.1.7 Central Air Conditioner and Heat Pump Tune-Up

Measure Description

This measure applies to central air conditioners and heat pumps. An AC tune-up, in general terms, involves checking, adjusting and resetting the equipment to factory conditions, such that it operates closer to the performance level of a new unit. For this measure, the service technician must complete the following tasks according to industry best practices:

Air Conditioner Inspection and Tune-Up Checklist[361]

- Inspect and clean condenser, evaporator coils, and blower.
- Inspect refrigerant level and adjust to manufacturer specifications.
- Measure the static pressure across the cooling coil to verify adequate system airflow and adjust to manufacturer specifications.
- Inspect, clean, or change air filters.
- Calibrate thermostat on/off set points based on building occupancy.
- Tighten all electrical connections, and measure voltage and current on motors.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the starting cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Provide documentation showing completion of the above checklist to the utility or the utility’s representative.

Baseline and Efficiency Standards

The baseline is a system with demonstrated imbalances of refrigerant charge or if there are other pre-tune-up field measured inefficiencies.

After the tune-up, the equipment must meet airflow and refrigerant charge requirements. To ensure the greatest savings when conducting tune-up services, the eligibility minimum requirement for airflow is the manufacturer specified design flow rate, or 350 CFM/ton, if unknown. Also, the refrigerant charge must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or a capillary.

The efficiency standard, or efficiency after the tune-up, is assumed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump , or the measured or calculated system EER as detailed below.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) for refrigerant charge correction is 10 years.

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[361] Based on ENERGY STAR® HVAC Maintenance Checklist. http://www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

Calculation of Deemed Savings

Deemed peak demand and annual energy savings for unitary AC/HP tune-up should be calculated using the following formulas:

$$kW_{savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times CF$$

(190)

$$kWh_{savings,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right)$$

(191)

$$kWh_{savings,H} = CAP_H \times \frac{1\ kW}{1{,}000\ W} \times EFLH_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right)$$

(192)

$$\boldsymbol{kWh_{savings,AC} = kWh_{savings,C}}$$

(193)

$$kWh_{savings,HP} = kWh_{savings,C} + kWh_{savings,H}$$

(194)

Where:

CAP_C = Rated or calculated equipment cooling capacity (BTU/hr)

CAP_H = Rated or calculated equipment heating capacity (BTU/hr)

EER_{pre} = Calculated or measured efficiency of the equipment for cooling before tune-up, Equation (195)

$\boldsymbol{EER_{post}}$ = Nameplate efficiency of the existing equipment for cooling; if unknown, use default EER value from Table 236 and Table 237.

Note: Site measurements may be substituted for EER_{pre} and EER_{post}, providing that the measurements are taken on the same site visit and under similar operating conditions using reliable, industry accepted techniques. If onsite measurements are used to measure savings for measures other than refrigerant charge, then the implementer should use an EUL of three years.

$HSPF_{pre}$ = Calculated or measured efficiency of the equipment for heating before tune-up, Equation (198)

$HSPF_{post}$ = Nameplate, measured or calculated efficiency of the existing equipment for heating; if unknown, use default HSPF value from Table 238.

CF = Coincidence Factor (Table 475)

$EFLH_C$ = Equivalent full-load cooling hours (Table 477)

$EFLH_H$ = Equivalent full-load heating hours (Table 478)

There are two methods for calculating system pre and post efficiencies as described below:

Method 1: Change of efficiency based on change in system charge.

In method 1, the efficiency improvement resulting from the refrigerant charge adjustment depends on the pre-adjustment refrigerant charge. This method may be used for air conditioners and heat pumps operating in cooling mode.

$$EER_{pre} = (1 - EL) \times EER_{post}$$

(195)

Where:

EER_{pre} = Calculated efficiency of the cooling equipment before tune-up

$\boldsymbol{EER_{post}}$ = Nameplate efficiency of the existing cooling equipment; if unknown, use default EER value from Table 236 and Table 237.

EL = Efficiency Loss (Fixed Orifice: Table 234; TXV: Table 235) determined by averaging reported efficiency losses from multiple studies.[362],[363],[364],[365],[366] Interpolation of the efficiency loss values presented is allowed. Extrapolation is not allowed.

Table 234: Efficiency Loss Percentage by Refrigerant Charge Level (Fixed Orifice)

% Charged	EL
< 70	0.37
75	0.29
80	0.20
85	0.15
90	0.10
95	0.05
100	0.00
> 120	0.03

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[362] Architectural Energy Corporation, managed by New Buildings Institute. "Small HVAC System Design Guide." Prepared for the California Energy Commission. October 2003. Figure 11.

[363] Davis Energy Group. "HVAC Energy Efficiency Maintenance Study," California Measurement Advisory Council (CALMAC). December 29, 2010. Figure 14.

[364] Proctor Engineering Group. "Innovative Peak Load Reduction Program CheckMe! Commercial and Residential AC Tune-Up Project." California Energy Commission. November 6, 2003. Table 6-3.

[365] Proctor Engineering Group. PEG Tune-Up Calculations spreadsheet.

[366] Pennsylvania Technical Reference Manual (TRM). June 2012. Measure 3.3.2, Table 3-96.

Table 235: Efficiency Loss Percentage by Refrigerant Charge Level (TXV)

% Charged	EL
< 70	0.12
75	0.09
80	0.07
85	0.06
90	0.05
95	0.03
100	0.00
> 120	0.04

Table 236: Default Air Conditioner EER per Size Category[367]

Size Category (BTU/hr)	Default EER[368]
< 65,000	11.8
> 65,000 and < 135,000	11.0
> 135,000 and < 240,000	10.8
> 240,000 and < 760,000	9.8
> 760,000	9.5

Method 2: Calculation of savings based on pre or pre and post measurement of system efficiency, and age of equipment

In method 2, direct site measurements of EER pre and post values are used.

Pre and post EER measurements should be conducted and the measurements should be taken on the same site visit and under similar operating conditions using reliable, industry accepted techniques.

If onsite measurements are used to determine savings for improvements other than refrigerant charge, then the implementer should use an EUL of three years.

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[367] Code specified SEER or EER value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

[367] Code specified SEER or EER value from ASHRAE 90.1-2010 (efficiency value effective January 1, 2015

[368] SEER values converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). “Building America House Simulation Protocols.” U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

When using this approach, the system capacity (CAPc) is adjusted using the following calculation:

$$CAPc = CAP_{nameplate} * EER_{post} / EER_{namplate}$$

(196)

In cases where only a pre-tune up efficiency can be completed, then post tune-up efficiency may be estimated using the lesser of the nameplate efficiency or the results of equation 197. Equation 197 estimates the efficiency of the unit based on the age as well as typical maintenance practices of the customer.

$$EER_{post} = \frac{(EER_{pre})}{(1 - M)^{age}}$$

(197)

Where:

M = Maintenance factor,[369] use 0.01 if annual maintenance conducted or 0.03 if maintenance is seldom; use default value of 0.03 if maintenance history is unknown.

Age = Age of equipment in years, up to a maximum of 20 years, use a default of 10 years if unknown.

Heat Pump Heating Credit

For heat pump systems, an additional saving credit may be taken as follows:

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[369] "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. Table 32. Page 40. http://www.nrel.gov/docs/fy11osti/49246.pdf.

Table 237: Default Heat Pump EER per Size Category[370]

Size Category (BTU/hr)	Default EER
< 65,000	11.8
≥ 65,000 and < 135,000	10.8
≥ 135,000 and < 240,000	10.4
≥ 240,000	9.3

$$HSPF_{pre} = (HSPF_{post}) \times (1 - M)^{age} \tag{198}$$

Where:

$HSPF_{post}$= Nameplate efficiency of the existing equipment for heating; if unknown, use default HSPF value from Table 238)

M = Maintenance factor[371], use 0.01 if annual maintenance conducted or 0.03 if maintenance is seldom; use default value of 0.03 if maintenance history is unknown.
Age = Age of equipment in years, up to a maximum of 20 years, use a default of 10 years if unknown.

Table 238: Default Heat Pump HSPF per Size Category[372]

Size Category (BTU/hr)	Subcategory or Rating Condition	Default HSPF[373]
< 65,000	Split System	8.2
	Single Package	8.0
≥ 65,000 and < 135,000	47°F db/43°F wb Outdoor Air	11.3
≥ 135,000	47°F db/43°F wb Outdoor Air	10.9

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[370] Code specified SEER or EER value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

[371] "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. Table 32. Page 40. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[372] Code specified HSPF or COP value from 2013 Addenda to ASHRAE 90.1-2010 (efficiency value effective January 1, 2015 for units < 65,000 Btu/hr and prior to January 1, 2010 for units > 65,000 Btu/hr).

[373] COP values converted to HSPF using COP=HSPF÷3.412

3.1.8 Commercial and Industrial Boilers

Measure Description

Commercial and industrial boilers are used in facilities to provide space or process heating via hot water or steam distribution. This measure includes natural gas-fired boilers of the following types: 1) Non-condensing hot water heating boiler, 2) Condensing hot water heating boiler and 3) Steam heating boiler (low and high pressure).

Commercial boilers normally are categorized 300,000 BTU/hr or larger. Small commercial boilers have a capacity range of 300,000 - 2,500,000 BTU/hr while large commercial boilers have a capacity range greater than 2,500,000 BTU/hr

Baseline and Efficiency Standards

The baseline efficiency standards for replace-on-burnout projects are based on the federal energy conservation standards[374] as shown in Table 239. The baseline efficiency standards for early retirement projects are based on the IECC 2003, as shown in Table 239.

For early retirement, the maximum lifetime age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

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[374] Federal Standards for boilers over 300,000 BTU/hr: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/74, and for boilers under 300,000 BTU/hr; http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/72, accessed May 2013.

Table 239: Commercial and Industrial Boilers – Baseline Efficiencies

Project Type	Size Category (BTU/hr)	Subcategory or Rating Condition	Baseline Efficiency[375,376]	Test Procedure
Replace-on-Burnout	< 300,000	Hot Water	82% AFUE	DOE 10 CFR Part 430.23
		Steam	80% AFUE	
	> 300,000 and ≤ 2,500,000	Hot Water	80% E_t	DOE 10 CFR Part 431.86
		Steam	79% E_t	
	> 2,500,000[c]	Hot Water	82% Ec	
		Steam	79% E_t	
Early Retirement	< 300,000	Hot Water	80% AFUE	DOE 10 CFR Part 430.23
		Steam	75% AFUE	
	> 300,000 and ≤ 2,500,000	Hot Water	75% E_t	DOE 10 CFR Part 431.86
		Steam	75% E_t	
	> 2,500,000[c]	Hot Water	80% Ec	
		Steam	79% E_t[377]	
These requirements apply to boilers with rated input of 8,000,000 BTU/h or less that are not packaged boilers, and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.				

The savings calculations assume that the minimum boiler efficiency exceeds that published in Table 239.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 20 years.

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[375] Ec = Combustion efficiency (100 percent less flue losses). See reference document for detailed information.

[376] Et = Thermal efficiency. See reference document for detailed information.

[377] IECC 2003 calls for an efficiency of 80% for steam boilers greater than 2,500,000 BTU/hr. However, because this is higher than the federal requirement, early retirement projects may use the replace on burnout baseline efficiency.

Measure/Technology Review

All of the primary data sources reviewed for this effort contained information about boilers. A summary of the key resources is included in Table 240 below:

Table 240: Commercial and Industrial Boilers – Review of High-Efficiency Boiler Information

Resource	Notes
DEER 2008*65*	Savings estimates for multiple boiler retrofits at a variety of building types; incremental boiler cost data for common measure types. Boiler capacities and full-load hours are not available.
ENERGY STAR®*69*	Report on Central Heating Systems: Best Opportunities. Calculation template for boiler efficiency improvement – residential.
GAMA 2007*22*	Annual publication from the Hydronics Institute Division of GAMA, I=B=R Ratings for Boilers, Baseboard Radiation, Finned Tube (commercial) Radiation and Indirect-Fired Water Heaters, January 2007 edition, documents boiler manufacture ratings and efficiencies

Note: Italic numbers are endnotes not footnote. (See Section 4.4 Commercial Measure References)

Code Review

The 2004 Arkansas Energy Code for New Building Construction states that, effective October 1, 2004, Arkansas adopts the IECC 2003 Edition. For commercial structures, IECC 2003 adopts by reference ASHRAE / IESNA Standard 90.1.1-2001. IECC 2003 indicates on page 63, Table 803.2.(5) Boilers, Gas- and Boiler-Fired, Minimum Efficiency Requirement for commercial buildings.

Calculation of Deemed Savings

Unit Natural Gas Measure Savings

Replace on Burnout

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor} \quad \textbf{(199)}$$

$$Therm/hr_{savings} = \frac{Capacity \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor} \quad \textbf{(200)}$$

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478, or custom entry of full-load hours if project is for non-space heating applications,

η_{pre} = Efficiencies listed in Table 239 for replace on burnout projects should be used

η_{post} = Nameplate Efficiency of the new boiler

$Therm\ Conversion\ Factor$ = 100,000 BTU/therm

Early Retirement

Annual savings must be calculated separately for two time periods:

The estimated remaining life (RUL, see

1. Table 242) of the equipment that is being removed, designated the first N years, and
2. Years EUL - N through EUL, where EUL is 20 years.

For the first N years:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor}$$

(201)

$$Therm/hr_{savings} = \frac{Capacity \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor}$$

(202)

Where:

$Capacity$ = Rated equipment heating capacity, BTU/hr

$EFLH_H$ = Equivalent full-load hours for heating from Table 478, or custom entry of full-load hours if project is for non-space heating applications. If site specific ELFH values are used, then a full analysis report showing how the EFLH are calculated shall be provided with any submittal information

η_{pre} = Efficiency of the existing boiler, if unavailable, efficiencies listed in Table 239 for early retirement projects should be used. Alternately, participants can use measured boiler full load efficiency. If actual efficiency is used, then a full boiler efficiency test report shall be provided with any submittal information

η_{post} = Efficiency of the new boiler.

$Therm\ Conversion\ Factor$ = 100,000 BTU/therm

For Years EUL - N through EUL: Savings for years EUL – N should be calculated exactly as they are for replace on burnout projects.

Lifetime savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ therm_{savings} = \left(therm_{savings,ER} \times RUL\right) + \left[therm_{savings,ROB} \times (EUL - RUL)\right] \tag{203}$$

Table 241: Commercial Boilers – Efficiency Definitions

Performance Efficiency Nomenclature	Description
Annual Fuel Utilization Efficiency (AFUE)	Measures the annual heating efficiency of a boiler or furnace (< 0.3 million BTU/hr), which is the heat transferred to the conditioned space divided by the fuel energy supplied.
Combustion Efficiency (E_C)	Measures the ability of a boiler to burn fuel. E_C = 100 – flue loss (or the % of heat input rate)
Thermal Efficiency (E_t)	Measures (at steady state conditions) the ratio of heat energy output to the heat energy input, exclusive of jacket and heat losses through the boiler shell (> 0.3 million BTU/hr)

Table 242: Commercial Boilers Remaining Useful Life (RUL) of Replaced Systems[378]

Age of Replaced System (Years)	RUL (Years)	Age of Replaced System (Years)	RUL (Years)
5	14.7	15	6.2
6	13.7	16	5.5
7	12.7	17	5.0
8	11.8	18	4.5
9	10.9	19	4.0
10	10.0	20	3.6
11	9.1	21	3.2
12	8.3	22	2.9
13	7.5	23	2.6
14	6.8	24 +	0.0

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[378] Use of the early retirement baseline is capped at 23 years, representing the age at which 75 percent of existing equipment is expected to have failed. Equipment older than 23 years should use the ROB baseline.

Commercial boilers have an estimated useful life of 20 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described by the survival function in Figure 9.

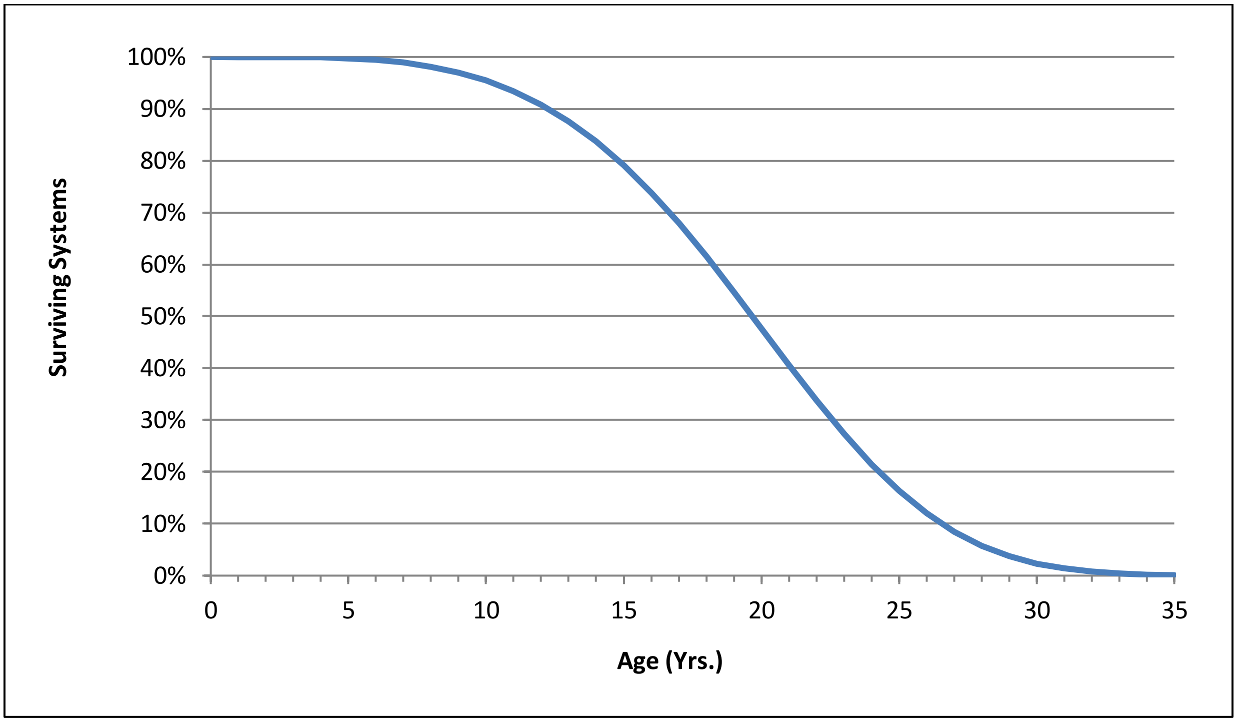

Figure 9: Survival Function for Commercial Boilers[379]

The method used for estimating RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 9. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[379] Source: Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html

3.1.9 Commercial Furnaces

Measure Description

Commercial natural gas furnaces use a burner and heat exchanger that heats air to meet the heating load of a given space. As a self-contained unit, the burner heats the heat exchanger while a blower fan forces air through the heat exchanger and then through ductwork into the conditioned space. Furnace manufacturers have been able to increase the overall efficiency of a typical unit by utilizing technologies such as increasing the heat exchanger efficiency, pulse combustion, and offering a condensing furnace.

Baseline and Efficiency Standards

Arkansas currently recognizes ASHRAE Standard 90.1 - 2007 commercial furnace minimum efficiencies as shown in Table 243.

Table 243: Commercial Furnaces – Baseline Efficiencies Requirement 380

Equipment Type	Size Category (Input)	Subcategory or Rating Condition[381]	Baseline Efficiency[382,383]	Test Procedure
Warm air furnaces, gas fired	< 225,000 Btu/h	———	78% AFUE or 80% E_t[b]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum capacity[b]	80% E_t[384]	ANSI Z21.47
Warm air duct furnaces, gas fired	All capacities	Maximum capacity[a]	80% E_c	ANSI Z83.9
Warm air unit heaters, gas fired	All capacities	Maximum capacity[a]	80% E_c	ANSI Z83.8

The savings calculations assume that the minimum furnace efficiency exceeds the figures shown in Table 243.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 20 years.

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[380] Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.

[381] Minimum ratings as provided for and allowed by the unit's controls.

[382] Et = Thermal efficiency. See test procedure for detailed discussion.

[383] Ec = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

[384] Ec = Combustion efficiency. Units must also include an Intermittent Ignition Device (IID), have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

Calculation of Deemed Savings

Unit Electrical Measure Savings

There are no deemed electrical savings for this measure. No provisions for early retirement are included because efficiency requirements for furnaces have not changed in almost 20 years.

Unit Natural Gas Measure Savings

Deemed annual natural gas savings for furnace should be calculated by the following formulas:

$$Therm_{savings} = \frac{Capacity \times EFLH_H \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor}$$

(204)

$$Therm/hr_{savings} = \frac{Capacity \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)}{Therm\ Conversion\ Factor}$$

(205)

Where:

$Capacity$ = Rated equipment heating capacity, Btu/h

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

η_{pre} = Efficiency of the existing furnace; if unavailable, use efficiencies listed in Table 243

η_{post} = Efficiency of the new furnace

$Therm\ Conversion\ Factor$ = 100,000Btu/therm

3.1.10 Direct Vent Heaters (Small Commercial and Converted Residences)

Measure Description

This measure applies to a direct vent[385], natural gas-fired, wall-type furnace with electronic ignition for small open areas not requiring ducted air distribution. Typical applications include single-room areas such as living areas, bedrooms, small offices or retail shops.

Baseline and Efficiency Standards

The baseline for retrofit is a gravity-type natural gas-fired furnace. These are wall systems that draw combustion air from the conditioned space and discharge products of combustion to the outside area. A separate baseline was established for retrofit of a fan-driven natural gas-fired furnace with standard venting.

Direct vent furnaces are available in sizes from 10,000 BTU/hr to 55,000 BTU/hr input. The federal efficiency standard for natural gas fired furnaces is 78 percent. The most efficient direct vented wall furnaces are rated 80-83 percent efficient when installed with a factory-supplied vent wall cap and in accordance with manufacturer’s recommendations. Direct vent wall furnaces are installed in exterior walls, utilizing outside air for combustion and directly discharging combustion products to the outside area. The energy savings are a result of utilizing a more efficient furnace and the use of outside air for combustion.

The equipment must meet the American National Standards Institute (ANSI) Z21.86 (latest standard) for Fan Type Direct-Vent Wall Furnaces (See Table 244).

Table 244: Direct Vent Heaters – Baseline and Efficiency Standards

Baseline	Efficiency Standard
Gravity Type Wall Furnace: 60% AFUE	Direct Vent Wall Furnace: 80.8% AFUE
Fan Driven Wall Furnace: 78% AFUE	

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[385] Non-vented space heaters were not considered, due to the hazard of carbon monoxide gas.

Estimated Useful Life (EUL)

The estimated useful life of this measure is 20 years, the same as gas furnaces. DEER 2008 does not list Direct Vent Heaters as a separate technology. The current technology for direct vent heaters is similar to gas furnaces listed in DEER 2008.

Deemed Savings Values

Table 245: Direct Vent Heaters – Deemed Savings Values

Weather Zone	Retrofit Std Vent Gravity-Type Natural Gas-Fired Wall Furnace		Retrofit Std Vent Fan-Driven Natural Gas-Fired Wall Furnace and New Construction	
	Annual Therms / kBTUh Furnace Capacity	Peak Therms / kBTUh Furnace Capacity	Annual Therms / kBTUh Furnace Capacity	Peak Therms / kBTUh Furnace Capacity
9 Fayetteville	4.809	0.074	1.333	0.022
8 Fort Smith	4.957	0.073	1.420	0.022
7 Little Rock	4.149	0.077	1.185	0.023
6 El Dorado	3.228	0.036	0.906	0.010

3.1.11 Duct Efficiency Improvements

Measure Description

These deemed savings are applicable to approved measures for sealing leaks in supply and return ducts in unconditioned spaces of commercial buildings, including vented attics and plenums, for repair and replacement of damaged ductwork. This measure is applicable to ductwork when:

- The building has an operable electric cooling and a gas or electric heating system and
- The maximum duct pressure class is 1.0 inches w.g. (water gauge)
- The maximum cooling capacity is equal to or less than 135,000 BTU/hr
- The maximum heating capacity is equal to or less than 285,000 BTU/hr

Baseline and Efficiency Standards

Pre- and post-installation duct leakage space may be evaluated by one of the following methods:

- Duct pressurization test by a certified and approved tester
- The "Leakage Classification Method," described below
- Other tests at the utilities' discretion

All testing and sealing procedures are more fully described in the *HVAC Air Duct Leakage Test Manual, Second Edition-2012*, published by Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

Duct sealing must meet the SMACNA Seal Class B requirements. All transverse joints and longitudinal seams shall be sealed using liquid sealants, mastics, and/or gaskets. Pressure-sensitive tape shall not be used as the primary sealant, unless it has been certified to comply with UL-181A or UL-181B by an independent testing laboratory and the tape is used in accordance with that certification.

Unconditioned space is defined as a space which is neither directly nor indirectly conditioned, and is isolated from conditioned space by partitions, such as walls and/or closeable doors, and ceilings and in which the temperature of the area traversed by the ductwork is greater than 100 degrees Fahrenheit during the cooling season and lower than 50 degrees Fahrenheit during the heating season.

Evaluation of Duct Leakage Using Pressurization Testing

Duct leakage testing shall be conducted according to the procedures specified in Chapter 4 of the *SMACNA HVAC Air Duct Leakage Test Manual*. Test pressure should approximate the normal system operating pressure of the section of the duct system being tested. For split-system air conditioner and heat pump units less than 65,000 Btuh cooling capacity, normal static pressures are often near 0.1 inches w.g., or 25 pascals.

To be eligible, a minimum of 75 percent of the ductwork must be located in unconditioned space and the ductwork must have a leakage rate greater than 15 percent of fan capacity at duct operating pressure. The maximum leakage rate reduction for this measure will be capped at 30 percent of fan capacity at duct operating pressure or at the fan rated capacity at 0.75 in. static pressure if design pressure is not known.

Pre-installation and post-installation testing should be performed using identical measurement procedures. Post-installation testing should be conducted after sealing materials have been allowed to cure.

Project savings shall be determined using the CFM difference in pre- and post-installation leakage test values, multiplied by the per-CFM deemed savings values for the appropriate weather zone. These tables are located at the end of this section.

Evaluation of Duct Leakage Using Leakage Classification Method

The leakage classification method relates duct leakage from ducts in unconditioned spaces to three variables:

- Surface area of ducts in unconditioned spaces (sq. ft.)
- Duct system operating pressure
- Leakage classification

Leakage classification is based on duct material, configuration, and whether ducts are sealed or unsealed. These variables are related to duct leakage per 100 square feet of duct area by the following:[386]

$$F = C_L \times P^{0.65}$$

(206)

Where:

F = Leakage Factor (CFM/100 sq. ft. of duct surface area)

C_L = Leakage Classification (Table 246)

P = Duct static pressure in the section of the duct being tested, in inches w.g.

Duct static pressure measurements shall be taken in accordance with *SMACNA HVAC Air Duct Leakage Test Manual*, Chapter 6.

Separate duct static pressure measurements shall be taken for duct sections of different type or size.

In the event duct static pressure measurement is impossible or impractical, the following default static pressure values may be used:

- Split system and package AC and HP systems, up to 65,000 Btuh cooling capacity: 0.1 inches w.g.(25 pascals)
- Other AC and HP systems, up to 135,000 Btuh cooling capacity: 0.5 inches w.g.

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[386] Source: *HVAC Air Duct Leakage Test Manual, Second Edition-2012,* p. 2.1

Duct system leakage (CFM) is then given by:

$$CFM = F \times A_u / 100$$

(207)

Where:

F = Leakage Factor (CFM/100 sq. ft. of duct surface area)

A_u = Surface area of duct system or section of duct system being evaluated, in sq. ft.

With these equations, the leakage in an entire duct system, or any section thereof, may be estimated. This measure is only applicable for duct systems or duct system sections that are in unconditioned spaces. For duct system sections that have different operating pressures, separate calculations for each section should be performed.

Calculations using the appropriate leakage classification values for unsealed and sealed ducts will provide pre- and post- installation CFM leakage rates.

Project savings shall be determined using the CFM difference in pre- and post-installation CFM leakage rates, multiplied by the per-CFM deemed savings values for the appropriate weather zone. These tables are located at the end of this section.

Table 246: Duct Leakage Classifications

Duct Type	**Leakage Classification**[387]			
	Unsealed/ Catastrophic Leaks	**Significant Leaks**	**Some Observable Leaks**	**Connections Sealed with Mastic**[388]
Rectangular Metal	48	35	22	8
Round Metal	24	17	10	4
Fibrous Glass Duct	24	18	12	6
Non-Metal Flexible Duct	30	24	18	12

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 18 years.

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[387] Adapted from SMACNA HVAC Air Duct Leakage Test Manual, Table 5-1. The original table had only values for Unsealed and Sealed. Additional categories for Some Observable Leaks and Significant Leaks were added by taking the midpoints between the existing Unsealed and Sealed values.

[388] Connections sealed with mastic or by other proven sealing methods.

Deemed Savings Values

Table 247: Duct Efficiency Improvements (SC) – Zone 9 Northwest

Duct Leakage	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Reduced**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh / 1,000 CFM reduction	**kW / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**
Savings/ CFM Reduction	1767	1.485	161.308	5.568	6028	1.787	4659	1.787

Table 248: Duct Efficiency Improvements (SC) – Zone 8 Northeast/North

Duct Leakage	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Reduced**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh / 1,000 CFM reduction	**kW / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**
Savings/ CFM Reduction	2022	0.595	170.468	4.295	6582	0.911	4989	0.911

Table 249: Duct Efficiency Improvements (SC) – Zone 7 Central Region

Duct Leakage	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Reduced**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh / 1,000 CFM reduction	**kW / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**
Savings/ CFM Reduction	2172	2.023	137.237	2.413	5933	2.383	4581	2.383

Table 250: Duct Efficiency Improvements (SC) – Zone 6 South Region

Duct Leakage	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Reduced**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh / 1,000 CFM reduction	**kW / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**therms / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**	**kWh / 1,000 CFM reduction**	**kW / 1,000 CFM reduction**
Savings/ CFM Reduction	3097	2.778	128.596	4.223	5774	2.817	4620	2.817

Calculation of Deemed Savings

Deemed savings for duct efficiency improvements were calculated using an eQuest model. Model runs were performed with TMY3 data that were converted to TMY2 format for each weather zone. As such, weather files were available for the cities of El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Leakage rates were calculated using a base unsealed leakage rate of 30 percent and an estimated reduction for sealed leakage rate of 12 percent, but the resulting 18 percent reduction is not claimed directly. These two endpoints were used to develop a linear relationship between reduction in duct leakage and cooling and heating energy use to determine the energy consumption for heating and cooling per CFM per square foot of duct surface area. These per CFM savings are applied against the site-specific CFM reduction determined by duct leakage pressurization testing or by the leakage classification method.

Peak savings were determined using two different building types: a strip mall and a small office building. Note that separate values are determined for natural gas savings. The prototype characteristics of the building models are outlined in Appendix A.

3.1.12 Duct Insulation (Converted Residences)

Measure Description

This measure consists of adding duct insulation with an R-value of 5.6 or 8.0 to uninsulated metal supply and return ductwork, located in unconditioned space that previously had no existing insulation.

Baseline and Efficiency Standards

The baseline for this measure is uninsulated sheet metal ducts or insulated metal ducts in which the insulation has failed. Failed insulation is insulation which has non-repairable tears to the vapor barrier, exhibits gaps with exposed metal between insulation, or insulation which is failing. Flex ducts, and fiber board ducts are not eligible for this measure. The ducts must be located in unconditioned spaces, such as attics or crawl spaces. Old ductwork insulation must be removed prior to installation of new duct wrap insulation.

Unconditioned space is defined as a space which is neither directly nor indirectly conditioned and is isolated from conditioned space by partitions, such as walls and/or closeable doors, and ceilings and in which the temperature of the area traversed by the ductwork is greater than 100 degrees Fahrenheit during the cooling season and lower than 50 degrees Fahrenheit during the heating season. Chapter 8, Table 1 provides a quick guide for determining if the area in which the ductwork is located may be considered unconditioned space.

The efficiency upgrade for this measure requires that ducts must be insulated with duct wrap to an R-value of 5.6 or 8.0. The R-value of 5.6 is the required duct insulation value in accordance with the Arkansas Energy Code Table 503.3.3.3.[389]The following table provides a quick guide for determining if the area in which the ductwork is located may be considered unconditioned space.

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[389] Source: http://www.sos.arkansas.gov/rulesRegs/Arkansas%20Register/2013/july13/168.00.11-003.pdf

Table 251: Conditioned vs. Unconditioned Areas

Description	**Approx. Temp. Summer/ Winter**	**Ventilated**	**Ceiling Insulation**	**Roof Deck Insulation**	**Sprayed Insulation**	**Radiant Barrier**	**Qualifies**
Attic #1 Converted Residence	130/50	N	Y	N	N	N	Y
Attic #2 Converted Residence	120/50	Y	Y	N	N	N	Y
Attic #3 Metal Bldg. w/Ceiling	110/60	Y	Y	Y	N	Y	N
Mechanical Rooms	110/60 w/o boiler	Y	N	Y	N	N	Y
Ventilated Warehouse	110/50	Y	N	N	N	N	N
Office Bldg. Ducted Return	90/60	N	N	Y	N	N	N
Office Bldg. Ducted Return[390]	130/50	N	Y	N	N	N	Y
Plenum Space Used for Return	90	Y	Y	Y	N	N	N
No Ceiling	85	N	N	Y	N	N	N

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[390] Only top floor common to roof qualifies.

Estimated Useful Life (EUL)

The estimated useful life of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Please note that the savings are a factor to be multiplied by the conditioned square footage of the converted residence. Gas Heat (No AC) kWh applies to forced-air systems only.

Table 252: Duct Insulation (CR) – Deemed Savings Values - Zone 9 Northwest

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.080	0	0.016	0.419	0.426	0.00015	0.00064
Attic to R-5.6	0.041	0	0.008	0.214	0.219	0.00008	0.00033
Crawl Space to R-8	0.058	0	0.019	0.388	0.402	0.00005	0.00054
Crawl Space to R-5.6	0.029	0	0.010	0.198	0.205	0.00002	0.00028

Table 253: Duct Insulation (CR) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms[391]
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.098	0	0.016	0.445	0.436	0.00017	0.00053
Attic to R-5.6	0.050	0	0.008	0.227	0.224	0.00009	0.00027
Crawl Space to R-8	0.067	0	0.020	0.425	0.420	0.00004	0.00048
Crawl Space to R-5.6	0.034	0	0.010	0.217	0.215	0.00002	0.00025

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[391] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.929 (Attic to R-8), m = 0.930 (Attic to R-5.6), m = 0.1.05 (Crawlspace to R-8), m = 1.05 (Crawlspace to R-5.6). For Fort Smith, m = 0.878 (Attic to R-8), m = 0.878 (Attic to R-5.6), m = 0.987 (Crawlspace to R-8), m = 0.987 (Crawlspace to R-5.6).

Table 254: Duct Insulation (CR) – Deemed Savings Values - Zone 7 Central Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.109	0	0.015	0.432	0.383	0.00017	0.00050
Attic to R-5.6	0.055	0	0.007	0.221	0.196	0.00009	0.00026
Crawl Space to R-8	0.072	0	0.018	0.421	0.383	0.00002	0.00063
Crawl Space to R-5.6	0.037	0	0.009	0.215	0.197	0.00001	0.00032

Table 255: Duct Insulation (CR) – Deemed Savings Values - Zone 6 South Region

Unconditioned Duct Location and added R-Value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Attic to R-8	0.125	0	0.011	0.380	0.350	0.00019	0.00048
Attic to R-5.6	0.064	0	0.006	0.194	0.180	0.00010	0.000245
Crawl Space to R-8	0.081	0	0.012	0.368	0.319	0.00007	0.00055
Crawl Space to R-5.6	0.041	0	0.006	0.188	0.164	0.00003	0.00028

Calculation of Deemed Savings

The building load simulation software EnergyGauge, which calculates hourly load data, was used to estimate energy savings for a prototype Arkansas converted residence.

A series of models was created to determine the difference in weather data throughout the four weather regions in Arkansas, as defined in IECC 2003. Since building shell measures are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype characteristics of the building model are outlined in Appendix A.

3.1.13 Duct Insulation (Small Commercial)

Measure Description

Duct insulation deemed savings are estimated per square foot of duct insulation installed. Deemed savings are provided for the addition of insulation to uninsulated , metal ducts installed in unconditioned space only, up to an R6 value. Duct insulation deemed savings values are estimated for buildings with roof deck insulation between R0-R9 and R10-R20. In order for a small commercial building duct insulation retrofit to qualify for these deemed savings, an HVAC tune-up (including refrigerant recharge) must first be performed.

Baseline and Efficiency Standards

The baseline is metal ducts of any size located in an unconditioned space inside a small commercial building that is uninsulated or in which the insulation has failed. Failed insulation is insulation which has non-repairable tears to the vapor barrier, exhibits gaps exposing metal, or insulation which has failed due to excess moisture. Flex ducts and fiber board ducts are not eligible for this measure. In a multi-story building, the baseline applies only to the top floor; for the purposes of this deemed savings estimate, ceiling space between floors is considered conditioned space. The baseline conditions modeled for HVAC supply and return fans are continuous operation during building operating hours (e.g., when the building is occupied), and cycling on and off with the HVAC unit during non-business operating hours.

The *ASHRAE Design Guide for Small Offices and Retail Buildings* recommends R-6 for the weather zones in which Arkansas is located. As such, duct insulation incentives require that insulation levels be brought up to R-6.

The following table provides a quick guide for determining if the area in which the ductwork is located may be considered unconditioned space.

Table 256: Conditioned vs. Unconditioned Areas

Description	**Approx. Temp. Summer/ Winter**	**Ventilated**	**Ceiling Insulation**	**Roof Deck Insulation**	**Sprayed Insulation**	**Radiant Barrier**	**Qualifies**
Attic #1 Converted Residence	130/50	N	Y	N	N	N	Y
Attic #2 Converted Residence	120/50	Y	Y	N	N	N	Y
Attic #3 Metal Bldg. w/Ceiling	110/60	Y	Y	Y	N	Y	N
Mechanical Rooms	110/60 w/o boiler	Y	N	Y	N	N	Y
Ventilated Warehouse	110/50	Y	N	N	N	N	N
Office Bldg. Ducted Return	90/60	N	N	Y	N	N	N
Office Bldg. Ducted Return[392]	130/50	N	Y	N	N	N	Y
Plenum Space Used for Return	90	Y	Y	Y	N	N	N
No Ceiling	85	N	N	Y	N	N	N

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[392] Only top floor common to roof qualifies.

Estimated Useful Life (EUL)

The estimated useful life of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Deemed savings values for annual electric energy use, peak demand, and peak gas reductions are provided in the following tables. *Note that deemed savings for duct insulation are per square foot of duct insulation added.*

Table 257: Duct Insulation (SC) – Deemed Savings Values - Zone 9 Northwest Region

Pre-Retrofit Roof Insulation R-value	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 000 sq. ft.	therms/ 000 sq. ft.	therms/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.
0 to 9	0.748	0.801	41.739	1.435	1.222	0.796	1.556	0.796
10 to 20	0.596	0.617	26.05	1.007	0.9	0.611	1.08	0.611

Table 258: Duct Insulation (SC) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Pre-Retrofit Roof Insulation R-value	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced[393]	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 000 sq. ft.	therms/ 000 sq. ft.	therms/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.
0 to 9	0.802	0.681	41.485	1.229 •	1.291	0.672	1.627	0.751
10 to 20	0.69	0.561	26.512	0.769 •	0.958	0.508	1.129	0.56

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[393] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying the Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.905 (R-0 to R-9) and m =0.885 (R-10 to R-20). For Fort Smith, m = 0.862 (R-0 to R-9) and m =0.847 (R-10 to R-20).

Table 259: Duct Insulation (SC) – Deemed Savings Values - Zone 7 Central Region

Pre-Retrofit Roof Insulation R-value	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 000 sq. ft.	therms/ 000 sq. ft.	therms/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.
0 to 9	0.843	0.683	34.59	0.988	1.255	0.746	1.535	0.842
10 to 20	0.72	0.573	22.354	0.683	0.924	0.574	1.07	0.653

Table 260: Duct Insulation (SC) – Deemed Savings Values - Zone 6 South Region

Pre-Retrofit Roof Insulation R-value	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 000 sq. ft.	therms/ 000 sq. ft.	therms/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.	kWh/ sq. ft.	kW/ 000 sq. ft.
0 to 9	0.994	0.869	27.37	1.354	1.303	0.864	1.503	1
10 to 20	0.767	0.676	16.997	1.04	0.982	0.669	1.073	0.77

Calculation of Deemed Savings

Deemed savings were calculated using eQuest models populated as shown in the following section. Model runs were performed with TMY3 data for cities in each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Three different buildings were used: a strip mall, a stand-alone retail building, and a small office building. Because roof deck insulation directly affects the temperature of the unconditioned space where candidate ducts are located, savings were estimated (on a per square foot basis) for each building type for two different levels of pre-retrofit roof deck insulation. The deemed savings values presented herein represent the average savings on a square foot basis for commercial buildings with gas or electric heating (including either electric resistance or heat pump) in each weather zone for buildings with pre-retrofit roof deck insulation levels of R-0 to R-9 and R-10 to R-20. The prototype characteristics of the building model are outlined in Appendix A.

3.1.14 Occupancy-Based PTAC/PTHP Controls

Measure Description

Packaged terminal air conditioners (PTAC) and packaged terminal heat pumps (PTHP) are commonly installed in the hospitality industry to provide heating and cooling of individual guest rooms. Occupancy-based PTAC/PTHP controllers are a combination of a control unit and occupancy sensor that operate in conjunction with each other to provide occupancy-controlled heating and/or cooling. The control unit plugs into a wall socket and the PTAC/PTHP plugs into the control unit. The control unit is operated by an occupancy sensor that is mounted in the room and turns the PTAC/PTHP on and off. The most common application for occupancy-based PTAC/PTHP controls is in hotel and motel rooms.

Hotel and motel guest rooms vary significantly. Hotel rooms typically have a larger area and volume than motel rooms. Additionally, a typical hotel and motel room will likely have a different number of exposed walls. A hotel room is likely to have only a single exposed wall with other walls adjoining conditioned space, while a motel room will have at least two exposed walls and an exposed attic (or roof structure) and/or slab foundation. For the purposes of this measure, a Motel is defined as having guest rooms that open to the exterior and are single story. All other lodging facilities should be defined as a Hotel.

Baseline and Efficiency Standards

The baseline for this measure is a PTAC or PTHP unit without an occupancy-based control system.

The efficiency condition for this measure is a PTAC or PTHP unit with an occupancy-based control system that has been configured with a 5 or 10 °F temperature setback.

Controller units must include an occupancy sensor and include the capability to configure the zone temperature control mode (occupied/unoccupied setback) based on guest room occupancy.

Estimated Useful Life (EUL)

In accordance with DEER 2014, the estimated useful life for an Energy Management System is 15 years, which is applicable to this measure.

Deemed Savings Values

Deemed savings values are configured per square foot of the room served by the PTAC/PTHP unit. If average guest room square footage is not available, assume 420 square feet for hotel guest rooms and 350 square feet for motel guest rooms.[394]

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[394] DOE Commercial Prototype Building Models. Available for download at: http://www.energycodes.gov/development/commercial/90.1_models.

Table 261: PTAC/PTHP Energy Savings per Square Foot for Hotels (kWh/ft2)

Weather Zone	PTAC		PTHP	
	5 °F Setback	10 °F Setback	5 °F Setback	10 °F Setback
El Dorado	0.752	1.302	0.602	1.041
Little Rock	0.822	1.449	0.658	1.159
Fort Smith	0.896	1.581	0.717	1.265
Fayetteville	0.774	1.352	0.620	1.081

Table 262: PTAC/PTHP Demand Savings per Square Foot for Hotels (kW/ft2)

Weather Zone	PTAC/PTHP	
	5 °F Setback	10 °F Setback
El Dorado	0.000186	0.000514
Little Rock	0.000331	0.000668
Fort Smith	0.000286	0.000616
Fayetteville	0.000256	0.000539

Table 263: PTAC/PTHP Energy Savings per Square Foot for Motels (kWh/ft2)

Weather Zone	PTAC		PTHP	
	5 °F Setback	10 °F Setback	5 °F Setback	10 °F Setback
El Dorado	1.165	2.015	0.932	1.612
Little Rock	1.272	2.243	1.018	1.794
Fort Smith	1.388	2.447	1.110	1.958
Fayetteville	1.199	2.093	0.959	1.674

Table 264: PTAC/PTHP Demand Savings per Square Foot for Motels (kW/ft2)

Weather Zone	PTAC/PTHP	
	5 °F Setback	10 °F Setback
El Dorado	0.000223	0.000617
Little Rock	0.000398	0.000802
Fort Smith	0.000343	0.000739
Fayetteville	0.000307	0.000646

Calculation of Deemed Savings

Hotel PTAC savings for this measure were modeled for each Arkansas weather zone using BEopt™ version 2.2, TMY3 weather data, and the EnergyPlus building modeling engine[395], averaging results for the four cardinal orientations. A single hotel room with three adiabatic walls and a super-insulated ceiling and floor, representing the most typical and conservative room configuration, was modeled with a 10.7 EER PTAC and electric resistance heat. Room area and volume assumptions were extracted from the DOE commercial prototype building models for the Small and Large Hotel building types.[396] Each room was modeled with a 24 square foot window.[397] All appliances were removed except for a refrigerator. All other default BEopt assumptions were maintained, and all assumptions were maintained in the base and change cases, except for the assumed temperature schedule for the 5 and 10 °F temperature setbacks. The base temperature schedule assumes the room is continuously maintained at 70 °F. The adjusted temperature schedule was developed by adding or subtracting the specified setup or setback temperature by the percent hour unoccupied.[398] Percent hours unoccupied were extracted from the occupancy schedule for the US DOE commercial prototype building model for the Small Hotel building type. Prototype guest room characteristics used in the BEopt building model can be found in Appendix A.

Modeled Hotel PTAC savings were adjusted to estimate savings for Hotel PTHPs and Motel PTACs and PTHPs. The adjustment factors were developed by comparing average savings values developed for comparable measures from the Technical Reference Manuals in Texas and Illinois.[399,400] Hotel PTHP energy savings were calculated by applying a 0.80 adjustment factor to corresponding Hotel PTAC energy savings. Motel PTAC/PTHP energy savings were calculated by applying a 1.29 adjustment factor to corresponding Hotel PTAC/PTHP energy savings. Modeled Hotel demand savings were applied to the Motel building type but were adjusted based on the reduction of the guest room square footage assumption from 420 square feet to 350 square feet.

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[395] U.S. DOE. http://apps1.eere.energy.gov/buildings/energyplus/ep_interfaces.cfm.

[396] Available for download at: http://www.energycodes.gov/development/commercial/90.1_models.

[397] Codes and Standards Enhancement Initiative (CASE), "*Guest Room Occupancy Controls: 2013 California Building Energy Efficiency Standards,"* October 2011. P. 11.

[398] Codes and Standards Enhancement Initiative (CASE), *"Guest Room Occupancy Controls: 2013 California Building Energy Efficiency Standards*,. October 2011. p. 14.

[399] Texas TRM Version 2.0: 2.6.2 Lodging Guest Room Occupancy Sensor Controls, Tables 2-111 and 2-112.

[400] Illinois TRM Version 3.0: 4.4.8 Guest Room Energy Management (PTAC & PTHP), pp. 203-208.

3.1.15 Packaged Terminal AC/HP (PTAC/PTHP) Equipment

Measure Description

This measure requires the installation of a PTAC or PTHP. AHRI Test Standard 310/380-2004 defines a PTAC or PTHP as “a wall sleeve and a separate non-encased combination of heating and cooling assemblies specified by the manufacturer and intended for mounting through the wall. It includes refrigeration components, separable outdoor louvers, forced ventilation, and heating availability by purchaser’s choice of, at least, hot water, steam, or electrical resistance heat.” These definitions are consistent with federal code (10 CFR Part 431.92).

PTAC/PTHP equipment is available in standard and non-standard sizes. Standard size refers to PTAC/PTHP equipment with wall sleeve dimensions having an external opening greater than or equal to 16 inches high or greater than or equal to 42 inches wide, and a cross-sectional area greater than or equal to 670 square inches. Non-standard size refers to PTAC/PTHP equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide, and a cross-sectional area less than 670 square inches.

Baseline and Efficiency Standards

The sections that follow describe the baseline efficiency values that should be used for measures in new construction applications or that replace burned-out equipment, designated “replace-on-burnout,” and for measures that replace equipment with remaining useful life, designated “early retirement.”

New Construction or Replace-on-Burnout

The baseline for units that are used in new construction or are replaced on burnout is the current federal minimum standard,[401] which went into effect September 30, 2012 for standard sized units and September 30, 2010 for non-standard sized units (Table 265).

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

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[401] 2010 U.S. Code: Title 42, Chapter 77, Subchapter III, Part A-1, Section 6313.

Table 265: PTAC/PTHP Equipment – Baseline Efficiency Levels [402]

Equipment Type	Size Category	Capacity (Btu/h)	Minimum Efficiency [403]
PTAC	Standard	< 7,000	EER = 11.7
		7,000 – 15,000	EER = 13.8 – (0.300 x CAP)
		> 15,000	EER = 9.3
	Non-Standard	< 7,000	EER = 9.4
		7,000 – 15,000	EER = 10.9 – (0.213 x CAP)
		> 15,000	EER = 7.7
PTHP	Standard	< 7,000	EER = 11.9 COP = 3.3
		7,000 – 15,000	EER = 14.0 – (0.300 x CAP) COP = 3.7 – (0.052 x CAP)
		> 15,000	EER = 9.5 COP = 2.9
	Non-Standard	< 7,000	EER = 9.3 COP = 2.7
		7,000 – 15,000	EER = 10.8 – (0.213 x CAP) COP = 2.9 – (0.026 x CAP)
		> 15,000	EER = 7.6 COP = 2.5

Early Retirement

Early retirement projects involve replacement of a working system. There is a dual baseline for early retirement applications. For the remaining useful life of the existing equipment, the baseline is the nameplate efficiency of the existing cooling equipment. If unavailable, use efficiencies listed in Table 266.

For the remainder of the estimated useful life, the baseline is the current federal minimum efficiency for the installed equipment type (Table 265).

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

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[402] Standards for Packaged Terminal Air Conditioners and Heat Pumps. U.S. DOE. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45

[403] “Cap” refers to cooling capacity in thousand Btu/h.

Table 266: PTAC/PTHP Equipment – Early Retirement Baseline Efficiencies [404]

Equipment Type	Capacity (Btu/h)	Minimum Efficiency [405]
PTAC (Cooling)	< 7,000	EER = 9.4
	7,000 – 15,000	EER = 10.9 – (0.213 × CAP/1000)
	> 15,000	EER = 7.7
PTHP (Cooling)	< 7,000	EER = 9.3
	7,000 – 15,000	EER = 10.8 – (0.213 × CAP/1000)
	> 15,000	EER = 7.6
PTHP (Heating)	< 7,000	COP = 2.7
	7,000 – 15,000	COP = 2.9 – (0.026 × CAP/1000)
	> 15,000	COP = 2.5

Estimated Useful Life (EUL)

The estimated useful life of the measure is 10 years, in accordance with the DOE's Packaged Terminal Air Conditioners and Heat Pumps Energy Conservation Standard Technical Support Document.[406]

Calculation of Deemed Savings

Deemed peak demand and annual energy savings for PTAC/PTHP equipment should be calculated using the following formulas:

New Construction or Replace-on-Burnout

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \times CF \tag{208}$$

$$kWh_{Savings,PTAC} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \tag{209}$$

$$kWh_{Savings,PTHP,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base,C}} - \frac{1}{\eta_{post,C}}\right) \tag{210}$$

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[404] IECC 2009, Table 503.2.3(3); consistent since IECC 2003.

[405] CAP refers to the rated cooling capacity of the product in Btu/h. If the capacity is less than 7,000 Btu/h, use 7,000 Btu/h in the calculation. If the capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

[406] U.S. DOE, Technical Support Document: "*Packaged Terminal Air Conditioners and Heat Pumps, 3.2.7 Equipment Lifetime*". http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45.

$$kWh_{Savings,PTHP,H} = CAP_H \times \frac{1\,kWh}{3{,}412\text{ BTU}} \times EFLH_H \times \left(\frac{1}{\eta_{base,H}} - \frac{1}{\eta_{post,H}}\right)$$

(211)

Where:

CAP_C= Rated equipment cooling capacity of the new unit (BTU/hr)

CAP_H= Rated equipment heating capacity of the new unit (BTU/hr)

$\eta_{base,C}$ = Baseline energy efficiency rating of the baseline cooling equipment (EER) (Table 266)

$\eta_{post,C}$= Nameplate energy efficiency rating of the installed cooling equipment (EER)

$\eta_{post,H}$= Nameplate energy efficiency rating of the installed heating equipment (COP)

Note: heating efficiencies expressed as a heating seasonal performance factor (HSPF) will need to be converted to a coefficient of performance (COP) using the following equation:

$$COP = HSPF \div 3.412$$

(212)

$3{,}412$= Constant to convert from BTU/hr to kWh

CF = Coincidence factor (Table 475)

$EFLH_C$ = Equivalent full-load hours for cooling (Table 477)

$EFLH_H$ = Equivalent full-load hours for heating (Table 478)

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated as the RUL, and
2. The remaining time in the EUL period (EUL – RUL).

For the RUL:

$$kW_{Savings} = CAP_C \times \frac{1\,kW}{1{,}000\,W} \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right) \times CF$$

(213)

$$kWh_{savings,PTAC} = CAP_C \times \frac{1\,kW}{1{,}000\,W} \times EFLH_C \times \left(\frac{1}{\eta_{pre}} - \frac{1}{\eta_{post}}\right)$$

(214)

$$kWh_{Savings,PTHP,C} = CAP_C \times \frac{1\,kW}{1{,}000\text{ W}} \times EFLH_C \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right)$$

(215)

$$kWh_{Savings,PTHP,H} = CAP_H \times \frac{1\ kWh}{3{,}412\ \text{BTU}} \times EFLH_H \times \left(\frac{1}{\eta_{pre,H}} - \frac{1}{\eta_{post,H}}\right)$$

(216)

For the remaining time in the EUL period (EUL – RUL):

> Calculate annual savings as you would for a replace-on-burnout project using Equations (208), (209), (210), and (211).

Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kwh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(217)

Where:

CAP = Rated equipment cooling capacity of the new unit (BTU/hr)

$\eta_{pre,C}$ = Energy efficiency rating of the existing cooling equipment (EER) (if unavailable, use default efficiency from Table 266)

$\eta_{pre,H}$ = Energy efficiency rating of the existing heating equipment (COP) (if unavailable, use default efficiency from Table 266)

$\eta_{post,C}$ = Energy efficiency rating of the installed cooling equipment (EER)

$\eta_{post,H}$ = Energy efficiency rating of the installed heating equipment (COP)

Note: heating efficiencies expressed as a heating seasonal performance factor (HSPF) will need to be converted to a coefficient of performance (COP) using the following equation:

$$COP = HSPF \div 3.412$$

(218)

CF = Coincidence factor (Table 475)

$EFLH_C$ = Equivalent full-load hours for cooling from Table 477

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

RUL = Remaining Useful Life (Table 267)

EUL = Estimated Useful Life = 10 years

Table 267: Remaining Useful Life (RUL) of Replaced Systems[407]

Age of Replaced System (Years)	RUL (Years)
1	9.5
2	9.0
3	8.5
4	8.0
5	7.5
6	7.0
7	6.5
8	6.0
9	5.5
10	5.0
11	4.5
12	4.0
13	3.5
14	3.0
15	2.5
16 +	0.0

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[407] Use of the early retirement baseline is capped at 15 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 15 years should use the ROB baseline.

Derivation of RULs

Commercial PTAC/PTHP systems have an estimated useful life of ten years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described by the survival function in Figure 10.

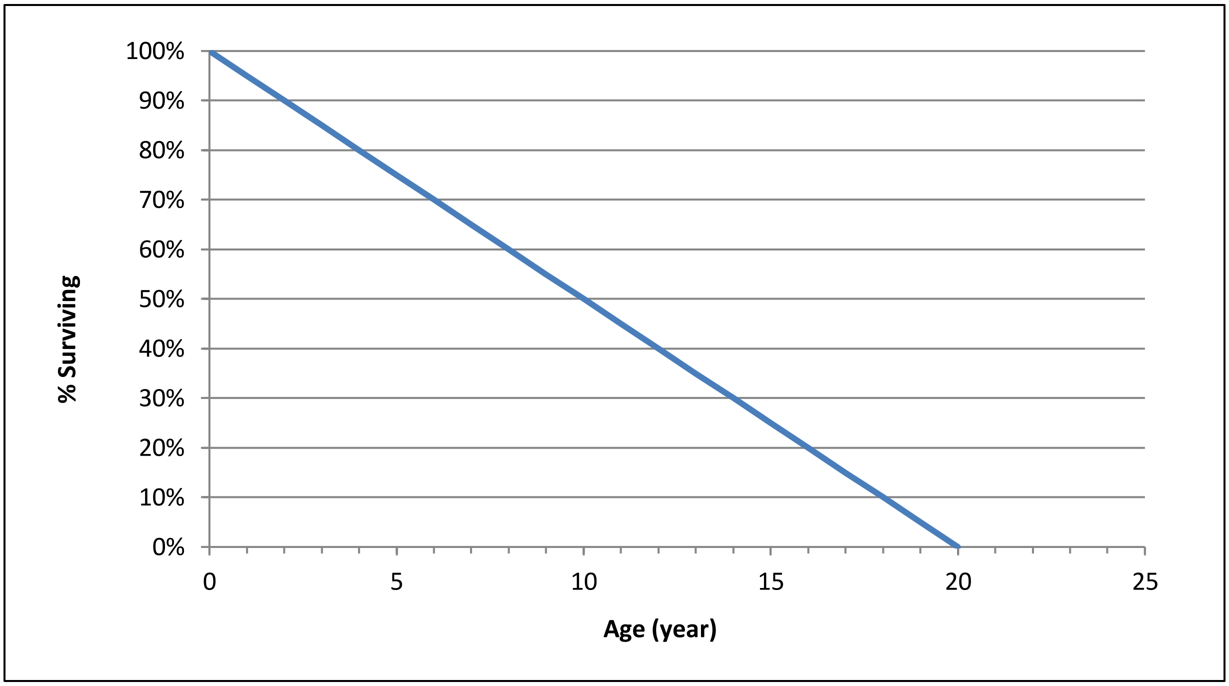

Figure 10: Survival Function for Commercial PTAC/PTHP Systems[408,409]

The method used for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 10. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[408] U.S. DOE, "*Technical Support Document: "Packaged Terminal Air Conditioners and Heat Pumps, Chapter 8*". http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45.

[409] Life Cycle Cost Analysis Spreadsheet, "ptac_lcc_fr.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

3.1.16 (Empty)

3.1.17 Steam Trap Replacement

Measure Description

Steam traps are important elements of steam and condensate systems, and may represent a major energy conservation opportunity. The primary function of a steam trap is to allow condensate formed in the heating process to be drained from the heating equipment. A second crucial function of a steam trap is to facilitate the removal of air from the steam system. Steam traps often fail in the open position, which make steam traps among the biggest energy wasters in a facility. If a steam trap fails in the open position, steam is allowed to pass through the trap and directly into the condensate return system, therefore wasting the available heat within the steam. The boiler continues to generate steam that is being wasted through the failed open steam trap. For steam traps that fail in the closed position, no energy savings will be realized and the heating equipment will not meet its designed capacity.

Baseline and Efficiency Standards

According to the NYSERDA[31] Natural Gas Database, 70 percent is indicated for baseline combustion efficiency for a steam trap maintenance project. The efficiency to generate steam is stipulated at 100 percent for electric boilers.

Estimated Useful Life (EUL)

According to the NYSERDA Natural Gas Database, the estimated useful life (EUL) is five years.

Calculation of Deemed Savings

When electric boilers are being used to generate steam, deemed electrical savings for steam trap replacements should be calculated by the following formulas:

$$kW_{savings} = \frac{Steam\ Trap\ Discharge\ Rate\ \times h_{fg}}{E_{Elec} \times Conversion\ Factor} \tag{219}$$

$$kWh_{savings} = \frac{Steam\ Trap\ Discharge\ Rate\ \times OpHrs\ \times h_{fg}}{E_{Elec} \times Conversion\ Factor} \tag{220}$$

Where:

$Steam\ Trap\ Discharge\ Rate$ = Steam loss in lb/hr. See Table 268.

$Conversion\ Factor$ = 3,412 (BTU/hr)/kW

$OpHrs$ = annual hours the steam system is pressurized (if unknown, default to equivalent full load heating hours, $EFLH_H$, Table 478)

h_{fg} = Latent heat of vaporization in BTU/lb from the saturated steam tables

E_{Elec} = Efficiency for an electric boiler, 100 percent

When natural gas-fired boilers are being used to generate steam, deemed annual natural gas savings for steam trap replacements should be calculated by the following formulas:

$$Therm_{savings} = \frac{Steam\ Trap\ Discharge\ Rate\ \times OpHrs\ \times\ h_{fg}}{Ec_{Base} \times Therm\ Conversion\ Factor}$$

(221)

Where:

$Steam\ Trap\ Discharge\ Rate$ = Steam loss in lb/hr. See Table 268.

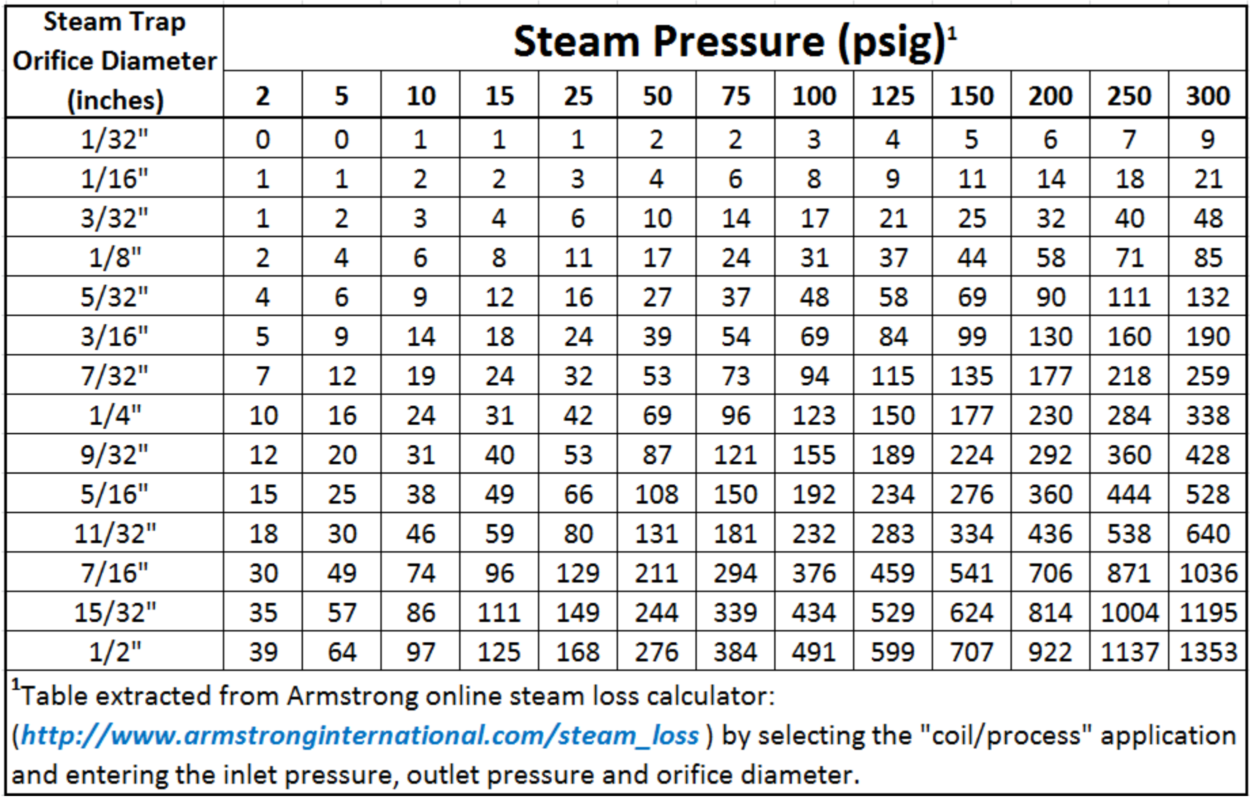
$OpHrs$ = annual hours the steam system is pressurized (if unknown, default to equivalent full load heating hours, $EFLH_H$, Table 478)

h_{fg}= Latent heat of evaporation in Btu/lb from steam tables (970.4).

Ec_{Base} = Combustion efficiency for boiler (if unavailable, estimate at 70%)

$Therm\ Conversion\ Factor$ = 100,000BTU/therm

Table 268: Steam Trap Replacement – Leaking Steam Trap Discharge Rate - Steam Loss (lbs./hr.)



Steam Trap Orifice Diameter (inches)	Steam Pressure (psig)[1]												
	2	5	10	15	25	50	75	100	125	150	200	250	300
1/32"	0	0	1	1	1	2	2	3	4	5	6	7	9
1/16"	1	1	2	2	3	4	6	8	9	11	14	18	21
3/32"	1	2	3	4	6	10	14	17	21	25	32	40	48
1/8"	2	4	6	8	11	17	24	31	37	44	58	71	85
5/32"	4	6	9	12	16	27	37	48	58	69	90	111	132
3/16"	5	9	14	18	24	39	54	69	84	99	130	160	190
7/32"	7	12	19	24	32	53	73	94	115	135	177	218	259
1/4"	10	16	24	31	42	69	96	123	150	177	230	284	338
9/32"	12	20	31	40	53	87	121	155	189	224	292	360	428
5/16"	15	25	38	49	66	108	150	192	234	276	360	444	528
11/32"	18	30	46	59	80	131	181	232	283	334	436	538	640
7/16"	30	49	74	96	129	211	294	376	459	541	706	871	1036
15/32"	35	57	86	111	149	244	339	434	529	624	814	1004	1195
1/2"	39	64	97	125	168	276	384	491	599	707	922	1137	1353

[1] Table extracted from Armstrong online steam loss calculator: (***http://www.armstronginternational.com/steam_loss***) by selecting the "coil/process" application and entering the inlet pressure, outlet pressure and orifice diameter.

Measure/Technology Review

Several of the primary data sources reviewed for this effort contained information about steam traps.

Table 269: Steam Trap Replacement – Review of Steam Trap Information

Resource	Notes
NYSERDA [410]	Life of steam trap 5 years, 70% boiler efficiency, 10-20% natural gas savings.
FEMP [411]	Report: Steam Trap Performance Assessment – shows methods to test for failed traps, how to calculate energy savings, table showing energy loss for failed traps at various pressures and orifice sizes, recommends not using the full orifice diameter when calculating savings (recommends 0.50 coefficient of discharge).
U.S. DOE [412]	Report: Energy Tips – Steam, Table for steam loss in lb/hr. for steam trap failed open with coefficient of discharge of 0.72.
ENERGY STAR®[413]	Report: Wise Rules for Industrial Energy Efficiency, September 2003
XCEL Energy [414]	Reports and rebate application show minimum installation and equipment standards to be eligible for rebate, recommend testing steam traps annually.

Code Review

No energy codes related to steam trap replacement were found.

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[410] Nexant. 2005. *NYSERDA Deemed Savings Measure Database*. Prepared for NYSERDA.

[411] Federal Energy Management Program (FEMP). 1999. *Steam Trap Assessment*.

[412] U.S. DOE. 2006. Energy Tips – Steam Inspect and Repair Steam Traps. January, 2006.

[413] ENERGY STAR®. 2003. Wise Rules for Industrial Energy Efficiencies. September 2003.

[414] Xcel Energy. 2006. 2007/2008/2009 *Triennial Plan Minnesota Natural Gas and Electric Conversation Improvement Program.*

3.1.18 Unitary and Split System AC/HP Equipment

Measure Description

This measure requires the installation of packaged or split system air conditioners (AC) or heat pumps (HP), excluding PTACs/PTHPs. Unitary or split system ACs/HPs consist of one or more factory-made assemblies that normally include an evaporator or cooling coil(s), compressor(s), and condenser(s). They provide the function of air cooling, and may include the functions of air heating, air circulation, air cleaning, dehumidifying, or humidifying.

Baseline and Efficiency Standards

The sections that follow describe the different baseline efficiency values that should be used for measures in new construction applications or that replace burned-out equipment, designated "replace-on-burnout," and for measures that replace equipment with remaining useful life, designated "early retirement."

New Construction or Replace-on-Burnout

The baseline for units that are used in new construction or are replaced on burnout is the current federal minimum standard,[415] which went into effect January 1, 2010 (Table 270).

As of January 1, 2015, split system heat pumps < 65,000 Btu/h must comply with 10 CFR 430.32(c)(3) for Residential Central Air Conditioners and Heat Pumps. Split systems are not explicitly covered by originally specified federal standard 10 CFR 431.97 for Commercial package air condition and heating equipment. Split system air conditioners are not affected because the existing SEER and HSPF values remain unchanged.

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

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[415] 2010 U.S. Code: Title 42, Chapter 77, Subchapter III, Part A-1, Section 6313.

Table 270: Unitary AC/HP Equipment – Baseline Efficiency Levels [416]

Equipment Type	Capacity (Btu/h)	Heating Section Type	Sub-Category	Minimum Efficiency
Air Conditioners, Air Cooled	< 65,000	All	Split System & Single Package	11.8 EER[417] 14.0 SEER
	≥ 65,000 & < 135,000	Electric Resistance (or none)	Split System & Single Package	11.2 EER 11.4 IEER
	≥ 65,000 & < 135,000	All other	Split System & Single Package	11.0 EER 11.2 IEER
	≥ 135,000 & < 240,000	Electric Resistance (or none)	Split System & Single Package	11.0 EER 11.2 IEER
	≥ 135,000 & < 240,000	All other	Split System & Single Package	10.8 EER 11.0 IEER
	≥ 240,000 & < 760,000	Electric Resistance (or none)	Split System & Single Package	10.0 EER 10.1 IEER
	≥ 240,000 & < 760,000	All other	Split System & Single Package	9.8 EER 9.9 IEER
	≥ 760,000	Electric Resistance (or none)	Split System & Single Package	9.7 EER 9.8 IEER
	≥ 760,000	All other	Split System & Single Package	9.5 EER 9.6 IEER
Air Conditioners, Water and Evaporative Cooled [418]	< 65,000	All	Split System & Single Package	12.1 EER 12.3 IEER
	≥ 65,000 & < 135,000	Electric Resistance (or none)	Split System & Single Package	11.5 EER 11.7 IEER
	≥ 65,000 & < 135,000	All other	Split System & Single Package	11.3 EER 11.5 IEER
	≥ 135,000 & < 240,000	Electric Resistance (or none)	Split System & Single Package	11.0 EER 11.2 IEER
	≥ 135,000 & < 240,000	All other	Split System & Single Package	10.8 EER 11.0 IEER

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[416] IECC 2012, Table C403.2.3(1) & C403.2.3(2); full-load efficiencies consistent with ASHRAE Standard 90.1-2007, Table 6.8.1A & 6.8.1B and compliant with the federal standard.

[417] Code specified SEER value converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

[418] Used IECC 2012 values for before 6/1/2011 to be consistent with ASHARAE 90.1-2007.

Equipment Type	**Capacity (Btu/h)**	**Heating Section Type**	**Sub-Category**	**Minimum Efficiency**
	≥ 240,000	Electric Resistance (or none)	Split System & Single Package	11.0 EER 11.1 IEER
	≥ 240,000	All other	Split System & Single Package	10.8 EER 10.9 IEER
Heat Pumps, Air Cooled (Cooling Mode)	< 65,000	All	Single Package	11.8 EER[419] 14.0 SEER
			Single Package (before 1/1/2015)	11.2 EER[420] 13.0 SEER
			Single Package (after 1/1/2015)[421]	11.8 EER[422] 14.0 SEER
	≥ 65,000 & < 135,000	Electric Resistance (or none)	Split System & Single Package	11.0 EER 11.2 IEER
	≥ 65,000 & < 135,000	All other	Split System & Single Package	10.8 EER 11.0 IEER
	≥ 135,000 & < 240,000	Electric Resistance (or none)	Split System & Single Package	10.6 EER 10.7 IEER
	≥ 135,000 & < 240,000	All other	Split System & Single Package	10.4 EER 10.5 IEER
	≥ 240,000	Electric Resistance (or none)	Split System & Single Package	9.5 EER 9.6 IEER
	≥ 240,000	All other	Split System & Single Package	9.3 EER 9.4 IEER
Heat Pumps, Air Cooled (Heating Mode)	< 65,000	n/a	Split System & Single Package (before 1/1/2015)	7.7 HSPF

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[419] Code specified SEER value converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). *"Building America House Simulation Protocols."* U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[420] Ibid.

[421] As specified by 10 CFR 430.32(c)(3) for Residential Central Air Conditioners and Heat Pumps. Split systems are not explicitly covered by originally specified federal standard 10 CFR 431.97 for Commercial package air condition and heating equipment. Split system air conditioners are not affected (SEER value remains unchanged).

[422] Code specified SEER value converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

Equipment Type	**Capacity (Btu/h)**	**Heating Section Type**	**Sub-Category**	**Minimum Efficiency**
			Split System (after 1/1/2015)[423]	8.2 HSPF
			Single Package (after 1/1/2015)[424]	8.0 HSPF
	≥ 65,000 & < 135,000	n/a	Split System & Single Package	3.3 COP
	≥ 135,000	n/a	Split System & Single Package	3.2 COP

Early Retirement

Early retirement projects involve the replacement of a working system. There is a dual baseline for early retirement applications. For the remaining useful life of the existing equipment, the baseline is the nameplate efficiency of the existing cooling equipment. If unavailable, baseline efficiency will be estimated according to the ASHRAE standard that was in effect at the time of manufacture based on the type, size, and year of manufacture for the replaced system. Baseline efficiency levels for systems installed from 1990 to 2007 are provided in Table 271 through Table 274. For the remainder of the estimated useful life, the baseline is the current federal minimum efficiency for the installed equipment type (Table 270).

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

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[423] As specified by 10 CFR 430.32(c)(3) for Residential Central Air Conditioners and Heat Pumps. Split systems are not explicitly covered by originally specified federal standard 10 CFR 431.97 for Commercial package air condition and heating equipment. Split system air conditioners are not affected (HSPF value remains unchanged).

[424] Ibid.

Table 271: Baseline Full-Load Efficiency of Air Conditioners (ACs) Replaced via Early Retirement [425]

Mfg. Year of Replaced System	Split Systems < 65,000 BTU/hr	Packaged Systems < 65,000 BTU/hr	All Systems ≥ 65,000 & < 135,000 BTU/hr	All Systems ≥ 135,000 & < 240,000 Btu/hr	All Systems ≥ 240,000 & < 760,000 BTU/hr	All Systems ≥ 760,000 BTU/hr
	EER [426]	**EER** [427]	**EER**	**EER**	**EER**	**EER**
1990	9.2	9.0	8.9	8	8	7.8
1991	9.2	9.0	8.9	8	8	7.8
1992	9.2	9.0	8.9	8.3	8.3	8
1993	9.2	9.0	8.9	8.3	8.3	8
1994	9.2	9.0	8.9	8.3	8.3	8
1995	9.2	9.0	8.9	8.3	8.3	8
1996	9.2	9.0	8.9	8.3	8.3	8
1997	9.2	9.0	8.9	8.3	8.3	8
1998	9.2	9.0	8.9	8.3	8.3	8
1999	9.2	9.0	8.9	8.3	8.3	8
2000	9.2	9.0	8.9	8.3	8.3	8
2001	9.2	9.0	8.9	8.3	8.3	8
2002	9.2	9.0	10.1	9.5	9.3	9
2003	9.2	9.0	10.1	9.5	9.3	9
2004	9.2	9.0	10.1	9.5	9.3	9
2005	9.2	9.0	10.1	9.5	9.3	9
2006	11.2	11.2	10.1	9.5	9.3	9
2007	11.2	11.2	10.1	9.5	9.3	9

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[425] Consolidation of ASHRAE 90.1-1989-2007

[426] Code specified SEER value converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x SEER. National Renewable Energy Laboratory (NREL). *"Building America House Simulation Protocols."* U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[427] Ibid.

Table 272: Baseline Part-Load Efficiency of Air Conditioners (ACs) Replaced via Early Retirement [428]

Mfg. Year of Replaced System	Split Systems < 65,000 BTU/hr	Packaged Systems < 65,000 BTU/hr	All Systems ≥ 65,000 & < 135,000 BTU/hr	All Systems ≥ 135,000 & < 240,000 BTU/hr	All Systems ≥ 240,000 & < 760,000 BTU/hr	All Systems ≥ 760,000 BTU/hr
	SEER	**SEER**	**IEER**	**IEER**	**IEER**	**IEER**
1990	10.0	10.4	10.3	9.3	9.3	9.0
1991	10.0	10.4	10.3	9.3	9.3	9.0
1992	10.0	10.4	10.3	9.6	9.6	9.3
1993	10.0	10.4	10.3	9.6	9.6	9.3
1994	10.0	10.4	10.3	9.6	9.6	9.3
1995	10.0	10.4	10.3	9.6	9.6	9.3
1996	10.0	10.4	10.3	9.6	9.6	9.3
1997	10.0	10.4	10.3	9.6	9.6	9.3
1998	10.0	10.4	10.3	9.6	9.6	9.3
1999	10.0	10.4	10.3	9.6	9.6	9.3
2000	10.0	10.4	10.3	9.6	9.6	9.3
2001	10.0	10.4	10.3	9.6	9.6	9.3
2002	10.0	10.4	11.7	11.0	10.8	10.4
2003	10.0	10.4	11.7	11.0	10.8	10.4
2004	10.0	10.4	11.7	11.0	10.8	10.4
2005	10.0	10.4	11.7	11.0	10.8	10.4
2006	13.0	13.0	11.7	11.0	10.8	10.4
2007	13.0	13.0	11.7	11.0	10.8	10.4

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[428] IEER = EER x 1.16 based on review of existing AHRI Unitary Large Equipment. Accessed 7/16/2014.

Table 273: Baseline Full-Load Efficiency of Heat Pumps (HPs) Replaced via Early Retirement [429]

Mfg. Year of Replaced System	Split Systems < 65,000 BTU/hr	Packaged Systems < 65,000 BTU/hr	All Systems ≥ 65,000 & < 135,000 BTU/hr	All Systems ≥ 135,000 & < 240,000 BTU/hr	All Systems ≥ 240,000 & < 760,000 BTU/hr	All Systems ≥ 760,000 BTU/hr
	EER [430]	EER [431]	EER	EER	EER	EER
1990	9.2	9.0	8.9	8	8	7.8
1991	9.2	9.0	8.9	8	8	7.8
1992	9.2	9.0	8.9	8.3	8.3	8.5
1993	9.2	9.0	8.9	8.3	8.3	8.5
1994	9.2	9.0	8.9	8.3	8.3	8.5
1995	9.2	9.0	8.9	8.3	8.3	8.5
1996	9.2	9.0	8.9	8.3	8.3	8.5
1997	9.2	9.0	8.9	8.3	8.3	8.5
1998	9.2	9.0	8.9	8.3	8.3	8.5
1999	9.2	9.0	8.9	8.3	8.3	8.5
2000	9.2	9.0	8.9	8.3	8.3	8.5
2001	9.2	9.0	8.9	8.3	8.3	8.5
2002	9.2	9.0	9.9	9.1	8.8	8.8
2003	9.2	9.0	9.9	9.1	8.8	8.8
2004	9.2	9.0	9.9	9.1	8.8	8.8
2005	9.2	9.0	9.9	9.1	8.8	8.8
2006	11.2	11.2	9.9	9.1	8.8	8.8
2007	11.2	11.2	9.9	9.1	8.8	8.8

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[429] Consolidation of ASHRAE 90.1-1989-2007

[430] Code specified SEER value converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). “Building America House Simulation Protocols.” U.S. DOE. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[431] Ibid.

Table 274: Baseline Part-Load Efficiency of Heat Pumps (HPs) Replaced via Early Retirement [432]

Mfg. Year of Replaced System	Split Systems < 65,000 BTU/hr	Packaged Systems < 65,000 BTU/hr	All Systems ≥ 65,000 & < 135,000 BTU/hr	All Systems ≥ 135,000 & < 240,000 BTU/hr	All Systems ≥ 240,000 & < 760,000 BTU/hr	All Systems ≥ 760,000 BTU/hr
	SEER	**SEER**	**IEER**	**IEER**	**IEER**	**IEER**
1990	10.0	10.4	10.3	9.3	9.3	9.0
1991	10.0	10.4	10.3	9.3	9.3	9.0
1992	10.0	10.4	10.3	9.6	9.6	9.9
1993	10.0	10.4	10.3	9.6	9.6	9.9
1994	10.0	10.4	10.3	9.6	9.6	9.9
1995	10.0	10.4	10.3	9.6	9.6	9.9
1996	10.0	10.4	10.3	9.6	9.6	9.9
1997	10.0	10.4	10.3	9.6	9.6	9.9
1998	10.0	10.4	10.3	9.6	9.6	9.9
1999	10.0	10.4	10.3	9.6	9.6	9.9
2000	10.0	10.4	10.3	9.6	9.6	9.9
2001	10.0	10.4	10.3	9.6	9.6	9.9
2002	10.0	10.4	11.5	10.6	10.2	10.2
2003	10.0	10.4	11.5	10.6	10.2	10.2
2004	10.0	10.4	11.5	10.6	10.2	10.2
2005	10.0	10.4	11.5	10.6	10.2	10.2
2006	13.0	13.0	11.5	10.6	10.2	10.2
2007	13.0	13.0	11.5	10.6	10.2	10.2

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[432] IEER = EER x 1.16 based on review of existing AHRI Unitary Large Equipment. Accessed 7/16/2014.

Equipment Useful Life (EUL)

According to the DEER 2008, the EUL for this measure is 15 years.

Calculation of Deemed Savings

Deemed peak demand and annual energy savings for unitary AC and HP equipment should be calculated as shown below. Note that these savings calculations are different depending on whether the measure is replace-on-burnout or early retirement.

New Construction or Replace-on-Burnout

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{base,C}} - \frac{1}{\eta_{post,C}}\right) \times CF$$

(222)

$$kWh_{Savings,AC} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base,C}} - \frac{1}{\eta_{post,C}}\right)$$

(223)

$$kWh_{Savings,HP,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{base,C}} - \frac{1}{\eta_{post,C}}\right)$$

(224)

$$kWh_{Savings,HP,H} = CAP_H \times \frac{1\ kW}{1{,}000\ \mathrm{W}} \times EFLH_H \times \left(\frac{1}{\eta_{base,H}} - \frac{1}{\eta_{post,H}}\right)$$

(225)

Where:

CAP_C= Rated equipment cooling capacity of the new unit (BTU/hr)

CAP_H= Rated equipment heating capacity of the new unit (BTU/hr)

$\eta_{base,C/H}$ = Baseline energy efficiency rating of the cooling/heating equipment (Table 270)

$\eta_{post,C/H}$= Nameplate energy efficiency rating of the installed cooling/heating equipment

Note: Use EER for kW savings calculations and SEER/IEER and HSPF for kWh savings calculations.

CF = Coincidence factor (Table 475)

$EFLH_C$ = Equivalent full-load hours for cooling from Table 477

$EFLH_H$ = Equivalent full-load hours for heating from Table 478

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (15 – RUL).

For the RUL (Table 275):

$$kW_{Savings} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right) \times CF$$

(226)

$$kWh_{Savings,AC} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right)$$

(227)

$$kWh_{Savings,HP,C} = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times EFLH_C \times \left(\frac{1}{\eta_{pre,C}} - \frac{1}{\eta_{post,C}}\right)$$

(228)

$$kWh_{Savings,HP,H} = CAP_H \times \frac{1\ kW}{1{,}000\ \mathrm{W}} \times EFLH_H \times \left(\frac{1}{\eta_{pre,H}} - \frac{1}{\eta_{post,H}}\right)$$

(229)

$$kWh_{Savings,HP} = kWh_{Savings,HP,C} + kWh_{Savings,HP,H}$$

(230)

For the remaining time in the EUL period (15 – RUL):

> Calculate annual savings as you would for a replace-on-burnout project using Equations (222), (223), and (224).

Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kwh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(231)

Where:

ROB = Replace-on-Burnout

ER = Early Retirement

CAP_C= Rated equipment cooling capacity of the new unit (BTU/hr)

CAP_H= Rated equipment heating capacity of the new unit (BTU/hr)

$\eta_{pre,AC/HP}$ = Nameplate energy efficiency rating of the existing cooling/heating equipment (if unavailable, use default efficiency from Table 271 and Table 272 for air conditioners or Table 273 and Table 274 for heat pumps)

$\eta_{post,AC/HP}$ = Nameplate energy efficiency rating of the installed cooling/heating equipment

Note: use EER for kW savings calculations and SEER/IEER and HSPF for kWh savings calculations.

Note: heating efficiencies expressed as a coefficient of performance (COP) will need to be converted to a heating seasonal performance factor (HSPF) using the following equation:

$$HSPF = COP \times 3.412$$

(232)

CF = Coincidence factor (Table 475)

$EFLH_C$ = Equivalent full-load hours for cooling (Table 477)

$EFLH_H$ = Equivalent full-load hours for heating (Table 478)

RUL = Remaining Useful Life (Table 275)

EUL = Estimated Useful Life = 15 years

Table 275: Remaining Useful Life (RUL) of Replaced Systems[433]

Age of Replaced System (Years)	RUL (Years)
5	10.0
6	9.1
7	8.2
8	7.3
9	6.5
10	5.7
11	5.0
12	4.4
13	3.8
14	3.3
15	2.8
16	2.5
17	2.2
18	1.9
19 +	0.0

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[433] Use of the early retirement baseline is capped at 18 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 18 years should use the ROB baseline.

Derivation of RULs

Commercial HVAC systems have an EUL of 15 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described by the survival function in Figure 11.

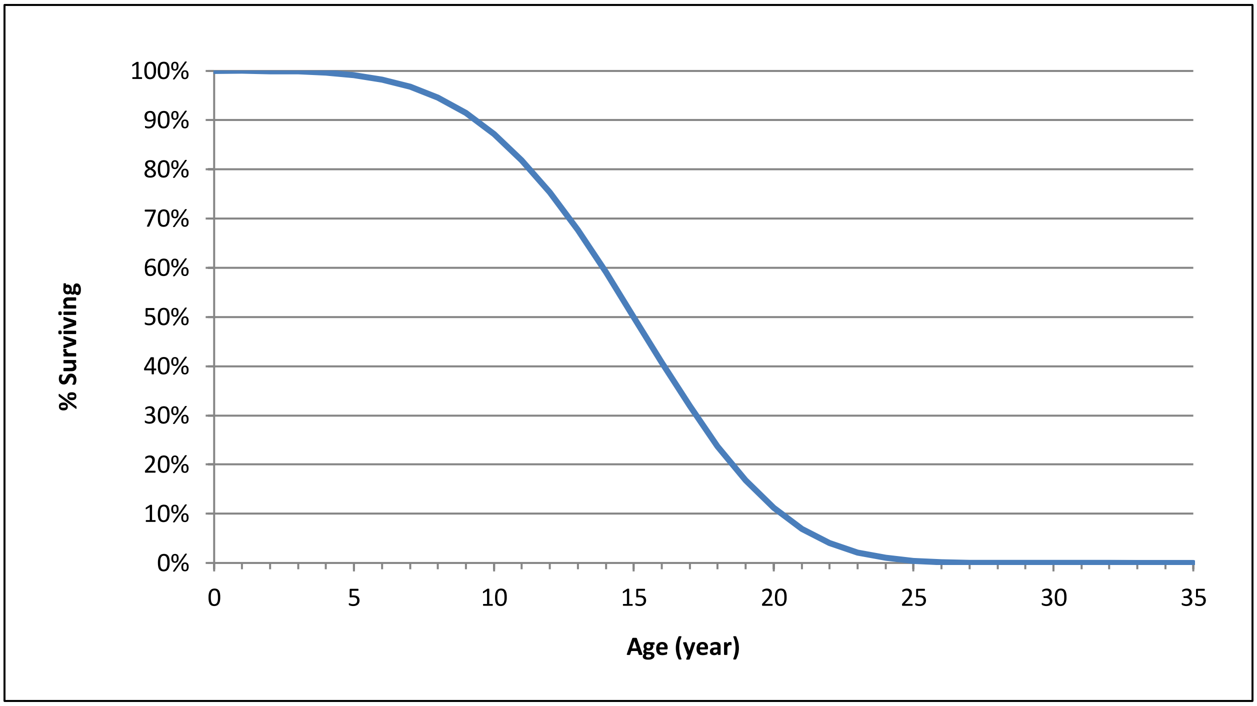

Figure 11: Survival Function for Commercial Unitary HVAC Systems[434]

The method used for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 11. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[434] Source: Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

3.1.19 Air or Water Cooled Chilling Equipment (Chillers)

Measure Description

This measure requires the installation of any air cooled or water cooled chilling package, referred to as a chiller. AHRI Test Standard 550/590-2003 defines a water-chilling package as “a factory-made and prefabricated assembly of one or more compressor, condensers, and evaporators, with interconnections and accessories, designed for the purpose of cooling water. It is a machine specifically designed to make use of a vapor compression refrigeration cycle to remove heat from water and reject the heat to a cooling medium, usually air or water.” A chiller is commonly used to provide cooling for a variety of building types and process loads.

The most common applications are for larger cooling loads (e.g., 50 to 100 tons and greater). Chiller types include centrifugal, rotary, screw, scroll, reciprocating, and gas absorption. Absorption chillers are subject to a different AHRI test standard and not reviewed as part of this analysis. When a water-cooled chiller is replacing an air-cooled chiller, the additional auxiliary electrical loads for the condenser water pump and the cooling tower fan have to be considered. Thus a penalty factor is necessary as a downward adjustment to account for the peak demand and energy savings.

Baseline and Efficiency Standards

The sections that follow describe the different baseline efficiency values that should be used for measures in new construction applications or that replace burned-out equipment, designated “replace-on-burnout” and for measures that replace equipment with remaining useful life, designated “early retirement.”

New Construction or Replace-on-Burnout

The baseline for units that are used in new construction or are replaced on burnout is the current state minimum standard,[435] which went into effect January 21, 2013 (Table 276).

As specified in Protocol E2 of TRM Volume 1, the enforcement date for a code or standard update is the end of the current program year if the effective date of the code or standard update is before July 1. For code or standard effective dates on or after July 1, the enforcement date is the end of the following program year. The specified lag period is to allow for the sale and/or use of existing equipment inventory. See Protocol E2 for more details.

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[435] ASHRAE Standard 90.1-2007.

Table 276: Chillers – Baseline Efficiency Levels for Chilled Water Packages [436]

Equipment Type	Chiller Type	Capacity (Tons)	Minimum Efficiency[437]
Air cooled	All	< 150	9.562 EER 12.5 IPLV
		≥ 150	9.562 EER 12.75 IPLV
Water cooled	Rotary/ Screw/Scroll/ Reciprocating	< 75	0.780 kW/ton 0.630 IPLV
		≥ 75 and < 150	0.775 kW/ton 0.615 IPLV
		≥ 150 and < 300	0.680 kW/ton 0.580 IPLV
		≥ 300	0.620 kW/ton 0.540 IPLV
Water cooled	Centrifugal	< 300	0.634 kW/ton 0.596 IPLV
		≥ 300 and < 600	0.576 kW/ton 0.549 IPLV
		≥ 600	0.570 kW/ton 0.539 IPLV

Early Retirement

Early retirement projects involve replacement of a working system. There is a dual baseline for early retirement applications. For the remaining useful life of the existing equipment, the baseline is the nameplate efficiency of the existing cooling equipment. If unavailable, baseline efficiency will be estimated according to the ASHRAE standard that was in effect at the time of manufacture based on the type, size, and year of manufacture for the replaced system. Baseline efficiency levels for systems installed from 1990 to 2012 are provided in Table 277 through Table 282. The remainder of the estimated useful life, the baseline is the current state minimum efficiency for the installed equipment type (Table 276).

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

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[436] The values in the table reflect IECC 2009, Table 503.2.3(7). These values supersede current Arkansas state commercial energy code and ASHRAE Standard 90.1-2007 due to the Environmental Protection Agency (EPA) 2010 Hydro chlorofluorocarbon (HCFC) Phase-out Regulations.

[437] Note that the efficiency values listed in this table is for Path A type chillers without a VSD. Chillers that exceed Path B requirements are eligible for this measure. However the savings were calculated using the Path A baseline efficiency values.

Table 277: Baseline Full-Load Efficiency for Air-Cooled Chillers Replaced via Early Retirement [438]

Year Installed (Replaced System)	< 75 Tons	≥ 75 to 150 Tons	≥ 150 to 300 Tons	≥ 300 to 600 Tons	≥ 600 Tons
	Full-load EER	Full-load EER	Full-load EER	Full-load EER	Full-load EER
1990	9.210	9.210	8.529	8.529	8.529
1991	9.210	9.210	8.529	8.529	8.529
1992	9.210	9.210	8.529	8.529	8.529
1993	9.210	9.210	8.529	8.529	8.529
1994	9.210	9.210	8.529	8.529	8.529
1995	9.210	9.210	8.529	8.529	8.529
1996	9.210	9.210	8.529	8.529	8.529
1997	9.210	9.210	8.529	8.529	8.529
1998	9.210	9.210	8.529	8.529	8.529
1999	9.210	9.210	8.529	8.529	8.529
2000	9.210	9.210	8.529	8.529	8.529
2001	9.210	9.210	8.529	8.529	8.529
2002	9.554	9.554	9.554	9.554	9.554
2003	9.554	9.554	9.554	9.554	9.554
2004	9.554	9.554	9.554	9.554	9.554
2005	9.554	9.554	9.554	9.554	9.554
2006	9.554	9.554	9.554	9.554	9.554
2007	9.554	9.554	9.554	9.554	9.554
2008	9.554	9.554	9.554	9.554	9.554
2009	9.554	9.554	9.554	9.554	9.554
2010	9.554	9.554	9.554	9.554	9.554
2011	9.554	9.554	9.554	9.554	9.554
2012	9.562	9.562	9.562	9.562	9.562

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[438] Consolidation of ASHRAE 90.1-1989-2007.

Table 278: Baseline Part-Load Efficiency for Air-Cooled Chillers Replaced via Early Retirement [439]

Year Installed (Replaced System)	< 75 Tons	> 75 to 150 Tons	> 150 to 300 Tons	> 300 to 600 Tons	> 600 Tons
	IPLV (EER)	IPLV (EER)	IPLV (EER)	IPLV (EER)	IPLV (EER)
1990	12.157	12.157	11.258	11.258	11.258
1991	12.157	12.157	11.258	11.258	11.258
1992	12.157	12.157	11.258	11.258	11.258
1993	12.157	12.157	11.258	11.258	11.258
1994	12.157	12.157	11.258	11.258	11.258
1995	12.157	12.157	11.258	11.258	11.258
1996	12.157	12.157	11.258	11.258	11.258
1997	12.157	12.157	11.258	11.258	11.258
1998	12.157	12.157	11.258	11.258	11.258
1999	12.157	12.157	11.258	11.258	11.258
2000	12.157	12.157	11.258	11.258	11.258
2001	12.157	12.157	11.258	11.258	11.258
2002	12.611	12.611	12.611	12.611	12.611
2003	12.611	12.611	12.611	12.611	12.611
2004	12.611	12.611	12.611	12.611	12.611
2005	12.611	12.611	12.611	12.611	12.611
2006	12.611	12.611	12.611	12.611	12.611
2007	12.611	12.611	12.611	12.611	12.611
2008	12.611	12.611	12.611	12.611	12.611
2009	12.611	12.611	12.611	12.611	12.611
2010	12.611	12.611	12.611	12.611	12.611
2011	12.611	12.611	12.611	12.611	12.611
2012	12.622	12.622	12.622	12.622	12.622

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[439] IPLV = EER x 1.32 based on comparison of corresponding IECC 2009 EER and IPLV baseline efficiency values.

Table 279: Baseline Full-Load Efficiency for Centrifugal Water-Cooled Chillers Replaced via Early Retirement [440]

Year Installed (Replaced System)	< 75 Tons	≥ 75 to 150 Tons	≥ 150 to 300 Tons	≥ 300 to 600 Tons	≥ 600 Tons
	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton
1990	0.926	0.926	0.837	0.748	0.748
1991	0.926	0.926	0.837	0.748	0.748
1992	0.926	0.926	0.837	0.748	0.748
1993	0.926	0.926	0.837	0.748	0.748
1994	0.926	0.926	0.837	0.748	0.748
1995	0.926	0.926	0.837	0.748	0.748
1996	0.926	0.926	0.837	0.748	0.748
1997	0.926	0.926	0.837	0.748	0.748
1998	0.926	0.926	0.837	0.748	0.748
1999	0.926	0.926	0.837	0.748	0.748
2000	0.926	0.926	0.837	0.748	0.748
2001	0.926	0.926	0.837	0.748	0.748
2002	0.703	0.703	0.634	0.577	0.577
2003	0.703	0.703	0.634	0.577	0.577
2004	0.703	0.703	0.634	0.577	0.577
2005	0.703	0.703	0.634	0.577	0.577
2006	0.703	0.703	0.634	0.577	0.577
2007	0.703	0.703	0.634	0.577	0.577
2008	0.703	0.703	0.634	0.577	0.577
2009	0.703	0.703	0.634	0.577	0.577
2010	0.703	0.703	0.634	0.577	0.577
2011	0.703	0.703	0.634	0.577	0.577
2012	0.703	0.703	0.634	0.577	0.577

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[440] Consolidation of ASHRAE 90.1-1989-2007.

Table 280: Baseline Part-Load Efficiency for Centrifugal Water-Cooled Chillers Replaced via Early Retirement [441]

Year Installed (Replaced System)	< 75 Tons	≥ 75 to 150 Tons	≥ 150 to 300 Tons	≥ 300 to 600 Tons	≥ 600 Tons
	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)
1990	0.815	0.815	0.737	0.658	0.658
1991	0.815	0.815	0.737	0.658	0.658
1992	0.815	0.815	0.737	0.658	0.658
1993	0.815	0.815	0.737	0.658	0.658
1994	0.815	0.815	0.737	0.658	0.658
1995	0.815	0.815	0.737	0.658	0.658
1996	0.815	0.815	0.737	0.658	0.658
1997	0.815	0.815	0.737	0.658	0.658
1998	0.815	0.815	0.737	0.658	0.658
1999	0.815	0.815	0.737	0.658	0.658
2000	0.815	0.815	0.737	0.658	0.658
2001	0.815	0.815	0.737	0.658	0.658
2002	0.619	0.619	0.558	0.508	0.508
2003	0.619	0.619	0.558	0.508	0.508
2004	0.619	0.619	0.558	0.508	0.508
2005	0.619	0.619	0.558	0.508	0.508
2006	0.619	0.619	0.558	0.508	0.508
2007	0.619	0.619	0.558	0.508	0.508
2008	0.619	0.619	0.558	0.508	0.508
2009	0.619	0.619	0.558	0.508	0.508
2010	0.619	0.619	0.558	0.508	0.508
2011	0.619	0.619	0.558	0.508	0.508
2012	0.619	0.619	0.558	0.508	0.508

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[441] IPLV = kW/ton x 0.88 based on comparison of corresponding IECC 2009 kW/ton and IPLV baseline efficiency values.

Table 281: Baseline Full-Load Efficiency for Screw, Scroll, and Reciprocating Water-Cooled Chillers Replaced via Early Retirement [442]

Year Installed (Replaced System)	< 75 Tons	≥ 75 to 150 Tons	≥ 150 to 300 Tons	≥ 300 to 600 Tons	≥ 600 Tons
	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton	Full-load kW/Ton
1990	0.926	0.926	0.837	0.748	0.748
1991	0.926	0.926	0.837	0.748	0.748
1992	0.926	0.926	0.837	0.748	0.748
1993	0.926	0.926	0.837	0.748	0.748
1994	0.926	0.926	0.837	0.748	0.748
1995	0.926	0.926	0.837	0.748	0.748
1996	0.926	0.926	0.837	0.748	0.748
1997	0.926	0.926	0.837	0.748	0.748
1998	0.926	0.926	0.837	0.748	0.748
1999	0.926	0.926	0.837	0.748	0.748
2000	0.926	0.926	0.837	0.748	0.748
2001	0.926	0.926	0.837	0.748	0.748
2002	0.790	0.790	0.718	0.639	0.639
2003	0.790	0.790	0.718	0.639	0.639
2004	0.790	0.790	0.718	0.639	0.639
2005	0.790	0.790	0.718	0.639	0.639
2006	0.790	0.790	0.718	0.639	0.639
2007	0.790	0.790	0.718	0.639	0.639
2008	0.790	0.790	0.718	0.639	0.639
2009	0.790	0.790	0.718	0.639	0.639
2010	0.790	0.790	0.718	0.639	0.639
2011	0.790	0.790	0.718	0.639	0.639
2012	0.790	0.790	0.718	0.639	0.639

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[442] Consolidation of ASHRAE 90.1-1989-2007.

Table 282: Baseline Part-Load Efficiency for Screw, Scroll, and Reciprocating Water-Cooled Chillers Replaced via Early Retirement [443]

Year Installed (Replaced System)	< 75 Tons	≥ 75 to 150 Tons	≥ 150 to 300 Tons	≥ 300 to 600 Tons	≥ 600 Tons
	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)	IPLV (kW/ton)
1990	0.815	0.815	0.737	0.658	0.658
1991	0.815	0.815	0.737	0.658	0.658
1992	0.815	0.815	0.737	0.658	0.658
1993	0.815	0.815	0.737	0.658	0.658
1994	0.815	0.815	0.737	0.658	0.658
1995	0.815	0.815	0.737	0.658	0.658
1996	0.815	0.815	0.737	0.658	0.658
1997	0.815	0.815	0.737	0.658	0.658
1998	0.815	0.815	0.737	0.658	0.658
1999	0.815	0.815	0.737	0.658	0.658
2000	0.815	0.815	0.737	0.658	0.658
2001	0.815	0.815	0.737	0.658	0.658
2002	0.695	0.695	0.632	0.562	0.562
2003	0.695	0.695	0.632	0.562	0.562
2004	0.695	0.695	0.632	0.562	0.562
2005	0.695	0.695	0.632	0.562	0.562
2006	0.695	0.695	0.632	0.562	0.562
2007	0.695	0.695	0.632	0.562	0.562
2008	0.695	0.695	0.632	0.562	0.562
2009	0.695	0.695	0.632	0.562	0.562
2010	0.695	0.695	0.632	0.562	0.562
2011	0.695	0.695	0.632	0.562	0.562
2012	0.695	0.695	0.632	0.562	0.562

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[443] IPLV = kW/ton x 0.88 based on comparison of corresponding IECC 2009 kW/ton and IPLV baseline efficiency values.

Estimated Useful Life (EUL)

The 2011 ASHRAE Handbook for HVAC Applications, Chapter 37.3, supports a measure life of over 25 years for centrifugal chillers. However, the sample size diminishes for older systems such that the study can only reliably substantiate an EUL of 25 years for centrifugal chillers.[444]

For all other high-efficiency chillers, according to the DEER 2008, the estimated useful life (EUL) is 20 years.

Calculation of Deemed Savings

Deemed peak demand and annual energy savings for chillers should be calculated using the following formulas:

New Construction or Replace-on-Burnout

$$kW_{Savings} = CAP \times \left(\eta_{base} - \eta_{post}\right) \times CF$$

(233)

$$kWh_{savings} = CAP \times EFLH_C \times \left(\eta_{base} - \eta_{post}\right)$$

(234)

Where:

CAP = Rated equipment cooling capacity of the new unit (Tons)

η_{base} = Baseline energy efficiency rating of the baseline cooling equipment (kW/ton or EER converted to kW/ton from Table 276)

η_{post} = Nameplate energy efficiency rating of the installed cooling equipment (kW/ton)

Note: use full-load efficiency (in units of kW/ton) for kW savings calculations and IPLV (in units of kW/ton) for kWh savings calculations. Cooling efficiencies expressed as an EER will need to be converted to kW/ton using the following equation:

$$\frac{kW}{Ton} = \frac{12}{EER}$$

(235)

CF = Coincidence factor (Table 475)

$\boldsymbol{EFLH_C}$ = Equivalent full-load hours for cooling (Table 477)

$EFLH_H$ = Equivalent full-load hours for heating (Table 478)

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[444] Frontier Associates on behalf of Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to Approve Revisions to Commercial HVAC Deemed Savings for Energy Efficiency Programs: Docket No. 40885." Public Utility Commission of Texas. Approved January 30, 2013. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp.

Early Retirement

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL), where the EUL is either 20 or 25, depending on the chiller type.

For the RUL (Table 283):

$$kW_{Savings} = CAP \times \left(\eta_{pre} - \eta_{post}\right) \times CF$$

(236)

$$kWh_{savings} = CAP \times EFLH_C \times \left(\eta_{pre} - \eta_{post}\right)$$

(237)

For the remaining time in the EUL period (EUL – RUL):

Calculate annual savings as you would for a replace-on-burnout project using Equation (233) and (234).

Lifetime kWh savings for Early Retirement Projects is calculated as follows:

$$Lifetime\ kWh_{savings} = \left(kwh_{savings,ER} \times RUL\right) + \left[kWh_{savings,ROB} \times (EUL - RUL)\right]$$

(238)

Where:

CAP = Rated equipment cooling capacity of the new unit (Tons)

η_{pre} = Nameplate energy efficiency rating of the existing cooling equipment (if unavailable, use default efficiency from Table 277 through Table 282)

η_{post} = Nameplate energy efficiency rating of the installed cooling equipment

Note: use full-load efficiency (in units of kW/ton) for kW savings calculations and IPLV (in units of kW/ton) for kWh savings calculations. Cooling efficiencies expressed as an EER will need to be converted to kW/ton using the following equation:

$$\frac{kW}{Ton} = \frac{12}{EER}$$

(239)

CF = Coincidence factor (Table 475)

$EFLH_C$ = Equivalent full-load hours for cooling from (Table 477)

EUL = Estimated Useful Life = 25 years (centrifugal chillers); 20 years (all other chillers)

RUL = Remaining Useful Life (Table 283)

Table 283: Remaining Useful Life (RUL) of Replaced Systems[445]

Non-Centrifugal Chilled Water Systems	
Age of Replaced System (Years)	**RUL (Years)**
5	14.7
6	13.7
7	12.7
8	11.8
9	10.9
10	10.0
11	9.1
12	8.3
13	7.5
14	6.8
15	6.2
16	5.5
17	5.0
18	4.5
19	4.0
20	3.6
21	3.2
22	2.9
23	2.6
24 +	0.0

Centrifugal Chilled Water Systems	
Age of Replaced System (Years)	**RUL (Years)**
5	19.9
6	18.9
7	17.9
8	16.9
9	15.9
10	14.9
11	13.9
12	12.9
13	11.9
14	10.9
15	10.1
16	9.3
17	8.7
18	8.1
19	7.5
20	7.1
21	6.6
22	6.3
23	5.9
24	5.9
25	5.4
26	5.1
27	4.9
28	4.7
29	4.5
30	4.3
31 +	0.0

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[445] Use of the early retirement baseline is capped at 23 years (non-centrifugal) and 30 years (centrifugal), representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 23 years (non-centrifugal) or 30 years (centrifugal) years should use the ROB baseline.

Derivation of RULs

Commercial centrifugal chillers have an EUL of 25 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described by the survival function in Figure 12.

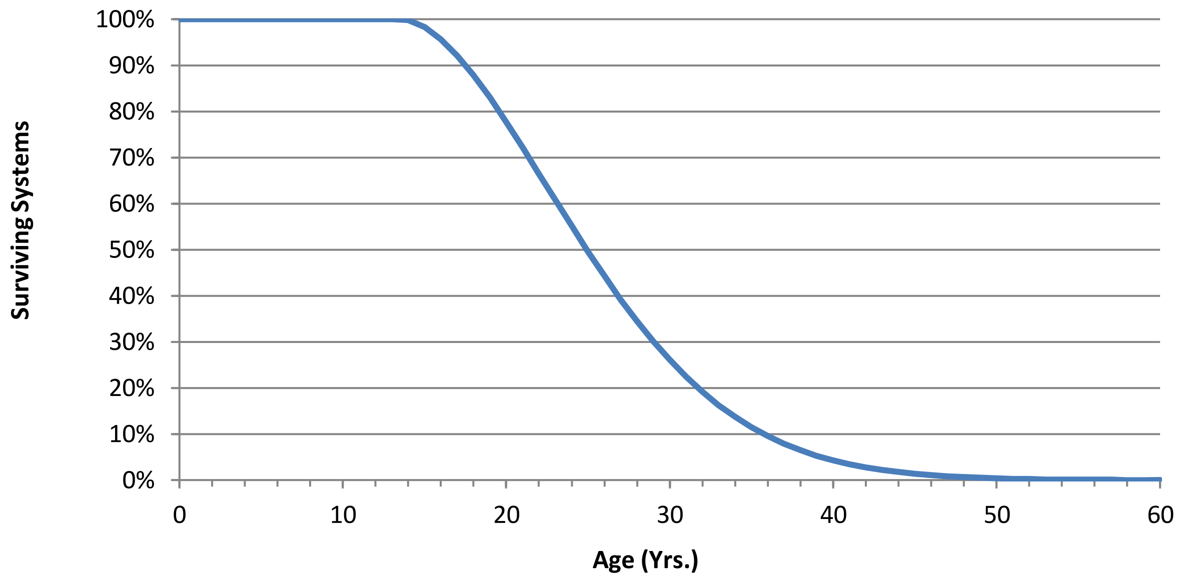

Figure 12: Survival Function for Commercial Centrifugal Chillers[446]

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[446] Source: Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

Commercial non-centrifugal chillers have an EUL of 20 years. This estimate is consistent with the age at which 50 percent of systems installed in a given year will no longer be in service, as described by the survival function in Figure 13.

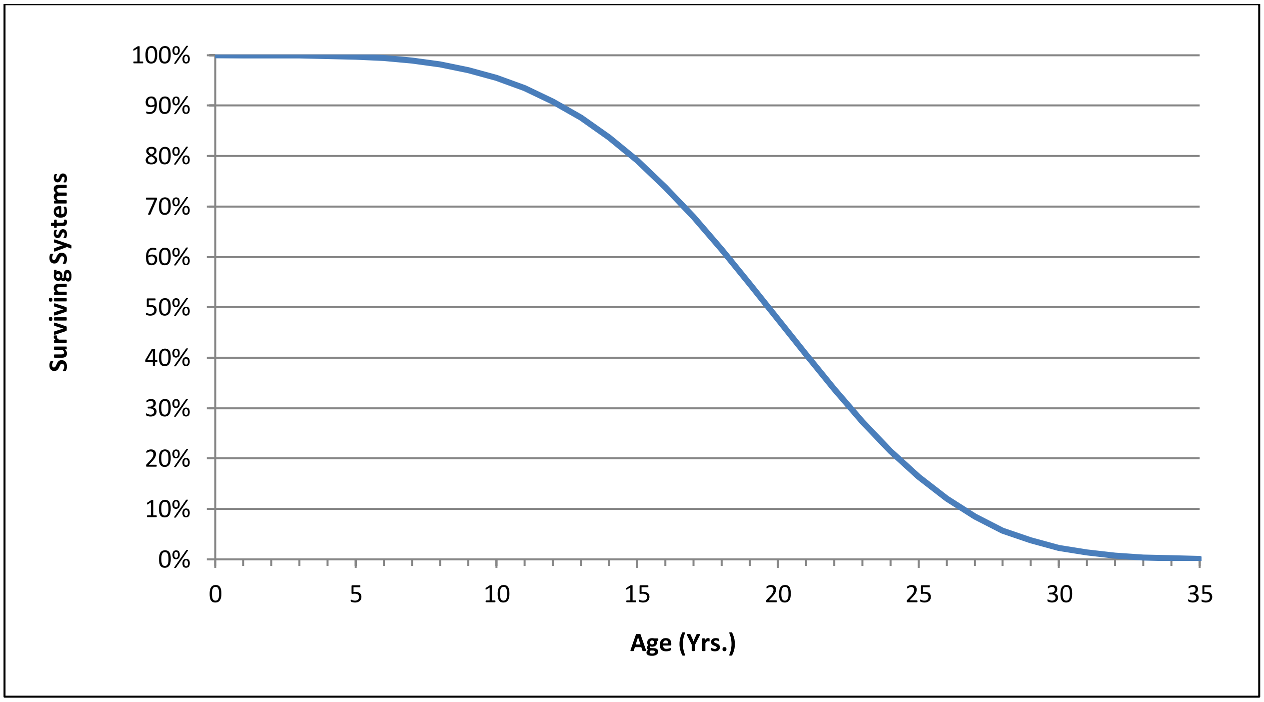

Figure 13: Survival Function for Commercial Non-Centrifugal Chillers[447]

The method used for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 12 and Figure 13. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[447] Source: Life Cycle Cost Analysis Spreadsheet, “lcc_cuac_hourly.xls”. http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

3.2 Envelope Measures

3.2.1 Ceiling Insulation (Converted Residences)

Measure Description

This measure consists of adding ceiling insulation over a conditioned area in a converted residence (CR) of existing construction.

Baseline and Efficiency Standards

In existing construction, ceiling insulation levels vary greatly, depending on the age of the converted residence, type of insulation, and attic space utilization (such as using the attic for storage and HVAC equipment). Deemed savings tables are based on the current level of ceiling insulation in the converted residence from R-0 to R-22. The current insulation level of each converted residence will be determined and documented by the installation contractor. Field measurements of insulation thicknesses, condition, and R-values per inch, as typically recorded by weatherization staff, are generally not sufficiently precise to determine existing insulation levels to the nearest whole-number R-value. Based on this experience, the research team divided existing R-values into the ranges shown in the table below. Degradation due to age and density of the existing insulation will need to be considered by the insulation contractor.

A ceiling insulation level of R-38 is recommended throughout Arkansas, as prescribed by DOE.[448] The combined R-values of the existing insulation and the insulation being added will total at least R-38.

Table 284: Ceiling Insulation – Baseline and Efficiency Standards

Baseline	Efficiency Standard
R-0 to R-4	R-38
R-5 to R-8	
R-9 to R-14	
R-15 to R-22	

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the ceiling area over a conditioned space that is being insulated. Gas Heat (no AC) kWh applies to forced-air furnace systems only.

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[448] Insulation Fact Sheet, Energy Efficiency and Renewable Energy, U.S. DOE, Circular CE-180 with Addendum 1, 2002.

Table 285: Ceiling Insulation (CR) – Deemed Savings Values - Zone 9 Northwest Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0	1.601	0.186	0.263	7.588	4.474	0.00087	0.00502
1 to 4	1.020	0.111	0.161	4.708	2.808	0.00081	0.00326
5 to 8	0.670	0.059	0.075	2.373	1.492	0.00068	0.00133
9 to 14	0.393	0.035	0.046	1.430	0.897	0.00043	0.00083
15 to 22	0.220	0.021	0.027	0.841	0.522	0.00023	0.00051

Table 286: Ceiling Insulation (CR) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0	0.678	0.131	0.198	5.453	3.116	0.00057	0.00389
1 to 4	0.371	0.070	0.106	2.830	1.609	0.00036	0.00208
5 to 8	0.179	0.034	0.051	1.364	0.773	0.00018	0.00099
9 to 14	0.096	0.018	0.028	0.737	0.417	0.00010	0.00053
15 to 22	0.049	0.009	0.014	0.367	0.207	0.00005	0.00027

Table 287: Ceiling Insulation (CR) – Deemed Savings Values - Zone 7 Central Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0	1.606	0.161	0.227	6.773	4.062	0.00050	0.00413
1 to 4	1.061	0.095	0.138	4.208	2.516	0.00050	0.00271
5 to 8	0.710	0.050	0.064	2.167	1.375	0.00049	0.00116
9 to 14	0.423	0.030	0.039	1.312	0.830	0.00039	0.00071
15 to 22	0.241	0.017	0.023	0.770	0.482	0.00022	0.00043

Table 288: Ceiling Insulation (CR) – Deemed Savings Values - Zone 6 South Region

Ceiling Insulation Base R-value	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
0	1.959	0.139	0.196	6.443	4.044	0.00070	0.00403
1 to 4	1.284	0.083	0.120	4.021	2.533	0.00069	0.00250
5 to 8	0.871	0.043	0.056	2.148	1.449	0.00067	0.00111
9 to 14	0.513	0.026	0.034	1.286	0.864	0.00047	0.00070
15 to 22	0.294	0.015	0.020	0.752	0.501	0.00026	0.00043

Calculation of Deemed Savings

EnergyGauge USA® was used to estimate energy savings for a prototype Arkansas converted residence.

A series of models was created to determine the difference in weather data throughout the four weather regions in Arkansas as defined in IECC 2003. Since building shell measures are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype characteristics of the building model are outlined in Appendix A.

3.2.2 Ceiling Insulation (Small Commercial)

Measure Description

Ceiling insulation deemed savings are estimated per square foot of treated ceiling area above conditioned space(s) for various levels of pre-retrofit ceiling insulation. To qualify for this measure, contractors must raise the R-value of ceiling insulation to R-30 in a building in which the pre-retrofit ceiling insulation is judged to have an R-value no greater than R-22. Furthermore, because of the interactive nature of the relationship between ceiling insulation and roof deck insulation, the deemed savings values are estimated based on the number of existing levels of pre-retrofit ceiling and roof-deck insulation. Buildings in which the combined pre-retrofit roof deck and ceiling insulation R-values exceed R-30 are not eligible for this measure. The combined roof insulating values are only applicable for non-ventilated attic spaces and spaces in which the attic area is not used as a return air plenum.

Baseline and Efficiency Standard

In existing construction, ceiling insulation levels vary greatly, depending on a number of factors, including the construction style, age of the structure, and the type of insulation. The savings that can be achieved by installing additional ceiling insulation depend on both the existing levels of ceiling insulation and the insulating capacity of the roof deck. As such, deemed savings tables detail savings from ceiling insulation installations for each Arkansas weather zone, based on three different levels of roof deck insulation and four different levels of existing ceiling insulation. Specifically, deemed savings are presented for buildings with three different levels of existing roof deck insulation: R-0 to R-5, R-6 to R-12, and R-13 to R-20. The R-value of the pre-retrofit roof deck insulation can be no greater than R-20, the R-value of the pre-retrofit ceiling insulation can be no greater than R-22, and the combined R-value of ceiling and roof deck insulation cannot exceed R-30. The pre-existing insulation level of each building will be determined and documented by the insulation installer. Degradation, due to age and density of the existing insulation, should be taken into account.

In the event that existing insulation is or has been removed, the existing R-value will be based on the R-value of the existing insulation prior to removal.

The IECC of 2006 calls for R-30 attic insulation in commercial buildings for the weather zones in which Arkansas is located. As such, ceiling insulation rebates are designed to bring building attic insulation up to R-30 levels. All typical ceiling insulation materials are eligible for this measure.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Deemed savings values for annual electric energy use (kWh), peak demand (kW), and annual and peak gas usage (therms) for the small commercial (SC) ceiling insulation measure are provided in the following tables:

Table 289: Ceiling Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 9 Northwest Region

Pre-Retrofit Ceiling R-value	Electric		Gas	
	Annual Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	therms/sq. ft.	therms/1,000 sq. ft.
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	0.413	0.337	0.178	1.549
R-5 to R-8	0.146	0.151	0.08	0.611
R-9 to R-14	0.08	0.089	0.047	0.351
R-15 to R-22	0.033	0.038	0.02	0.15
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.191	0.244	0.076	0.91
R-5 to R-8	0.09	0.1095	0.043	0.47
R-9 to R-14	0.051	0.065	0.026	0.283
R-15 to R-22	0.02	0.028	0.011	0.123
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.127	0.151	0.034	0.732
R-5 to R-8	0.053	0.068	0.018	0.344
R-9 to R-14	0.031	0.041	0.011	0.21
R-15 to R-22	0.013	0.018	0.005	0.101

Table 290: Ceiling Insulation (SC) – Electric Savings for Electric Heat - Zone 9 Northwest Region

Pre-Retrofit Ceiling R-value	Heat Pump		Electric Resistance	
	Annual Energy Savings	Peak Demand Savings	Annual Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	kWh/sq. ft.	kW/1,000 sq. ft.
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	1.106	0.337	1.978	0.334
R-5 to R-8	0.431	0.151	0.789	0.15
R-9 to R-14	0.247	0.089	0.453	0.089
R-15 to R-22	0.104	0.038	0.191	0.038
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.755	0.244	1.339	0.242
R-5 to R-8	0.3125	0.1095	0.572	0.109
R-9 to R-14	0.1845	0.065	0.339	0.065
R-15 to R-22	0.08	0.028	0.1475	0.028
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.404	0.151	0.7	0.15
R-5 to R-8	0.194	0.068	0.355	0.068
R-9 to R-14	0.122	0.041	0.225	0.041
R-15 to R-22	0.056	0.018	0.104	0.018

Table 291: Ceiling Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 8 Northeast/North Central Region

Pre-Retrofit Ceiling R-value	**Electric**		**Gas**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Savings**[449]
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**therms/sq. ft.**	**therms/1,000 sq. ft.**
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	0.487	0.316	0.098	1.465
R-5 to R-8	0.182	0.149	0.038	0.57
R-9 to R-14	0.103	0.088	0.022	0.327
R-15 to R-22	0.042	0.038	0.009	0.141
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.286	0.2305	0.06	1.004
R-5 to R-8	0.113	0.107	0.027	0.428
R-9 to R-14	0.066	0.064	0.016	0.257
R-15 to R-22	0.028	0.028	0.007	0.112
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.163	0.145	0.034	0.67
R-5 to R-8	0.066	0.065	0.018	0.306
R-9 to R-14	0.04	0.04	0.011	0.187
R-15 to R-22	0.018	0.018	0.005	0.091

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[449] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying the Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.943 (R-0 to R-4), 1.008 (R-5 to R-8), 1.025 (R-9 to R-14), and 1.034 (R-15 to R-22). For Fort Smith, m = 0.930 (R-0 to R-4), 0.998 (R-5 to R-8), 1.016 (R-9 to R-14), and 1.024 (R-15 to R-22).

Table 292: Ceiling Insulation (SC) – Electric Savings for Electric Heat - Zone 8 Northeast/North Central Region

Pre-Retrofit Ceiling R-value	Heat Pump		Electric Resistance	
	Annual Energy Savings	Peak Demand Savings	Annual Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	kWh/sq. ft.	kW/1,000 sq. ft.
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	1.166	0.316	2.021	0.314
R-5 to R-8	0.448	0.149	0.806	0.148
R-9 to R-14	0.256	0.088	0.463	0.088
R-15 to R-22	0.108	0.038	0.196	0.038
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.7975	0.2305	1.3785	0.2295
R-5 to R-8	0.3095	0.107	0.5895	0.108
R-9 to R-14	0.1825	0.064	0.35	0.065
R-15 to R-22	0.079	0.028	0.153	0.0285
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.429	0.145	0.736	0.145
R-5 to R-8	0.171	0.065	0.373	0.068
R-9 to R-14	0.109	0.04	0.237	0.042
R-15 to R-22	0.05	0.018	0.11	0.019

Table 293: Ceiling Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 7 Central Region

Pre-Retrofit Ceiling R-value	**Electric**		**Gas**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**therms/sq. ft.**	**therms/1,000 sq. ft.**
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	0.428	0.315	0.104	1.291
R-5 to R-8	0.158	0.144	0.042	0.498
R-9 to R-14	0.089	0.087	0.024	0.283
R-15 to R-22	0.037	0.038	0.01	0.119
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.272	0.216	0.057	0.869
R-5 to R-8	0.109	0.1025	0.028	0.371
R-9 to R-14	0.064	0.062	0.017	0.217
R-15 to R-22	0.027	0.0275	0.007	0.094
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.169	0.117	0.029	0.568
R-5 to R-8	0.071	0.061	0.016	0.254
R-9 to R-14	0.043	0.037	0.01	0.155
R-15 to R-22	0.019	0.017	0.005	0.074

Table 294: Ceiling Insulation (SC) – Electric Savings for Electric Heat - Zone 7 Central Region

Pre-Retrofit Ceiling R-value	**Heat Pump**		**Electric Resistance**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Energy Savings**	**Peak Demand Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**kWh/sq. ft.**	**kW/1,000 sq. ft.**
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	1.019	0.315	1.804	0.315
R-5 to R-8	0.397	0.144	0.718	0.144
R-9 to R-14	0.228	0.087	0.412	0.086
R-15 to R-22	0.097	0.038	0.175	0.038
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.6655	0.216	1.232	0.231
R-5 to R-8	0.3065	0.1025	0.5245	0.1075
R-9 to R-14	0.163	0.062	0.311	0.0655
R-15 to R-22	0.071	0.0275	0.136	0.029
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.312	0.117	0.66	0.147
R-5 to R-8	0.216	0.061	0.331	0.071
R-9 to R-14	0.098	0.037	0.21	0.045
R-15 to R-22	0.045	0.017	0.097	0.02

Table 295: Ceiling Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace – Zone 6 South Region

Pre-Retrofit Ceiling R-value	**Electric**		**Gas**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**therms/sq. ft.**	**therms/1,000 sq. ft.**
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	0.428	0.315	0.104	1.291
R-5 to R-8	0.158	0.144	0.042	0.498
R-9 to R-14	0.089	0.087	0.024	0.283
R-15 to R-22	0.037	0.038	0.01	0.119
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.272	0.216	0.057	0.869
R-5 to R-8	0.109	0.1025	0.028	0.371
R-9 to R-14	0.064	0.062	0.017	0.217
R-15 to R-22	0.027	0.0275	0.007	0.094
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.169	0.117	0.029	0.568
R-5 to R-8	0.071	0.061	0.016	0.254
R-9 to R-14	0.043	0.037	0.01	0.155
R-15 to R-22	0.019	0.017	0.005	0.074

Table 296: Ceiling Insulation (SC) – Electric Savings for Electric Heat - Zone 6 South Region

Pre-Retrofit Ceiling R-value	Heat Pump		Electric Resistance	
	Annual Energy Savings	Peak Demand Savings	Annual Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	kWh/sq. ft.	kW/1,000 sq. ft.
Pre-Retrofit Roof Insulation R-0 to R-5				
R-0 to R-4	0.911	0.323	1.699	0.323
R-5 to R-8	0.361	0.14	0.676	0.14
R-9 to R-14	0.209	0.084	0.389	0.084
R-15 to R-22	0.088	0.038	0.165	0.038
Pre-Retrofit Roof Insulation R-6 to R-12				
R-0 to R-4	0.631	0.2385	1.1445	0.2385
R-5 to R-8	0.2625	0.105	0.485	0.105
R-9 to R-14	0.1565	0.064	0.2875	0.064
R-15 to R-22	0.0675	0.029	0.1255	0.029
Pre-Retrofit Roof Insulation R-13 to R-20				
R-0 to R-4	0.351	0.154	0.59	0.154
R-5 to R-8	0.164	0.07	0.294	0.07
R-9 to R-14	0.104	0.044	0.186	0.044
R-15 to R-22	0.047	0.02	0.086	0.02

Calculation of Deemed Savings

Deemed savings were calculated using an eQuest model populated as shown in the following section. Model runs were performed with TMY3 data for each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Three different buildings were used: a strip mall, a stand-alone retail store, and a small office building. Savings for each combination of pre-retrofit conditions (ceiling and roof deck insulation levels) were estimated on a per square foot basis for each building type. The deemed savings values presented herein represent the average savings per square foot for each building type modeled, the weather zone and combination of pre-retrofit conditions. The prototype characteristics of the building models are outlined in Appendix A.

3.2.3 Cool Roofs

Measure Description

To qualify for this measure, at least 75 percent of the roof area must be replaced with a cool roof. A cool roof reflects the sun's heat and emits absorbed radiation back into the atmosphere. A cool roof is defined by ASHRAE 90.1 as a roof having a minimum solar reflectivity equal to 0.55 and a minimum thermal emittance equal to 0.75. ASHRAE 90.1-2007 provides an alternative approach allowing products with a minimum Solar Reflective Index (SRI) equal to 64. The Cool Roof Rating Council (www.coolroofs.org) maintains a SRI database.

Baseline and Efficiency Standards

The baseline roof is assumed to have a solar reflectance of 0.23 and a thermal emittance of 0.90. This was calculated using a weighted average method from the following data:

- Predominant roof material used in west south central region for non-small commercial buildings as obtained from CBECS 2003, Table B4.
- Average reflectance properties of roofing material as obtained from the publication *Laboratory Testing of Reflectance Properties of Roofing Material* by Florida Solar Energy Center (FSEC)

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 15 years for metal roofs and 10 years if paint is applied, in accordance with DEER 2008.

Deemed Savings Values

Deemed savings values for annual electric energy use (kWh), peak demand (kW), and annual and peak gas usage (therms) are provided in the following tables.

Table 297: Cool Roofs (SC) – Deemed Savings Values – Retail Strip Mall

Weather Zone	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Gas Savings**	**Peak Gas Savings**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh/sq. ft.	**kW/1000 sq. ft.**	**therms/1000 sq. ft.**	**therms/1000 sq. ft.**	**kWh/sq. ft.**	**kW/1000 sq. ft.**	**kWh/sq. ft.**	**kW/1000 sq. ft.**
El Dorado (Zone 6)	0.1014	0.0218	-3.9599	Negligible	0.0699	0.0221	0.0206	0.0219
Little Rock (Zone 7)	0.0953	0.0223	-4.8018	Negligible	0.0536	0.0225	-0.0021	0.0226
Fort Smith (Zone 8)	0.0885	0.0222	-5.1528	Negligible	0.0411	0.0226	-0.0174	0.0226
Fayetteville (Zone 9)	0.0838	0.0211	-6.0212	Negligible	0.0296	0.0207	-0.0116	0.0249

Table 298: Cool Roofs (SC) – Deemed Savings Values – Big Box Retail

Weather Zone	**Gas-Electric**				**All Electric**			
	DX Coils with Furnace				**Heat Pump**		**Electric Resistance**	
	Energy Savings	**Peak Demand Savings**	**Gas Savings**	**Peak Gas Savings**	**Energy Savings**	**Peak Demand Savings**	**Energy Savings**	**Peak Demand Savings**
	kWh/sq. ft.	**kW/1000 sq. ft.**	**therms/ 1000 sq. ft.**	**therms/1000 sq. ft.**	**kWh/sq. ft.**	**kW/1000 sq. ft.**	**kWh/sq. ft.**	**kW/1000 sq. ft.**
El Dorado (Zone 6)	0.1864	0.0901	-5.3104	Negligible	0.1415	0.0894	0.0709	0.0876
Little Rock (Zone 7)	0.1444	0.0703	-5.7814	Negligible	0.0885	0.0704	0.0194	0.0692
Fort Smith (Zone 8)	0.1687	0.0900	-6.7557	Negligible	0.1004	0.0883	0.0226	0.0874
Fayetteville (Zone 9)	0.1575	0.0812	-6.4549	Negligible	0.0823	0.0770	0.0184	0.0788

Table 299: Cool Roofs (SC) – Deemed Savings Values – Full Service Restaurant

Weather Zone	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Gas Savings	Peak Gas Savings	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1000 sq. ft.	therms/ 1000 sq. ft.	therms/1000 sq. ft.	kWh/sq. ft.	kW/1000 sq. ft.	kWh/sq. ft.	kW/1000 sq. ft.
El Dorado (Zone 6)	0.1037	0.0538	-1.8153	-0.0010	0.0917	0.0541	0.0717	0.0530
Little Rock (Zone 7)	0.0936	0.0510	-2.0929	-0.0010	0.0763	0.0513	0.0520	0.0502
Fort Smith (Zone 8)	0.0919	0.0532	-2.4715	-0.0010	0.0702	0.0535	0.0422	0.0524
Fayetteville (Zone 9)	0.0893	0.0474	-2.3386	-0.0009	0.0689	0.0477	0.0437	0.0466

Table 300: Cool Roofs (SC) – Deemed Savings Values – Secondary School

<table>
<tr><th rowspan="4">Weather Zone</th><th colspan="8">Gas-Electric</th></tr>
<tr><th colspan="4">DX Coils with Furnace</th><th colspan="4">Chiller with Boiler</th></tr>
<tr><th>Energy Savings</th><th>Peak Demand Savings</th><th>Gas Savings</th><th>Peak Gas Savings</th><th>Energy Savings</th><th>Peak Demand Savings</th><th>Energy Savings</th><th>Peak Demand Savings</th></tr>
<tr><th>kWh/sq. ft.</th><th>kW/1000 sq. ft.</th><th>therms/ 1000 sq. ft.</th><th>therms/ 1000 sq. ft.</th><th>kWh/sq. ft.</th><th>kW/1000 sq. ft.</th><th>therms/ 1000 sq. ft.</th><th>therms/ 1000 sq. ft.</th></tr>
<tr><td>El Dorado (Zone 6)</td><td>0.1136</td><td>0.0376</td><td>-0.4361</td><td>-0.0006</td><td>0.2662</td><td>0.0638</td><td>-0.2731</td><td>-0.0006</td></tr>
<tr><td>Little Rock (Zone 7)</td><td>0.1140</td><td>0.0392</td><td>-0.7047</td><td>-0.0006</td><td>0.3005</td><td>0.0721</td><td>-0.5505</td><td>-0.0006</td></tr>
<tr><td>Fort Smith (Zone 8)</td><td>0.1073</td><td>0.0364</td><td>-1.0793</td><td>-0.0006</td><td>0.2695</td><td>0.0653</td><td>-0.7874</td><td>-0.0006</td></tr>
<tr><td>Fayetteville (Zone 9)</td><td>0.1002</td><td>0.0351</td><td>-0.8386</td><td>-0.0006</td><td>0.2521</td><td>0.0616</td><td>-0.6880</td><td>-0.0005</td></tr>
<tr><th rowspan="3"></th><th colspan="8">All Electric</th></tr>
<tr><th colspan="4">Heat Pump</th><th colspan="4">Electric Resistance</th></tr>
<tr><th colspan="2">kWh/sq. ft.</th><th colspan="2">kW/1000 sq. ft.</th><th colspan="2">kWh/sq. ft.</th><th colspan="2">kW/1000 sq. ft.</th></tr>
<tr><td>El Dorado (Zone 6)</td><td colspan="2">0.1016</td><td colspan="2">0.0365</td><td colspan="2">0.0964</td><td colspan="2">0.0358</td></tr>
<tr><td>Little Rock (Zone 7)</td><td colspan="2">0.0988</td><td colspan="2">0.0378</td><td colspan="2">0.0903</td><td colspan="2">0.0372</td></tr>
<tr><td>Fort Smith (Zone 8)</td><td colspan="2">0.0926</td><td colspan="2">0.0351</td><td colspan="2">0.0805</td><td colspan="2">0.0345</td></tr>
<tr><td>Fayetteville (Zone 9)</td><td colspan="2">0.0848</td><td colspan="2">0.0339</td><td colspan="2">0.0758</td><td colspan="2">0.0333</td></tr>
</table>

Table 301: Cool Roofs (SC) – Deemed Savings Values – Office Building

Weather Zone	Gas-Electric							
	DX Coils with Furnace				Chiller with Boiler			
	Energy Savings	Peak Demand Savings	Gas Savings	Peak Gas Savings	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1000 sq. ft.	therms/ 1000 sq. ft.	therms/ 1000 sq. ft.	kWh/sq. ft.	kW/1000 sq. ft.	therms/ 1000 sq. ft.	therms/ 1000 sq. ft.
El Dorado (Zone 6)	0.0906	0.0599	-1.1547	Negligible	0.1343	0.0978	-1.2917	Negligible
Little Rock (Zone 7)	0.0858	0.0629	-1.8316	Negligible	0.1171	0.1006	-1.9466	Negligible
Fort Smith (Zone 8)	0.0849	0.0620	-2.2312	Negligible	0.1229	0.0984	-2.1914	Negligible
Fayetteville (Zone 9)	0.0827	0.0581	-2.2615	Negligible	0.1153	0.0951	-2.2589	Negligible

	All Electric			
	Heat Pump		Electric Resistance	
	kWh/sq. ft.	kW/1000 sq. ft.	kWh/sq. ft.	kW/1000 sq. ft.
El Dorado (Zone 6)	0.0780	0.0589	0.0631	0.0578
Little Rock (Zone 7)	0.0601	0.0603	0.0432	0.0608
Fort Smith (Zone 8)	0.0521	0.0584	0.0336	0.0596
Fayetteville (Zone 9)	0.0517	0.0547	0.0325	0.0557

Table 302: Cool Roofs (SC) – Deemed Savings Values – All Other Building Types

Weather Zone	Gas-Electric							
	DX Coils with Furnace				Chiller with Boiler			
	Energy Savings	Peak Demand Savings	Gas Savings	Peak Gas Savings	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/1000 sq. ft.	therms/ 1000 sq. ft.	therms/ 1000 sq. ft.	kWh/ sq. ft.	kW/1000 sq. ft.	therms/ 1000 sq. ft.	therms/ 1000 sq. ft.
El Dorado (Zone 6)	0.1191	0.0526	-2.5353	Negligible	0.2003	0.0808	-0.7824	Negligible
Little Rock (Zone 7)	0.1066	0.0491	-3.0425	Negligible	0.2088	0.0864	-1.2486	Negligible
Fort Smith (Zone 8)	0.1083	0.0528	-3.5381	Negligible	0.1962	0.0819	-1.4894	Negligible
Fayetteville (Zone 9)	0.1027	0.0486	-3.5830	Negligible	0.1837	0.0784	-1.4735	Negligible

	All Electric			
	Heat Pump		Electric Resistance	
	kWh/sq. ft.	kW/1000 sq. ft.	kWh/sq. ft.	kW/1000 sq. ft.
El Dorado (Zone 6)	0.0965	0.0517	0.0798	0.0710
Little Rock (Zone 7)	0.0755	0.0335	0.0668	0.0670
Fort Smith (Zone 8)	0.0713	0.0282	0.0571	0.0675
Fayetteville (Zone 9)	0.0635	0.0278	0.0542	0.0639

Calculation of Deemed Savings

Deemed savings for commercial measures were calculated using eQuest models populated according to the commercial building prototypes developed by the US DOE Building Energy Codes Program, applying ASHRAE Standard 90.1-2007.[450] Model runs were performed with TMY3 data for each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), and Fort Smith (Zone 8), and Fayetteville (Zone 9).

Energy models for commercial cool roofs were developed for a retail strip mall, an office, a secondary school, a full-service restaurant, and a big box retail store. “All other building types” estimates, presented in Table 302, were calculated as averages of the five modeled building types. The baseline roof for the simulations was a built-up tar and felt roof. The deemed savings values presented herein represent the average savings on a per square foot or per thousand square foot basis for each weather zone. Peak demand savings were averaged across the period of 3pm-6pm during non-holiday weekdays in the months of June, July, and August.

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[450] U.S. DOE commercial building prototypes, developed in accordance with the minimum efficiencies outlined in ASHRAE Standard 90.1, can be found here: http://www.energycodes.gov/development/commercial/90.1_models

3.2.4 Air Infiltration (Converted Residences)

Measure Description

This measure reduces air infiltration into converted residences (CR), using pre- and post-treatment blower door air pressure readings to confirm air leakage reduction.

Blower door air pressure post-measurements will be used to ensure that air infiltration in a converted residence is not reduced to less than 0.35 air changes per hour (ACH_{Nat}),[451] verified using Table 303, which has been converted from ACH_{Nat} to CFM_{50} for simplified comparison to field measurements. Savings should not be claimed for CFM/ft^2 readings less than those displayed in Table 303.

Utilities may require competency testing of personnel who will perform the blower door tests.

Table 303: Air Infiltration (CR) – Minimum Final Ventilation Rate in CFM/ft2 of conditioned floor area

	Number of Stories		
Wind Shielding	**Single Story**	**Two Story**	**Three + Story**
Well Shielded	1.35	1.08	0.95
Normal	1.13	0.90	0.79
Exposed	1.02	0.81	0.71

Well Shielded is defined as urban areas with high buildings or sheltered areas, and buildings surrounded by trees, bermed earth, or higher terrain.

Normal is defined as buildings in a residential neighborhood or subdivision setting, with yard space between buildings; 80-90 percent of houses fall in this category.

Exposed is defined as buildings in an open setting with few buildings or trees around and buildings on top of a hill or ocean front, exposed to winds.

As an example, the minimum post-installation air exchange rate for an 1,800 square foot, one-story home with normal shielding is 2,034 CFM_{50} (1,800 x 1.13).

In order to qualify for the air infiltration control deemed savings, there must be at least a 10 percent reduction of the ventilation rate, comparing pre- and post-installation. Therefore, in this example, the pre-installation ventilation rate must be at least 2,260 CFM_{50} (2,034 ÷ 0.9) in order to be considered for air infiltration control measures.

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[451] ASHRAE 62-2001: minimum ACH_{Nat} = 0.35, or 15 CFM/person.

Baseline and Efficiency Standards

The baseline for this measure is the existing leakage rate of the converted residence to be treated. Baseline assumptions used in the development of these deemed savings are based on the 2009 ASHRAE Handbook of Fundamentals, Chapter 16, which provides typical infiltration rates for residential structures. In a worst-case scenario, ACH rates reported in ASHRAE averaged 0.90, with about 70 percent of the houses rating below 1.25 ACH_{Nat}.[452] Therefore, to reflect the majority of participants, these savings are only appropriate for participants whose starting ACH_{Nat} is 1.25 or lower.

To calculate ACH_{Pre}, use the following equation:

$$ACH_{N,pre} = \frac{CFM_{50,pre} \times 60}{Vol \times N}$$

(240)

Where:

$CFM_{50,pre}$ = Pre-installation ventilation rate at 50 Pa (ft^3/min).

60 = Constant to convert from minutes to hours.

Vol = Volume of the treated space (ft^3) = Square Footage x Weighted Average Ceiling Height.

N = N factor (Table 304).

Table 304: Air Infiltration – N Factor[453]

		Number of Stories		
Zone	**Wind Shielding**	**Single Story**	**Two Story**	**Three + Story**
3	Well Shielded	25.8	20.6	18.1
	Normal	21.5	17.2	15.1
	Exposed	19.4	15.5	13.5

Typical baseline CFM_{50} ratings derived from EnergyGauge simulations used to create the deemed savings for this measure (Calculation of Deemed Savings) did not exceed 7,500 CFM_{50} in any of the four weather zones examined. Pre-retrofit leakage rates are limited to a maximum of 7,500 CFM_{50} as this generally indicates severe structural damage not repairable by typical infiltration reduction techniques. Participants reporting more than 4,000 CFM_{50} in reduction are subject to a pre-treatment inspection by utility administrators. Pre-approval is required from utility administrators prior to any treatment.

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[452] 2009 ASHRAE Handbook of Fundamentals, Chapter 15, pp. 16.17-16, 18.

[453] Krigger, J. & Dorsi, C., 2005,*Residential Energy: Cost Savings and Comfort for Existing Buildings, 4th Edition. Version RE.* December 20. Appendix A-11: Building Tightness Limits, p. 284.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 11 years for Air Infiltration.

Deemed Savings Values

The following formula shall be used to calculate deemed savings for infiltration efficiency improvements. The formula applies to single-family and multifamily dwellings, and to all building heights and shielding factors.

$$Deemed\ Savings\ =\ (CFM_{50,pre} - CFM_{50,post}) \times V$$

(241)

Where:

CFM_{50} = Air infiltration reduction in cubic feet per minute at 50 pascals, as measured by the difference between pre and post installation blower door air leakage tests.

V = the corresponding therm, kWh, and kW values taken from the following tables. Gas Heat (no AC) is the reduction in electricity used by the furnace's air handler during the heating season.

Table 305: Infiltration (CR) – Deemed Savings Values - Zone 9: Northwest Region

Air Infiltration Reduction	**AC/Gas Heat kWh**	**Gas Heat (no AC) kWh**	**Gas Heat Therms**	**AC/Electric Resistance kWh**	**Heat Pump kWh**	**AC Peak Savings kW**	**Peak Gas Savings Therms**
	(/CFM$_{50}$ Reduced)	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**
	0.106	0.029	0.043	1.067	0.583	0.00013	0.00134

Table 306: Infiltration (CR) – Deemed Savings Values - Zone 8: Northeast/North Central Region

Air Infiltration Reduction	**AC/Gas Heat kWh**	**Gas Heat (no AC) kWh**	**Gas Heat Therms**	**AC/Electric Resistance kWh**	**Heat Pump kWh**	**AC Peak Savings kW**	**Peak Gas Savings Therms**[454]
	(/CFM$_{50}$ Reduced)	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**	**(/CFM$_{50}$ Reduced)**
	0.125	0.032	0.046	1.154	0.625	0.00016	0.00123

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[454] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.862. For Fort Smith, m = 0.821.

Table 307: Infiltration (CR) – Deemed Savings Values - Zone 7: Central Region

Air Infiltration Reduction	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)
	0.142	0.026	0.038	0.988	0.542	0.00014	0.00114

Table 308: Infiltration (CR) – Deemed Savings Values - Zone 6: South Region

Air Infiltration Reduction	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)	(/CFM$_{50}$ Reduced)
	0.174	0.020	0.029	0.836	0.480	0.00018	0.00093

Calculation of Deemed Savings

EnergyGauge USA was used to model hourly energy consumption for prototype converted residences in each Arkansas weather region. This series of model runs was created using available TMY3 weather data for four Arkansas weather regions.

A series of model runs was completed in order to establish the relationship between various CFM$_{50}$ leakage rates and heating and cooling energy consumption. The resulting analysis of model outputs was used to create the deemed savings tables of kWh, kW, and therm savings per CFM$_{50}$ of air infiltration reduction. The prototype characteristics of the building models are outlined in Appendix A.

3.2.5 Roof Deck Insulation (Small Commercial)

Measure Description

Roof Deck insulation deemed savings are estimated per square foot of treated roof deck area above a conditioned space for increasing the roof deck insulation in small commercial (SC) buildings from various levels of pre-retrofit roof deck insulation to R-19. Because of the interactive nature of the relationship between roof deck and ceiling insulation, the deemed savings values are estimated based on a number of existing levels of pre-retrofit roof-deck and ceiling insulation. To qualify for this measure, contractors must raise the R-value of the roof deck insulation to R-19 on a building in which the pre-retrofit ceiling insulation is judged to have an R-value no greater than R-9, and the ceiling insulation no greater than R-22. Buildings in which the combined pre-retrofit roof deck and ceiling insulation R-values exceed R-30 are not eligible for this measure, and buildings participating in the ceiling insulation measure are not eligible for the roof deck insulation measure. The combined roof insulating values are only applicable for non-ventilated attic spaces and spaces in which the attic area is not used as a return air plenum.

Eligible roof deck insulation material is rigid foam board and spray foam insulation. Spray foam insulation is not an eligible measure for ventilated attic spaces or when gas-fired equipment is located in the attic space.

Baseline and Efficiency Standards

In existing construction, roof deck insulation levels vary depending on a number of factors, including the construction style and the age and type of insulation used. The savings that can be achieved by installing additional roof deck insulation depend on both the existing levels of ceiling insulation and the insulating capacity of the pre-retrofit roof deck. As such, deemed savings tables detail savings from roof deck insulation installations for each Arkansas weather zone based on four different levels of pre-retrofit roof deck insulation and three different levels of ceiling insulation. Specifically, deemed savings are presented for buildings with pre-retrofit roof deck insulation in three ranges: R-0 to R-3.5, R-4 to R-6, R-7 to R-9, and R-10 to R-12. For a roof deck insulation project to qualify for deemed savings, the R-value of the pre-retrofit roof deck insulation can be no greater than R-12, the R-value of the pre-retrofit ceiling insulation can be no greater than R-22, and the combined R-value of ceiling and roof deck insulation cannot exceed R-30. The pre-existing insulation level for each building will be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing insulation is (or has been) removed, the existing R-value used to estimate the retrofit’s deemed savings will be the R-value provided by the insulation in existence prior to removal.

IECC 2003 calls for above-deck insulation of up to R-15, continuously installed, and up to R-19 for metal buildings in the weather zones in which Arkansas is located. Roof deck insulation rebates are designed to encourage the installation of building attic insulation that meets the higher of these values, R-19. All typical roof deck insulation materials are eligible for this measure.

Any insulation retrofit shall be performed in accordance with the applicable safety and environmental standards for the type of insulation being installed. In some cases, this may require removal of existing insulation. For example, when retrofitting with spray-in polyurethane foam, existing ceiling insulation may need to be removed for fire safety. In this case, the expectation is that the contractor would return and replace the removed material; regardless, deemed savings shall only be paid according to the R-level of ceiling insulation existing prior to any removal of existing insulation.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Deemed savings values for annual electric energy use (kWh), peak demand (kW), and annual and peak gas usage (therms) are provided in the tables on the following pages.

Table 309: Roof Deck Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 9 Northwest Region

Pre-Retrofit Roof Deck R-value	Electric		Gas	
	Annual Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	therms/sq. ft.	therms/1,000 sq. ft.
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.269	0.222	0.128	0.659
R-4 to R-6	0.207	0.178	0.104	0.507
R-9 to R-14	0.123	0.114	0.064	0.307
R-15 to R-22	0.072	0.071	0.039	0.182
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.061	0.083	0.023	0.16
R-4 to R-6	0.05	0.066	0.019	0.134
R-9 to R-14	0.034	0.042	0.013	0.093
R-15 to R-22	0.021	0.026	0.009	0.059
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.034	0.057	0.009	0.102
R-4 to R-6	0.028	0.045	0.007	0.086
R-9 to R-14	0.021	0.028	0.005	0.06
R-15 to R-22	0.013	0.017	0.003	0.038

Table 310: Roof Deck Insulation (SC) – Electric Savings for Electric Heat - Zone 9 Northwest Region

Pre-Retrofit Roof Deck R-value	Heat Pump		Electric Resistance	
	Annual Energy Savings	Peak Demand Savings	Annual Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	kWh/sq. ft.	kW/1,000 sq. ft.
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.687	0.167	1.368	0.22
R-4 to R-6	0.348	0.086	0.662	0.12
R-7 to R-9	0.223	0.057	0.416	0.078
R-10 to R-12	0.137	0.036	0.252	0.047
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.252	0.077	0.405	0.092
R-4 to R-6	0.144	0.042	0.232	0.05
R-7 to R-9	0.095	0.028	0.155	0.033
R-10 to R-12	0.06	0.017	0.099	0.02
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.153	0.053	0.247	0.064
R-4 to R-6	0.09	0.029	0.146	0.035
R-7 to R-9	0.061	0.019	0.1	0.023
R-10 to R-12	0.04	0.012	0.064	0.014

Table 311: Roof Deck Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 8 Northeast/North Central Region

Pre-Retrofit Roof Deck R-value	**Electric**		**Gas**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Savings**[455]
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**therms/sq. ft.**	**therms/1,000 sq. ft.**
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.323	0.217	0.108	2.058
R-4 to R-6	0.254	0.177	0.09	1.907
R-7 to R-9	0.152	0.12	0.068	1.713
R-10 to R-12	0.091	0.074	0.055	1.596
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.076	0.083	0.015	0.155
R-4 to R-6	0.064	0.066	0.012	0.129
R-7 to R-9	0.042	0.042	0.008	0.087
R-10 to R-12	0.026	0.026	0.005	0.056
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.045	0.056	0.008	0.1
R-4 to R-6	0.038	0.045	0.007	0.084
R-7 to R-9	0.025	0.028	0.005	0.058
R-10 to R-12	0.016	0.017	0.003	0.037

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[455] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.861. For Fort Smith, m = 0.859.

Table 312: Roof Deck Insulation (SC) – Electric Savings for Electric Heat - Zone 8 Northeast/North Central Region

Pre-Retrofit Roof Deck R-value	**Heat Pump**		**Electric Resistance**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Energy Savings**	**Peak Demand Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**kWh/sq. ft.**	**kW/1,000 sq. ft.**
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.705	0.23	1.421	0.278
R-4 to R-6	0.361	0.117	0.696	0.141
R-7 to R-9	0.231	0.073	0.439	0.088
R-10 to R-12	0.141	0.046	0.266	0.055
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.261	0.1	0.406	0.1
R-4 to R-6	0.15	0.055	0.235	0.055
R-7 to R-9	0.102	0.036	0.159	0.036
R-10 to R-12	0.064	0.023	0.101	0.023
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.161	0.069	0.247	0.069
R-4 to R-6	0.095	0.037	0.148	0.037
R-7 to R-9	0.064	0.025	0.101	0.025
R-10 to R-12	0.041	0.015	0.066	0.015

Table 313: Roof Deck Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 7 Central Region

Pre-Retrofit Roof Deck R-value	**Electric**		**Gas**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Gas Savings**	**Peak Gas Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**therms/sq. ft.**	**therms/1,000 sq. ft.**
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.278	0.216	0.071	0.575
R-4 to R-6	0.214	0.176	0.054	0.434
R-7 to R-9	0.129	0.114	0.032	0.259
R-10 to R-12	0.076	0.07	0.019	0.154
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.071	0.082	0.014	0.142
R-4 to R-6	0.059	0.066	0.012	0.116
R-7 to R-9	0.039	0.043	0.008	0.077
R-10 to R-12	0.025	0.027	0.005	0.049
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.045	0.059	0.007	0.092
R-4 to R-6	0.038	0.047	0.006	0.076
R-7 to R-9	0.026	0.03	0.004	0.051
R-10 to R-12	0.017	0.019	0.003	0.032

Table 314: Roof Deck Insulation (SC) – Electric Savings for Electric Heat - Zone 7 Central Region

Pre-Retrofit Roof Deck R-value	Heat Pump		Electric Resistance	
	Annual Energy Savings	Peak Demand Savings	Annual Energy Savings	Peak Demand Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	kWh/sq. ft.	kW/1,000 sq. ft.
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.616	0.179	1.103	0.195
R-4 to R-6	0.314	0.097	0.613	0.12
R-7 to R-9	0.202	0.064	0.386	0.078
R-10 to R-12	0.124	0.04	0.234	0.048
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.224	0.091	0.332	0.083
R-4 to R-6	0.127	0.051	0.206	0.051
R-7 to R-9	0.084	0.034	0.139	0.034
R-10 to R-12	0.054	0.022	0.089	0.022
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.133	0.066	0.202	0.06
R-4 to R-6	0.08	0.037	0.13	0.037
R-7 to R-9	0.054	0.024	0.089	0.024
R-10 to R-12	0.035	0.015	0.058	0.015

Table 315: Roof Deck Insulation (SC) – Electric and Gas Savings for DX Coils with Gas Furnace - Zone 6 South Region

Pre-Retrofit Roof Deck R-value	Electric		Gas	
	Annual Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Savings
	kWh/sq. ft.	kW/1,000 sq. ft.	therms/sq. ft.	therms/1,000 sq. ft.
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.32	0.211	0.048	0.514
R-4 to R-6	0.25	0.171	0.036	0.408
R-7 to R-9	0.152	0.111	0.021	0.263
R-10 to R-12	0.091	0.068	0.012	0.16
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.086	0.078	0.011	0.148
R-4 to R-6	0.071	0.063	0.009	0.128
R-7 to R-9	0.047	0.041	0.006	0.093
R-10 to R-12	0.03	0.025	0.004	0.062
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.057	0.057	0.007	0.102
R-4 to R-6	0.048	0.046	0.006	0.092
R-7 to R-9	0.032	0.029	0.004	0.066
R-10 to R-12	0.021	0.018	0.002	0.044

Table 316: Roof Deck Insulation (SC) – Electric Savings for Electric Heat - Zone 6 South Region

Pre-Retrofit Roof Deck R-value	**Heat Pump**		**Electric Resistance**	
	Annual Energy Savings	**Peak Demand Savings**	**Annual Energy Savings**	**Peak Demand Savings**
	kWh/sq. ft.	**kW/1,000 sq. ft.**	**kWh/sq. ft.**	**kW/1,000 sq. ft.**
Pre-Retrofit Ceiling Insulation R-0 to R-6				
R-0 to R-3.5	0.563	0.163	1.136	0.195
R-4 to R-6	0.281	0.089	0.546	0.111
R-7 to R-9	0.176	0.058	0.341	0.072
R-10 to R-12	0.107	0.036	0.205	0.045
Pre-Retrofit Ceiling Insulation R-7 to R-14				
R-0 to R-3.5	0.201	0.084	0.328	0.084
R-4 to R-6	0.111	0.047	0.185	0.047
R-7 to R-9	0.075	0.031	0.124	0.031
R-10 to R-12	0.048	0.02	0.079	0.02
Pre-Retrofit Ceiling Insulation R-15 to R-22				
R-0 to R-3.5	0.124	0.061	0.203	0.061
R-4 to R-6	0.073	0.034	0.118	0.034
R-7 to R-9	0.049	0.022	0.08	0.022
R-10 to R-12	0.032	0.014	0.052	0.014

Calculation of Deemed Savings

Deemed savings were calculated using an eQuest model populated as shown in the following section. Model runs were performed with TMY3 data for each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Two different buildings were used: a stand-alone retail store and a small office building. Savings for each combination of ceiling and pre-retrofit roof deck insulation level were estimated for each building type on a per-square-foot basis. The deemed savings values presented herein represent the average savings per square foot for each building type modeled, for each weather zone and combination of pre-retrofit roof deck and ceiling insulation level. The prototype characteristics of the building models are outlined in Appendix A.

3.2.6 (Empty)

3.2.7 Wall Insulation (Converted Residences)

Measure Description

This measure consists of adding wall insulation in the wall cavity in converted residences of existing construction to a minimum insulation level of R-13.

Baseline and Efficiency Standards

The baseline is considered to be a converted residence with no wall insulation (R-0) in the wall cavity.

In order to qualify for this measure, there must not be any existing wall insulation. This measure implements a wall insulation value of R-13.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 20 years, in accordance with DEER 2008.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the net wall area insulated. The wall area must be part of the thermal envelope of the home, and shall not include the window or door area. Gas Heat (no AC) kWh is the reduction in electricity used by the furnace's air handler during the heating season.

Table 317: Wall Insulation (CR) – Deemed Savings Values - Zone 9 North Region

Wall Insulation	**AC/Gas Heat kWh**	**Gas Heat (no AC) kWh**	**Gas Heat Therms**	**AC/Electric Resistance kWh**	**Heat Pump kWh**	**AC Peak Savings kW**	**Peak Gas Savings Therms**[456]
	(/ CFM_{50})	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**
R-13	0.725	0.154	0.233	6.100	3.462	0.00069	0.00504

Table 318: Wall Insulation (CR) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Wall Insulation	**AC/Gas Heat kWh**	**Gas Heat (no AC) kWh**	**Gas Heat Therms**	**AC/Electric Resistance kWh**	**Heat Pump kWh**	**AC Peak Savings kW**	**Peak Gas Savings Therms**[457]
	(/ CFM_{50})	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**	**(/ CFM_{50})**
R-13	0.810	0.157	0.237	6.307	3.610	0.00063	0.00468

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[456] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.902. For Fort Smith, m = 0.870.

[457] Peak gas savings in the Zone 8 table are for the Blytheville peak. Other Zone 8 peaks can be calculated by multiplying Blytheville peak by the appropriate factor, m. For Jonesboro, m = 0.902. For Fort Smith, m = 0.870.

Table 319: Wall Insulation (CR) – Deemed Savings Values - Zone 7: Central Region

Wall Insulation	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})
R-13	0.765	0.134	0.203	5.442	3.050	0.00039	0.00388

Table 320: Wall Insulation (CR) – Deemed Savings Values - Zone 6: South Region

Wall Insulation	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})	(/ CFM_{50})
R-13	0.942	0.113	0.171	4.897	2.828	0.00061	0.00392

Calculation of Deemed Savings

EnergyGauge USA® was used to estimate energy savings for a prototypical Arkansas home. The prototype characteristics of the building models are outlined in Appendix A.

3.2.8 Window Awnings (Small Commercial)

Measure Description

Opaque fixed or retractable window awnings on the east and west windows of commercial buildings less than 15,000 gross square feet are eligible for this measure. Window surfaces facing within 45 degrees of true north are not eligible for a rebate. Rebate amounts are based on the square footage of qualifying windows on which awnings are installed.

Baseline and Efficiency Standards

The baseline for this measure is a commercial building without shading or existing window awnings that has clear single or double pane glazing with a solar heat gain factor (SHGC) greater than 0.66. Existing Low E windows, windows with existing solar films or solar screens are not eligible for this measure.

In order to qualify for deemed savings, the window awning must be constructed of an opaque material and permanently installed. Overhangs may be inappropriate for sites within certain property associations with restrictive constitutions and covenants.

Exterior overhangs provide a practical method of shading windows. There is no simple formula for sizing overhangs. The methodology that works well for some locations may be inappropriate for others. Every climate requires special design attention to account for both sun and humidity conditions and to ensure awnings withstand wind and snow loading.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 10 years, in accordance with DEER 2006-7.

Deemed Savings Values

Deemed savings values for annual electric energy use (kWh), peak demand (kW), and annual and peak gas usage (therms) are provided in the tables on the following pages.

Table 321: Window Awnings (SC) – Deemed Savings Values - Zone 9 Northwest Region

Direction of Awnings	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	7.69786	2.95994	-198.30947	-2.24404	1.56379	2.57990	3.60504	2.58089
West	6.70542	4.05669	-104.17499	-0.86175	2.74996	3.55217	3.96992	3.55495

Table 322: Window Awnings (SC) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Direction of Awnings	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	8.82879	3.25398	-223.81941	-0.93350	1.88361	1.90021	4.19877	1.90110
West	7.65467	3.95058	-113.15231	-0.30009	3.08553	2.42634	4.46457	2.43003

Table 323: Window Awnings (SC) – Deemed Savings Values - Zone 7 Central Region

Direction of Awnings	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	8.72021	2.92977	-186.95363	-3.14738	2.60900	2.75343	4.64557	2.75432
West	7.66455	4.37778	-96.77596	-1.14721	3.55771	4.18680	4.77769	4.19685

Table 324: Window Awnings (SC) – Deemed Savings Values - Zone 6 South Region

Direction of Awnings	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	8.14063	2.44931	-134.09747	-0.89983	3.18828	2.43199	4.58778	2.43204
West	6.96181	3.38915	-69.56344	-0.73771	3.43340	3.46348	4.25743	3.46351

Calculation of Deemed Savings

Deemed savings were calculated using an eQuest model populated as shown in the following section. Model runs were performed with TMY3 data for each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Deemed savings are applicable to commercial buildings although only two different buildings were used for simulation of energy savings: a strip mall and a small office building. Savings for the east and west window surfaces were estimated based on a small office building with equal window surfaces on all four sides and for strip malls having glazing on one side. The deemed savings values presented herein represent the average savings per square foot of glazing for windows in each weather zone facing east and west. The prototype characteristics of the building models are outlined in Appendix A.

3.2.9 Window Film (Converted Residences)

Measure Description

This measure involves adding solar film to windows that face east or west.

Baseline and Efficiency Standards

This measure is applicable to existing homes only. The existing windows must be single- or double-pane clear glass. Low E windows and tinted windows are not applicable for this measure. The existing windows should have no existing solar films or solar screens.

In order to qualify for deemed savings, solar film should be applied to glass that faces east or west. The solar heat gain factor (SHGC) of the films must be less than 0.50.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 10 years, according to DEER 2008.

Deemed Savings Values

Please note that the savings per square foot is a factor to be multiplied by the square footage of the window area to which the films are being added. Gas Heat (no AC) kWh applies to forced-air furnace systems only.

Table 325: Window Film (CR) – Deemed Savings Values - Zone 9: Northwest

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.006	-0.162	-0.248	-2.372	0.778	0.00199	-0.00091
Double Pane	1.985	-0.107	-0.164	-1.480	0.495	0.00133	-0.00061

Table 326: Window Film (CR) – Deemed Savings Values - Zone 8: Northeast/North Central Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.328	-0.157	-0.237	-1.839	1.163	0.00187	-0.00019
Double Pane	2.255	-0.104	-0.158	-1.182	0.810	0.00124	-0.00005

Table 327: Window Film (CR) – Deemed Savings Values - Zone 7: Central Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.143	-0.126	-0.193	-1.118	1.391	0.00195	-0.00204
Double Pane	2.101	-0.086	-0.132	-0.670	0.961	0.00132	-0.00136

Table 328: Window Film (CR) – Deemed Savings Values - Zone 6: South Region

Existing Window Pane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings (kW)	Peak Gas Savings (therms)
	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)	(/ sq. ft.)
Single Pane	3.872	-0.104	-0.158	0.349	2.425	0.00195	-0.00038
Double Pane	2.589	-0.068	-0.103	0.296	1.640	0.00130	-0.00025

Calculation of Deemed Savings

The building load simulation software EnergyGauge® was used to estimate energy savings for a prototype Arkansas single-family home.

A series of models were created to determine the difference in weather data throughout the four weather regions in Arkansas as defined in IECC 2003. Since building-shell measures are sensitive to weather, available TMY3 weather data specific to each of the four Arkansas weather regions were used for the analysis. The prototype characteristics of the building models are outlined in Appendix A.

3.2.10 Window Film (Small Commercial)

Measure Description

This measure consists of the addition of solar film to the inside of glazing on the east and west windows of commercial buildings less than 15,000 gross square feet (any direction except 45 degrees of true north). This measure is based on square footage of qualifying windows.

Baseline and Efficiency Standards

This measure is applicable to existing commercial buildings with clear single- or double-pane glazing with a solar heat gain factor (SHGC) greater than 0.66. Existing Low E windows, windows with existing solar films or solar screens are not eligible for this measure.

In order to qualify for deemed savings, solar film should be applied to glass facing east or west. The SHGC of the films must be less than 0.50.

The windows must not be shaded by existing awnings, exterior curtains or blinds or any other shading device. They must be installed in a space conditioned by refrigerated air conditioning (central, window or wall unit).

The windows must meet all applicable codes and standards, including:

- ASTM-408: Standard Method for Total Normal Emittance by inspection meter.
- ASTM E-308: Standard Recommended Practice for Spectro-Photometry and Description of Color in CIE1931 (this is an indicator of luminous reflection and visibility).
- ASTM-E903: Standard Methods of Test for Solar Absorbance, Reflectance and Transmittance using an integrated sphere.
- ASTM G-90: Standard Practice for Performing Accelerated Outdoor Weatherizing for Non-Metallic Materials Using Concentrated Natural Light.
- ASTM G26: Xenon arc weathering to accelerate natural aging.
- ASTM E-84: Flammability for commercial and residential structures.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 10 years, according to DEER 2008.

Deemed Savings Values

Deemed savings values for annual electric energy use (kWh), peak demand (kW), and annual and peak gas usage (therms) are provided in the following tables.

Table 329: Window Film (SC) – Deemed Savings Values - Zone 9 Northwest Region

Direction of Window Film	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	8.48850	2.94185	-232.47726	-3.05131	1.37341	2.50694	3.81851	2.51051
West	8.42415	4.20904	-133.13357	-0.65406	3.31978	3.67578	4.94430	3.68156

Table 330: Window Film (SC) – Deemed Savings Values - Zone 8 Northeast/North Central Region

Direction of Window Film	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	9.03364	3.13629	-256.11116	-4.03404	1.31162	1.78451	3.97447	1.78672
West	8.97534	3.96477	-146.86459	-1.75580	3.33873	2.37713	5.07161	2.38301

Table 331: Window Film (SC) – Deemed Savings Values - Zone 7 Central Region

Direction of Window Film	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	9.13426	2.92164	-217.06250	-4.14786	2.25304	2.70430	4.62613	2.70981
West	8.62321	3.80052	-123.80487	-1.38202	3.54193	3.66854	5.01805	3.68440

Table 332: Window Film (SC) – Deemed Savings Values - Zone 6 South Region

Direction of Window Film	Gas-Electric				All Electric			
	DX Coils with Furnace				Heat Pump		Electric Resistance	
	Energy Savings	Peak Demand Savings	Annual Gas Savings	Peak Gas Reduced*	Energy Savings	Peak Demand Savings	Energy Savings	Peak Demand Savings
	kWh/ sq. ft.	kW/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	therms/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.	kWh/ sq. ft.	kW/ 1,000 sq. ft.
East	7.57526	1.87769	-150.97840	-1.41160	2.28138	1.91838	3.72385	1.91844
West	9.11300	3.90877	-95.22624	-0.98617	4.53187	4.01461	5.74195	4.01456

Calculation of Deemed Savings

Deemed savings were calculated using an eQuest model populated as shown in the following section. Model runs were performed with TMY3 data for each weather zone: El Dorado (Zone 6), Little Rock (Zone 7), Fort Smith (Zone 8), and Fayetteville (Zone 9).

Deemed savings are applicable to commercial buildings and were calculated using two representative buildings: a strip mall and a small office building. Estimated savings for the east and west window surfaces were based on a small office building with equal window surfaces on all four sides and for strip malls having glazing on one side. The deemed savings values presented herein represent the average savings per square foot of glazing for windows in each weather zone facing east and west. The prototype characteristics of the building models are outlined in Appendix A.

3.2.11 Commercial Door Air Infiltration

Measure Description

This measure applies to the installation of weather stripping on entrance/exit doors for a contained, pressurized space. Entrance and exit doors often leave clearance gaps to allow for proper operation. The gaps around the doors allow unconditioned air to infiltrate the building, adding to the cooling and heating load of the HVAC system. Door sweeps and weather stripping are designed to be installed along the bottom and jambs of exterior doors to prevent air infiltration to conditioned space.

Estimated Useful Life (EUL)

According to the DEER 2014, air infiltration measures are assigned an EUL of 11 years.[458] This measure life is consistent with residential and converted residence infiltration measures in the Arkansas TRM.

Baseline & Efficiency Standard

The baseline standard for this measure is a commercial building with exterior doors that are not sealed from unconditioned space. Doors must have visible gaps of at least 1/8 – 3/4 inches along the outside edge of the door. A space with interior vestibule doors would is not eligible. Interior space must be conditioned and/or heated.

The efficiency standard for this measure is a commercial building with exterior doors that have been sealed from unconditioned space using brush style door sweeps and/or weather stripping on entrance/exit doors.

Calculation of Deemed Savings

This savings methodology was derived by analyzing TMY3 weather data for each Arkansas weather zone representative city. To calculate HVAC load associated with air infiltration, the following sensible heat equation is used:

Electric Cooling Savings

$$Electric\ Clg\ kWh_{savings,day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{day}}{12{,}000\ \frac{Btu/h}{ton}}$$

(242)

$$Electric\ Clg\ kWh_{savings,night} = \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{night}}{12{,}000\ \frac{Btu/h}{ton}}$$

(243)

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[458] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

$$kWh_{savings,elect\ clg} = Electric\ Clg\ kWh_{savings,day} + Electric\ Clg\ kWh_{savings,night}$$

(244)

$$kW_{savings,elect\ clg} = \frac{kWh_{savings,elect,clg}}{ELFH_C}$$

(245)

Electric Heating Savings

$$Electric\ Htg\ kWh_{savings,day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{day}}{COP \times 3{,}412\ \frac{Btu/h}{kW}}$$

(246)

$$Electric\ Htg\ kWh_{savings,night} = \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{night}}{COP \times 3{,}412\ \frac{Btu/h}{kW}}$$

(247)

$$kWh_{savings,elect\ htg} = Electric\ Htg\ kWh_{savings,day} + Electric\ Htg\ kWh_{savings,night}$$

(248)

Gas Heating Savings

$$Gas\ Htg\ Therms_{savings,day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{day}}{80\%\ AFUE \times 100{,}000\ Btu/therm}$$

(249)

$$Gas\ Htg\ Therms_{savings,night} = \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0\ kW/ton * Hours_{night}}{80\%\ AFUE \times 100{,}000\ Btu/therm}$$

(250)

$$Therms_{savings,gas\ htg} = Gas\ Htg\ Therms_{savings,day} + Gas\ Htg\ Therms_{savings,night}$$

(251)

$$Peak\ Therms_{savings,gas\ htg} = \frac{Therms_{savings,gas\ htg}}{ELFH_H}$$

(252)

Where:

CFM_{pre} = Calculated pre-retrofit air infiltration rate (ft^3/min)

$CFM_{reduction}$ = 79%[459]

1.08 = Sensible heat equation conversion[460]

ΔT = Change in temperature across gap barrier

$Hours_{day}$ = 12 hour cycles per day, per month = 4,380 hours

$Hours_{night}$ = 12 hour cycles per day, per month = 4,380 hours

COP = Heating coefficient of performance; 1.0 for Electric Resistance and 3.3 for Heat Pumps

$EFLH_C$ = Average cooling equivalent full-load hours across all building types (section 4.3)

$EFLH_H$ = Average heating equivalent full-load hours across all building types (section 4.3)

Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).[461] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026[462], and an average building height of 20 feet (for typical Arkansas building stock) is assumed for the deemed savings approach.

Because air infiltration is a function of the differential pressure due to stack effect, wind speed, velocity head, and the design conditions of the building, TMY3 for each Arkansas weather zone was applied to account for the varying weather conditions that are characteristic throughout an average year.

Figure 5.13 from the ASHRAE CHLCM provides the infiltration rate based on various crack width and the corresponding pressure difference across a door. Figures 5.1 and 5.2 (CHLCM) provide the differential pressure due to stack and wind pressure necessary to determine the total pressure difference across the door.

Applying a regression analysis to Figure 5.1 returns an equation which allows solving for the pressure difference due to stack effect, Δp_s. The aggregate curve fit for Figure 5.1 is shown below where x is the based on the dry bulb temperature from the TMY3 data and the design temperature based on the appropriate seasonal condition.

$$\Delta p_s / C_d = 0.0000334003x - 0.000144683 \tag{253}$$

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[459] CLEAResult, *"Commercial Door Air Infiltration Memo"*. March 18, 2015. Average reduction based on the preliminary test results from the CLEAResult Brush Weather Stripping Testing Method & Results (59% infiltration reduction) averaged with the 98% infiltration reduction claimed by brush sweep manufacturing companies.

[460] *2013 ASHRAE Handbook of Fundamentals;* Equation 33, pp. 16, 11.

[461] ASHRAE Cooling and H eating Load Calculation Manual, p. 5.8. 1980. http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf.

[462] Cho, H., K. Gowri, & B. Liu, "Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements: Modeling of Air Infiltration through Door Openings." November 2010. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf.

Where C_d is an assumed constant, 0.63, and the neutral pressure distance is 10 feet.

From Figure 5.2, $\Delta p_w/C_p$ is determined by applying a polynomial regression, which returns an equation for solving for the pressure difference due to wind, Δp_w. The curve fit for Figure 5.2 is shown below where x is the wind velocity based on TMY3 data.

$$\Delta p_w/C_p = 0.00047749x^2 - 0.00013041x$$

(254)

Where C_p is an assumed constant, 0.13 (average wind pressure coefficient from Table 5.5 from CHLCM).

This yields the total pressure difference across the door, Δp_{Total}:

$$\Delta p_{Total} = \Delta p_s + \Delta p_w$$

(255)

Solving for Δp_{Total} allows for the air infiltration rate per linear foot to be determined in Figure 5.13 (CHLCM). Applying a power regression analysis for each crack width represented in Figure 5.13 returns the equations listed below:

$$Q/P_{1/8"} = 41.572x^{0.512}$$

(256)

$$Q/P_{1/4"} = 81.913x^{0.5063}$$

(257)

$$Q/P_{1/2"} = 164.26x^{0.5086}$$

(258)

$$Q/P_{3/4"} = 246.58x^{0.5086}$$

(259)

These infiltration rates were further disaggregated based on TMY3 average monthly day and night conditions.

Derivation of Design and Average Outside Ambient Temperatures

Taking average daytime and nighttime outdoor temperature values, standard set points and setbacks for daytime and nighttime design cooling and heating will yield the temperature difference needed for the sensible heat equation:

$$\Delta T = T_{design} - T_{avg\ outside\ ambient}$$

(260)

Where:

T_{design} = Daytime and nighttime design temperatures, in °F (Table 333).
$T_{avg\ outside\ ambient}$ = Average outside ambient temperatures, specified by month in °F (Table 334)

Table 333: Daytime and Nighttime Design Temperatures

Temperature Description	**T_{Design} (°F)**
Daytime Cooling Design Temperature	74
Daytime Heating Design Temperature	72
Nighttime Cooling Design Temperature (assuming 4 degree setback)	78
Nighttime Heating Design Temperature (assuming 4 degree setback)	68

Table 334: Average Monthly Ambient Temperatures[463]

Month	**Zone 9 Rogers**		**Zone 8 Fort Smith**		**Zone 7 Little Rock**		**Zone 6 El Dorado**	
	Day	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
	T_{avg} (°F)	**T_{avg} (°F)**	**T_{avg} (°F)**	**T_{avg} (°F)**	**T_{avg} (°F)**	**T_{avg} (°F)**	**T_{avg} (°F)**	**T_{avg} (°F)**
Jan	35.6	30.6	38.8	32.6	39.4	34.2	45.2	39.7
Feb	45.3	36.7	40.8	33.8	50.0	42.3	49.1	38.6
Mar	45.5	37.5	56.9	46.2	56.3	48.0	65.8	54.7
April	60.0	50.1	64.4	55.1	67.3	57.3	71.2	57.3
May	70.5	59.7	73.9	64.0	74.6	65.3	80.2	69.6
Jun	80.9	70.4	83.6	71.4	84.4	73.1	84.8	72.9
July	82.9	72.3	86.9	76.2	87.1	76.0	85.7	74.2
Aug	88.4	76.1	85.8	73.7	87.0	75.4	95.8	77.7
Sept	79.1	67.9	82.2	69.6	79.9	69.7	85.0	72.3
Oct	61.1	51.5	66.8	54.4	67.6	56.5	67.3	52.4
Nov	50.8	45.2	56.4	48.1	57.4	49.5	59.5	51.7
Dec	45.9	40.1	44.4	35.3	45.4	38.7	47.0	38.5

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[463] National Solar Radiation Database; 1991-2005 Update: TMY3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.

Deemed Savings[464]

Table 335: Door Sweeps – Deemed Electric Cooling Energy Savings Values (kWh per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	1/4	1/2	3/4
Zone 9: Rogers	2.73	5.54	10.99	16.49
Zone 8: Fort Smith	3.34	6.78	13.43	20.16
Zone 7: Little Rock	3.30	6.69	13.26	19.91
Zone 6: El Dorado	4.63	9.04	18.63	27.97

Table 336: Door Sweeps – Deemed Electric Resistance Heating Energy Savings Values (kWh per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	1/4	1/2	3/4
Zone 9: Rogers	125.19	253.13	502.35	754.10
Zone 8: Fort Smith	108.83	220.04	436.67	655.51
Zone 7: Little Rock	91.75	185.61	368.27	552.83
Zone 6: El Dorado	67.78	137.41	272.41	408.93

Table 337: Door Sweeps – Deemed Electric Heat Pump Heating Energy Savings Values (kWh per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	1/4	1/2	3/4
Zone 9: Rogers	37.94	76.71	152.23	228.51
Zone 8: Fort Smith	32.98	66.68	132.32	198.64
Zone 7: Little Rock	27.81	56.24	122.76	167.52
Zone 6: El Dorado	20.54	41.64	82.55	123.92

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[464] Used TMY3 data for Rogers, AR for Zone 9: Fayetteville.

Table 338: Door Sweeps – Deemed Electric Cooling Demand Savings Values (kW per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	**1/4**	**1/2**	**3/4**
Zone 9: Rogers	0.0022	0.0044	0.0087	0.0132
Zone 8: Fort Smith	0.0024	0.0049	0.0098	0.0147
Zone 7: Little Rock	0.0023	0.0047	0.0093	0.0140
Zone 6: El Dorado	0.0028	0.0055	0.0113	0.0170

Table 339: Door Sweeps – Deemed Gas Energy Savings Values (therms per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	**1/4**	**1/2**	**3/4**
Zone 9: Rogers	5.34	10.80	21.43	32.16
Zone 8: Fort Smith	4.64	9.38	18.62	27.96
Zone 7: Little Rock	3.91	7.92	15.71	23.58
Zone 6: El Dorado	2.89	5.86	11.62	17.44

Table 340: Door Sweeps – Deemed Gas Demand Savings Values (peak therms per linear foot)

Weather Zone	Gap Width (inches)			
	1/8	**1/4**	**1/2**	**3/4**
Zone 9: Rogers	0.0043	0.0086	0.0170	0.0256
Zone 8: Fort Smith	0.0054	0.0109	0.0216	0.0325
Zone 7: Little Rock	0.0049	0.0099	0.0196	0.0294
Zone 6: El Dorado	0.0052	0.0104	0.0207	0.0311

3.3 Domestic Hot Water

3.3.1 Water Heater Replacement

Measure Description[465]

This measure involves:

- The replacement of electric water heaters in commercial buildings by high efficiency electric resistance water heaters
- The replacement of electric water heaters in commercial buildings by heat pump water heaters
- The replacement of small (< 12 kW) electric water heaters in commercial buildings by electric tankless water heaters
- The replacement of gas water heaters in commercial buildings by high efficiency gas water heaters

Commercial water heater savings are measured per location and are calculated for new construction or replace-on-burnout. Storage tank models and tankless models, utilizing either electricity or natural gas, are eligible.

Baseline and Efficiency Standards

IECC 2003 and 2009 commercial standards specify the baseline and efficiency standards for this measure. These are detailed in Table 341. The 2003 IECC standard applies only in jurisdictions that have not yet adopted the 2009 IECC standard. Differences in performance requirements between IECC 2003 and 2009 standards have been noted where appropriate.

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[465] The previously filed version of the Arkansas TRM version contained separate measures for Commercial Water Heater Replacements and Water Heater Replacements for Converted Residences (3.35 in the initial filing). This version has combined the two measures, and Water Heater Replacements for Converted Residences is now empty.

Table 341: Commercial Water Heaters – Water Heater Performance Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[466,467]	Test Procedure
Storage water heaters, gas	≤ 75,000 Btu/hr	≥ 20 gal	IECC 2003: 0.62 - 0.0019V, EF	DOE 10 CFR Part 430
			IECC 2009: 0.67 - 0.0019V, EF	
	> 75,000 Btu/hr and ≤ 155,000 Btu/hr	< 4,000 Btu/hr/gal	80% E_t (Q/800 +110√V), SL (Btu/hr)	ANSI Z21.10.3
	> 155,000 Btu/hr	< 4,000 Btu/hr/gal	80% E_t (Q/800 +110√V), SL (Btu/hr)	
Tankless water heaters, gas	> 50,000 Btu /hr and < 200,000 Btu /hr [468]	≥ 4,000 (Btu/hr)/gal and < 2 gal	0.62 - 0.0019V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/hr	≥ 4,000 Btu /hr/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	> 200,000 Btu/hr	≥ 4,000 Btu/hr/gal and ≥ 10 gal	80% E_t (Q/800 +110√V), SL (Btu/hr)	
Water heaters, electric	≤ 12 kW	Resistance	IECC 2003: 0.93 - 0.00132V, EF	DOE 10 CFR Part 430
			IECC 2009: 0.97 - 0.00132V, EF	
	> 12 kW	Resistance	1.73V + 155, SL (Btu/hr)	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat Pump	0.93 - 0.00132V, EF	DOE 10 CFR Part 430

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[466] Energy factor (EF) and thermal efficiency (E_t) are minimum requirements. In the EF equation, V is the rated volume in gallons.

[467] Standby loss (SL) is the maximum Btu/hr based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, Q is the nameplate input rate in Btu/hr. In the SL equation for electric and gas water heaters and boilers, V is the rated volume in gallons.

[468] Tankless water heaters with input rates below 200,000 Btu/hr must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

For smaller water heaters where energy factor (EF) is used, EF takes into account the overall efficiency, including combustion efficiency and standby loss (SL). Regulated by DOE as "residential water heaters", these smaller water heaters manufactured on or after April 16, 2015 must comply with the amended standards found in the Code of Federal Regulations, 10 CFR 430.32(d), by April 16, 2015.

Table 342: "Residential Water Heater" Standards[469]

Product class	**Rated storage volume and input rating (if applicable)**	**Draw pattern**	**Uniform energy factor (EF)**
Gas-fired Storage Water Heater	≥ 20 gal and ≤ 55 gal	Very Small	0.3456 − (0.0020 × Vr)
		Low	0.5982 − (0.0019 × Vr)
		Medium	0.6483 − (0.0017 × Vr)
		High	0.6920 − (0.0013 × Vr)
	> 55 gal and ≤ 100 gal	Very Small	0.6470 − (0.0006 × Vr)
		Low	0.7689 − (0.0005 × Vr)
		Medium	0.7897 − (0.0004 × Vr)
		High	0.8072 − (0.0003 × Vr)
Oil-fired Storage Water Heater	≤ 50 gal	Very Small	0.2509 − (0.0012 × Vr)
		Low	0.5330 − (0.0016 × Vr)
		Medium	0.6078 − (0.0016 × Vr)
		High	0.6815 − (0.0014 × Vr)
Electric Storage Water Heaters	≥ 20 gal and ≤ 55 gal	Very Small	0.8808 − (0.0008 × Vr)
		Low	0.9254 − (0.0003 × Vr)
		Medium	0.9307 − (0.0002 × Vr)
		High	0.9349 − (0.0001 × Vr)
	> 55 gal and ≤ 120 gal	Very Small	1.9236 − (0.0011 × Vr)
		Low	2.0440 − (0.0011 × Vr)
		Medium	2.1171 − (0.0011 × Vr)
		High	2.2418 − (0.0011 × Vr)
	≥ 20 gal and ≤ 120	Very Small	0.6323 − (0.0058 × Vr)

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[469] https://energy.gov/energysaver/sizing-new-water-heater. Accessed August 7, 2017

Product class	**Rated storage volume and input rating (if applicable)**	**Draw pattern**	**Uniform energy factor (EF)**
Tabletop Water Heater		Low	0.9188 − (0.0031 × Vr)
		Medium	0.9577 − (0.0023 × Vr)
		High	0.9884 − (0.0016 × Vr)
Instantaneous Gas-fired Water Heater	< 2 gal and > 50,000 Btu/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92
Grid-Enabled Water Heater	>75 gal	Very Small	1.0136 − (0.0028 × Vr)
		Low	0.9984 − (0.0014 × Vr)
		Medium	0.9853 − (0.0010 × Vr)
		High	0.9720 − (0.0007 × Vr)

The new code requires that a draw pattern be determined in order to calculate the correct energy factor. The draw pattern is calculated based on the first hour rating (FHR) of the installed water heater, and is defined as the number of gallons of hot water the heater can supply per hour. [470]

Table 343, Table 344 and Table 345 provide the FHR ranges and corresponding draw pattern designation.

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[470] https://energy.gov/energysaver/sizing-new-water-heater. Accessed August 7, 2017

Table 343: Tank Water Heater Draw Pattern[471]

New FHR greater than or equal to:	and new FHR less than:	Draw pattern
0 gallons	18 gallons	Very Small
18 gallons	51 gallons	Low
51 gallons	75 gallons	Medium
75 gallons	No upper limit	High

Table 344: Instantaneous Water Heater Draw Pattern[472]

New max GPM greater than or equal to:	And new max GPM rating less than:	Draw pattern
0 gallons/minute	1.7 gallons/minute	Very Small
1.7 gallons/minute	2.8 gallons/minute	Low
2.8 gallons/minute	4 gallons/minute	Medium
4 gallons/minute	No upper limit	High

Table 345: Heat Pump Water Heater Draw Pattern[473]

Draw pattern	DV
Very Small	10 gallons
Low	38 gallons
Medium	55 gallons
High	84 gallons

For larger water heaters, thermal efficiency (E_t) is used and does not factor into SL; however, a limitation on SL is noted.

The savings calculations consider the minimum water heater efficiency requirements listed in Table 341 to be the baseline.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is dependent on the type of water heating. According to DEER 2008, the following measure lifetimes should be applied.[474]

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[471] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

[472] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

[473] https://www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. Accessed August 7, 2017

[474] http://www.deeresources.com/files/deer2008exante/downloads/EUL_Summary_10-1-08.xls

- 10 years for Heat Pump Water Heater (HPWH)
- 15 years for High Efficiency Commercial Storage Water Heater
- 20 years for Commercial Tankless Water Heater

Calculation of Deemed Savings

Typically, two types of ratings exist for water heaters: energy factor (EF) for smaller units, and thermal efficiency (E_t) for larger water heaters. Large heat pump water heaters may also be rated by a third method, coefficient of performance (COP), which is the ratio of heat energy output to electrical energy input, and is analogous to thermal efficiency. EF includes standby losses, while E_t and COP only consider the amount of energy required to heat the water. Therefore, in the formulas below, the baseline and energy efficiency measure may be compared for each type of water heater.

The electricity and natural gas savings for this measure are highly dependent on the estimated hot water consumption, which varies significantly by building type. The following tables list estimated hot water consumption for various building types by number of units, occupants, or building size.

Table 346: Hot Water Requirements by Building Type[475]

Building Type	Daily Demand (Gallons/nit/ Day)	Unit	Units/ 1,000 ft^2	Applicable Days/Year	Gallons/ 1,000 ft^2/day
Small Office	1	person	2.3	250	2.3
Large Office	1	person	2.3	250	2.3
Fast Food Restaurant	0.7	meal/day	784.6	365	549.2
Sit-Down Restaurant	2.4	meal/day	340	365	816.0
Retail	2	employee	1	365	2.0
Grocery	2	employee	1.1	365	2.2
Warehouse	2	employee	0.5	250	1.0
Elementary School	0.6	person	9.5	200	5.7
Jr. High/ High School	1.8	person	9.5	200	17.1
Health	90	patient	3.8	365	342.0
Motel	20	unit(room)	5	365	100.0
Hotel	14	unit(room)	2.2	365	30.8
Other	1	employee	0.7	250	0.7

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[475] Osman S, & Koomey, J. G J1995, National Laboratory 1995. *Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting.* December.

Table 347: Hot Water Requirements by Unit or Person[476,477,478]

Building Type	**Size Factor**	**Average Daily Demand**
Commercial/Industrial Laundry Facility	Pounds of Laundry	2.0 Gallons per pound
Dormitories	Men	13.1 Gallons per man
	Women	12.3 Gallons per woman
Hospitals	Per Bed	90.0 Gallons per patient
Hotels	Single Room with Bath	50.0 Gallons per unit
	Double Room with Bath	80.0 Gallons per unit
Laundromat	Pounds of Laundry	0.56 Gallons per pound
Motels	No. of Units:	
	Up to 20	20.0 Gallons per unit
	21 to 100	14.0 Gallons per unit
	101 and up	10.0 Gallons per unit
Nursing Homes		18.4 Gallons per bed
Restaurants	Full Meal Type	2.4 Gallons per meal
	Drive-in Snack Type	0.7 Gallons per meal
Schools	Elementary	0.6 Gallons per student
	Secondary and High School	1.8 Gallons per student

Table 348: Average Supply (Water Main) Temperature[479]

Weather Zone	**Average Water Main Temperature (°F)**
9 Rogers[480]	65.6
8 Fort Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

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[476] Figure for Commercial/Industrial laundry facilities from Sacramento M.U.D. at http://smud.apogee.net/comsuite/content/ces/?utilid=smud&id=1031.

[477] Figure for laundromats calculated from Report on the Monitoring and Assessment of Water Savings from the Coin-operated Multi-load Clothes Washers Voucher Initiative Program at http://www.allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=742.

[478] All other figures come from TEXAS LoanSTAR PROGRAM GUIDEBOOK VOLUME II. 2002

[479] Water main temperature data were approximated using an algorithm (Burch, J., Christensen, C.) 2007. "Towards Development of an Algorithm for Mains Water Temperature." Proceedings of the 2007 ASES Annual Conference, Cleveland, OH.

[480] Data for Zone 9 used Fayetteville, AR.

Small Electric Storage Water Heaters

As small (≤ 12 kW) electric water heaters are typically rated by EF, this section of this measure includes both higher-efficiency resistance water heaters and small (≤ 24 amps and ≤ 250 volts) heat pump water heaters. Deemed annual energy savings for small electric water heater replacements are calculated by formulas as follows:

$$kWh_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right) \times Days/Year}{3{,}412\ Btu/kWh}$$

(261)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb °F

GPD = Average daily hot water use (gallons). See Table 346 and Table 347 for estimates of water consumption

$T_{SetPoint}$ = Water heater set point; if unavailable, use 120 °F

$\boldsymbol{T_{Supply}}$ = Water-Main temperature; Table 348

EF_{pre} = Calculated energy factor of existing water heater, based on the water heater tank volume; Table 342

V_{Tank} = Volume of tank (gallons).

EF_{post} = Energy Factor of replacement water heater (taken from nameplate); the replacement water heater may be either a high efficiency electric storage water heater or a heat pump water heater

$\boldsymbol{Days/year}$ = Days of operation per year; appropriate values by building type are provided in Table 346; however, if using hot water requirements from Table 347, use 365 days

Deemed demand savings for small electric water heater replacements are calculated by formula as follows:

$$kW_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{3{,}412\ Btu/kWh} \times 1/24$$

(262)

Where all variables are the same as in the energy equation and the 1/24 ratio is a best estimate of peak coincidence for commercial hot water heater replacements.[481]

Large Electric Storage Water Heaters

Large (> 12 kW) electric resistance water heaters can be replaced with heat pump water heaters.

For replacement of large electric resistance water heaters with a heat pump water heater, deemed annual energy savings are calculated by the following formula:

$$kWh_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{Setoint} - T_{Supply}\right) \times \left(\frac{1}{E_{t,base}} - \frac{1}{COP_{post}}\right) \times Days/Year}{3{,}412\ Btu/kWh}$$

(263)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb·°F

$\boldsymbol{GPD}$ = Average daily hot water use (gallons per day); see Table 346 and Table 347 for estimates of water consumption

$T_{SetPoint}$ = Water heater set point, if unavailable, use 120°F

$\boldsymbol{T_{Supply}}$ = Water-Main temperature, see Table 348

$\boldsymbol{E_{t,base}}$ = 0.98

COP_{post} = Coefficient of performance of new heat pump water heater

$\boldsymbol{Days/Year}$ = Days of operation per year; appropriate values by building type are provided in Table 346; however, if using hot water requirements from Table 347, use 365 days

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[481] For replacement with high-efficiency electric storage water heaters and tankless water heaters, the 1/24 peak coincidence factor accurately reflects that improvements in the efficiency of electric resistance storage water heaters are driven almost entirely by reductions in storage losses (conversion efficiency, RE, is close to 1), which are distributed evenly throughout the day.

Deemed demand savings for replacement of large electric resistance water heaters with a heat pump water heater are calculated by the following formula:

$$kW_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{E_{t,base}} - \frac{1}{COP_{post}}\right)}{3{,}412\ Btu/kWh}\ x\ 1/24$$

(264)

Where all variables are the same as in the annual energy savings equation and 1/24 represents the fraction of daily hot water use that occurs during the peak hour.

Natural Gas Storage Water Heaters

Deemed annual natural gas savings for high-efficiency natural gas water heaters should be calculated by the formulas listed below. Two types of ratings exist for gas water heaters: energy factor (EF), which includes standby losses, for water heaters rated ≤ 75,000 Btu/h and thermal efficiency (E_t), which only includes the energy required to heat the water for water heaters larger than 75,000 Btu/hr. When making comparisons or savings estimations, only similarly rated systems can be directly compared. The following equations apply to replacement of a natural gas storage water heater with a higher efficiency gas storage water heater or a gas tankless water heater.

Deemed annual gas savings for natural gas water heaters up to 75,000 Btu/h should be calculated by the following formulas:

$$Therms_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{base}} - \frac{1}{EF_{post}}\right) \times Days/Year}{100{,}000\ Btu/therm}$$

(265)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb °F

$\boldsymbol{GPD}$ = Average daily hot water use (gallons per day); see Table 346 and Table 347 for estimates of water consumption

V_{Tank} = Volume of tank (gallons)

$T_{SetPint}$= Water heater set point; if unavailable, use 120°F

T_{Supply}= Water-Main temperature, see Table 348

$Days/Year$ = Days of operation per year; appropriate values by building type are provided in Table 346; however, if using hot water requirements from Table 347, use 365 days

Deemed peak day gas savings for natural gas water heaters ≤ 75,000 Btu/h should be calculated by the following formula:

$$Peak\ Day\ Therm_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{base}} - \frac{1}{EF_{post}}\right)}{100{,}000\ Btu/therm}$$

(266)

Where all variables are the same as in the formula for deemed annual gas savings for natural gas water heaters up to 75,000 Btu/h.

Deemed annual energy savings for natural gas water heaters larger than 75,000 Btu/hr (rating in E_t) should be calculated by the following formulas:

$$Therm_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{E_{t,base}} - \frac{1}{E_{t,post}}\right) \times Days/Year}{100{,}000\ Btu/therm}$$

(267)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb °F

GPD = Average daily hot water use (gallons per day); see Table 346 and Table 347 for estimates of water consumption

$T_{SetPoint}$ = Water heater set point; if unavailable, use 120°F

T_{Supply} = Water-Main temperature; see Table 348

$E_{t,base}$ = 80% per Table 341

$E_{t,post}$ = Thermal efficiency of new water heater

$Days/Year$ = Days of operation per year; see Table 346; or if using values from Table 347, use 365 days

Deemed peak day savings for natural gas water heaters larger than 75,000 Btu/hr (rating in E_t) should be calculated by the following formulas:

$$Peak\ Day\ Therm_{Savings} = \frac{\rho \times C_P \times GPD \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{E_{t,base}} - \frac{1}{E_{t,post}}\right)}{100{,}000\ Btu/therm}$$

(268)

Where all variables are the same as in the formula for deemed annual gas savings for natural gas water heaters ≥ 75,000 Btu/h. For large gas water heaters, additional gas savings can be achieved by replacing a water heater with one having lower standby losses. The deemed savings can be calculated using the following equation:

$$Therms_{Savings} = \frac{(SL_{base} - SL_{post})x\ 8{,}760\ hrs/yr}{100{,}000\ Btu/therm}$$

(269)

Where:

SL_{base} = Q/800 + 110√V where Q = nameplate input rating (Btu/hr)

SL_{post} = nameplate standby loss of new water heater (Btu/hr)

Associated additional peak day gas savings can be calculated using the following equation:

$$Peak\ Day\ Therm_{Savings} = \frac{(SL_{base} - SL_{post})}{100{,}000\ Btu/therm}$$

(270)

Where SL_{base} and SL_{post} have the same definition as in the preceding formula.

3.3.2 Faucet Aerators

Measure Description

This measure consists of installing low-flow faucet aerators in commercial facilities which reduce water usage and save energy associated with heating the water.

Baseline & Efficiency Standard

The savings values for low-flow faucet aerators are for the retrofit of existing operational faucet aerators with a flow rate of 2.2 gallons per minute or higher. Facilities that use both gas and electric water heaters are eligible for this measure.

The baseline faucet aerators are assumed to have a flow rate of 2.2 gallons per minute.[482] To qualify for this measure, the flow rate of installed low-flow faucet aerators must be at most 1.5 gallon per minute.[483]

Estimated Useful Life (EUL)

The estimated useful life (EUL) for this measure is 10 years.[484]

Deemed Savings Values

Annual gas savings and peak day gas savings can be calculated by using the following equations.

$$\Delta Therms = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times Days/Year}{100{,}000\ Btu/therm}$$

(271)

$$\Delta Peak\ Therms = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times P}{100{,}000\ Btu/therm}$$

(272)

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[482] Maximum flow rate federal standard for lavatories and aerators set in Federal Energy Policy Act of 1992 and codified at 2.2 GPM at 60 psi in 10CFR430.32.

[483] http://www.epa.gov/watersense/partners/faucets_final.html

[484] Database for Energy Efficiency Resources, 2008.

Annual kWh electric and peak kW savings can be calculated using the following equations:

$$\Delta kWh = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times Days/Year}{3{,}412\ Btu/kWh}$$

(273)

$$\Delta kW = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times P}{3{,}412\ Btu/kWh}$$

(274)

Table 349. Parameters for Annual Energy and Peak Demand Savings Calculations

Parameter	Description	Value
F_B	Average baseline flow rate of aerator (GPM)	2.2
F_P	Average post measure flow rate of aerator (GPM)	≤ 1.5
Days/Year	Annual building type operating days for the applications: 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 365[485] 365 274[486] 365 365 250 200
T_{supply}	Average supply (cold) water temperature (ºF) from Table 348	Zone 9: 65.6 Zone 8: 66.1 Zone 7: 67.8 Zone 6: 70.1
T_H	Average mixed water (after aerator) temperature (ºF)	105[487]

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[485] Sezgen, O. &. Koomey, J.. Lawrence Berkeley National Laboratory 1995. *Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting*. December 1995.

[486] Dormitories with few occupants in the summer: 365 x (9/12) = 274.

[487] ASHRAE Handbook 2011. HVAC Applications. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE), Inc., Atlanta, GA.

Parameter	Description	Value
U	Baseline water usage duration, following applications [488] 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 30 min/day/unit 3.0 min/day/unit 30 min/day/unit 3.0 min/day/unit 3.0 min/day/unit 30 min/day/unit 30 min/day/unit
ρ	Unit conversion: 8.33 pounds/gallon	8.33
Cp	Heat capacity of water – 1 Btu/lb °F	1
E_t	Thermal Efficiency of water heater	Default values: 0.98 for electric resistance 2.2 (COP) for heat pump, 0.80[489] for gas
P	Hourly water consumption during peak period as a fraction of average daily consumption for applications: [490] 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 0.04 0.03 0.04 0.03 0.02 0.08 0.05

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[488] Three minutes per day of usage is assumed for private lavatories used in multifamily, hotel guest rooms, hospital patient rooms, nursing homes; Connecticut UI and CLP Program Savings Documentation, September 25, 2009 uses assumption of three faucets per household and one minute per faucet; 30 minutes per day faucet use for commercial lavatories from Federal Energy Management Program Energy Cost Calculator for Faucets and Showerheads, default for aerators in commercial applications.

[489] Default values based on median thermal efficiency of commercial water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/cwh/defaultSearch.aspx

[490] Derived from *ASHRAE Handbook 2011. HVAC Applications.* American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The peak factor is the ratio of the gallons of hot water used during the peak times of 3pm to 6pm, to the total amount of hot water used during the day. This factor was derived by facility type, and is the same regardless of water heater fuel.

The following are gas and electric example calculations for a 1.0 GPM aerator replacement for a school in Weather Zone 9 (e.g. Fayetteville) using the previous equations and information. Example electric savings are based on heating water with a conventional electric resistance storage tank water heater.

$$\Delta Therms = \frac{8.33\ x\ 30\frac{min}{day}\ x\ [2.2 - 1.0]GPM\ x\ (105 - 65.6°\text{F})x\ \left(\frac{1}{0.8}\right)\ x\ \frac{200day}{year}}{100{,}000\ Btu/therm}$$

$$= 29.5\ therms$$

(275)

$$\Delta Peak\ Therms = \frac{8.33\ x\ 30\frac{min}{day}\ x\ [2.2 - 1.0]GPM\ x\ (105 - 65.6°\text{F})\ x\ \left(\frac{1}{0.8}\right) x\ 0.05}{100{,}000\ Btu/therm}$$

$$= 0.007\ therms/day$$

(276)

$$\Delta kWh = \frac{8.33\ x\ 30\frac{min}{day}\ x\ [2.2 - 1.0]GPM\ x\ (105 - 65.6°\text{F})\ x\frac{200day}{year}\ x\ \left(\frac{1}{0.98}\right)}{3412\ Btu/kWh}$$

$$= 707\ kWh$$

(277)

$$\Delta kW = \frac{8.33\ x\ 30\frac{min}{day}\ x\ [2.2 - 1.0]GPM\ x\ (105 - 65.6°\text{F})\ x\frac{1}{0.98}\ x\ 0.05}{3412\ Btu/kWh}$$

$$= 0.17\ kW$$

(278)

3.3.3 Water Heater Jackets

Measure Description

This measure involves the installation of water heater jackets (WHJ) on water heaters located in an unconditioned space in small commercial settings. These estimates apply to all weather regions.

Baseline and Efficiency Standards

The baseline is assumed to be a post-1991, storage-type water heater with no water heater jacket and manufactured R-value of six sq. ft. °F/Btu.

Water heater jackets must have a minimum fiberglass insulation thickness of 2 inches (R-value of approximately 6.6 h sq. ft. °F/Btu) and must be installed on storage water heaters having a capacity of 30 gallons or greater. Manufacturer's instructions on the water heater jacket and the water heater itself should be followed. If the water heater is electric, thermostat and heating element access panels must be left uncovered. If the water heater is a heat pump water heater, air intake and exhaust apertures must not be inhibited in any way. If it is gas, the water heater jacket installation instructions regarding combustion air and flue access must be followed.

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is seven years, according to DEER 2008.

Calculation of Deemed Savings

Energy Savings

Water heater jackets reduce water heater storage tank shell loss, bringing about savings which are calculated as follows:

$$Shell\ Loss\ Savings = \left(U_{pre} - U_{post}\right) \times A \times (T_{Water} - T_{ambient}) \times \left(\frac{1}{E_t}\right) \times \frac{Hours_{Total}}{conversion\ factor}$$

(279)

Where:

Shell Loss Savings = Annual energy savings in kWh/yr. for electric and therms/yr. for gas water heaters

U_{pre} = 1/(R-value of tank manufacturer's original insulation) Btu/hr sq. ft. °F

U_{post} = 1/(R-value of tank manufacturer's original insulation plus R value of water jacket)

A = Surface area in square feet (for a cylinder = $2\pi rh + \pi r^2$) where r = radius of the tank; see Table 350

T_{water}(°F) = Storage tank water temperature; if unknown, use 120°F

$T_{ambient}$ (°F) = For water heaters not installed in conditioned space, use the values in Table 351

E_t = Thermal efficiency (or in the case of heat pumps, COP)

$Hours_{Total}$ = 8,760 hr per year [491,492]

$Conversion\ factor$ = For electric water heating: 3,412 Btu/kWh; for gas water heating: 100,000 Btu/therm

Table 350: Approximate Surface Areas of Cylindrical Tanks

Tank Size (gallons)	Height (feet)	Radius (feet)	Surface Area (square feet) [493]
30 tall	4.67	0.67	20.94
30 short	2.50	0.92	17.04
40	4.67	0.75	23.76
50	4.75	0.83	27.05
75	4.92	1.00	34.03
100	5.38	1.18	44.11

Table 351: Average Ambient Temperature by Weather Zone

Weather Zone	Average Ambient Temperature (°F)
9 Fayetteville	59.6
8 Fort Smith	60.1
7 Little Rock	61.8
6 El Dorado	64.1

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[491] Ontario Energy's Measures and Assumptions for Demand Side Management (DSM) Planning http://www.ontarioenergyboard.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[492] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Residential, Multi-Family, and Commercial/Industrial Measures http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/NY_Standard_Approach_for_Estimating_Energy_Savings_12-08.pdf

[493] Note: Bottom of tank is not affected by measure so that area is not included in the surface area calculation.

Example: A 2-inch-thick fiberglass insulating jacket is installed on a 50-gallon electric water heater in Weather Zone 9 (e.g. Fayetteville).

R value before = 6

R value after = 12.6

Surface Area of tank = 27 sq. ft.

$T_{ambient}$ = 59.6 and T_{Water} =120°F

E_t = 0.98

$$Shell\ Loss\ Savings = (0.1667 - 0.0793) \times 27 \times (120 - 59.6) \times 8760 \times \frac{\frac{1}{0.98}}{3412}$$
$$= 373\ kWh/yr$$

Demand Savings

Demand savings were calculated using the following formula for electric:

$$Demand\ Shell\ Loss\ Savings\ (kW)$$
$$= \left(U_{pre} - U_{post}\right) \times A \times (T_{Water} - T_{ambientMAX}) \times \left(\frac{1}{E_t}\right) \times 3{,}412\ Btu/kWh$$

(280)

Where:

U_{pre} = 1/(R-value of tank manufacturer's original insulation) Btu/hr sq. ft. F°

U_{post} = 1/(R-value of tank manufacturer's original insulation plus water jacket)

A = Surface area in square feet (for a cylinder = $2\pi rh + \pi r^2$); see Table 350

T_{water} (°F) = Storage tank water temperature. If unknown, use 120°F

$T_{ambientMAX}$ (°F) =Use the maximum annual ambient temperatures in Table 352

E_t = Thermal Efficiency (or in the case of heat pumps, COP)

$Conversion\ Factor$ = 3,412 Btu/kWh

Table 352: Maximum and Minimum Temperatures per Weather Zone

Weather Zone	Ambient Temperature (°F)	
	Unconditioned Space	
	Maximum	Minimum
9 Fayetteville	101	4.3
8 Fort Smith	101	13.5
7 Little Rock	97	12.1
6 El Dorado	107	27.8

For gas, peak day demand savings were calculated using the following formula:

$$Demand\ Shell\ Loss\ Savings\ (therms/day) = \left(U_{pre} - U_{post}\right) \times A \times (T_{Water} - T_{ambientMIN}) \times \left(\frac{1}{E_t}\right) \times 100{,}000\ Btu/therm \times 24hrs/day$$

(281)

Where:

U_{pre} = 1/(R-value of tank manufacturer’s original insulation) Btu/hr sq. ft. F°

U_{post} = 1/(R-value of tank manufacturer’s original insulation plus water jacket)

A = Surface area in square feet (for a cylinder = $2\pi rh + \pi r^2$); see Table 350

T_{water} (°F) = Storage tank water temperature; if unknown, use 120 °F

$T_{ambientMIN}$ (°F) = Use the minimum annual ambient temperatures in Table 352

E_t =Thermal efficiency; if unknown, use 0.8 as a default (Not to be confused with the Energy Factor (EF))

Conversion Factor = 100,000 Btu/therm

3.3.4 Water Heater Pipe Insulation

Measure Description

This measure consists of installing water heater pipe insulation exceeding the IECC mandated standard (0.5-inch of insulation that delivers an R-value of at least 3.7 per inch) over at least the first 8 feet of exposed pipe in small commercial settings. Water heaters plumbed with heat traps or automatic-circulating systems are not eligible to receive incentives for this measure.[494]

Baseline and Efficiency Standards

Baseline insulation is R = 1.85 sq. ft. h °F/Btu, the mandated standard since IECC 2000.

Estimated Useful Life

The estimated useful life (EUL) of this measure is the remaining service life of the water heater.

Calculation of Deemed Savings

Energy Savings

Hot water pipe insulation energy savings are calculated using the following formula:

$$Annual\ Energy\ Savings = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient}\right) \times \left(\frac{1}{E_t}\right) \times \frac{Hours_{Total}}{Conversion\ factor}$$

(282)

Where:

U_{pre} = 1/(2.03[495]+1.85) = 0.26 Btu/hr sq. ft. °F

U_{post} = 1/(1.85+2.03+$R_{Additional}$)

$R_{Additional}$ = R-value of additional insulation that exceeds IECC standard

A = Surface Area in square feet (πDL) with L (length) and D pipe diameter in feet

T_{Pipe}(°F) = Average temperature of the pipe; default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambient}$(°F) = For water heaters not installed in conditioned space, use the values in Table 353; for water heaters inside the building envelope, use an average ambient temperature of 75 °F

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[494] A survey of several large online home-improvement retailers shows three general classes of commercially available pipe insulation: one around R-2.3 (typically 5/8" thick foam), another around R-3 (typically 1/2" thick rubber) and lastly high-end insulation in the R-6 to R-7 range (1" thick rubber).

[495] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe and between the surface and air. *Mark's Standard Handbook for Mechanical Engineers, 8th edition.*

E_t = Thermal efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric water heaters, 2.2 for a heat pump water heater, or 0.8 for natural gas water heaters.[496]

$Hours_{Total}$ = 8,760 hr per year [497,498]

$Conversion\ factor$ = For electric water heating: 3,412 Btu/kWh; for gas water heating: 100,000 Btu/therm

Table 353: Average Ambient Temperature by Weather Zone

Weather Zone	Average Ambient Temperature (°F)
9 Fayetteville	59.6
8 Fort Smith	60.1
7 Little Rock	61.8
6 El Dorado	64.1

Demand Savings

Electric peak demand savings for hot water heaters installed in conditioned space is calculated using the following formula:

$$Demand\ Savings\ (kW) = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambientMAX}\right) \times \left(\frac{1}{E_t}\right) \times 1/conversion\ factor \tag{283}$$

Where:

U_{pre} = 1/(2.03[499]+1.85) = 0.26 Btu/hr sq. ft. degree F

U_{post} = 1/(1.85+2.03+$R_{Additional}$)

$R_{Additional}$ = R-value of additional insulation that exceeds IECC standard

A = Surface area in square feet (πDL) with L (length) and D pipe diameter in feet

T_{Pipe}(°F) = Average temperature of the pipe. Default value = 90 °F (average temperature of pipe between water heater and the wall)

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[496] Default values based on median thermal efficiency of commercial water heaters by fuel type in the AHRI database, at https://www.ahridirectory.org/ahridirectory/pages/cwh/defaultSearch.aspx

[497] Ontario Energy's Measures and Assumptions for Demand Side Management (DSM) Planning http://www.ontarioenergyboard.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[498] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs Residential, Multi-Family, and Commercial/Industrial Measures http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/NY_Standard_Approach_for_Estimating_Energy_Savings_12-08.pdf

$T_{ambientMAX}$ (°F) =For water heaters not installed in conditioned space, no savings can be claimed; for water heaters inside the building envelope, use an average ambient temperature of 78 °F

E_t =Thermal efficiency (or in the case of heat pump water heater, COP); if unknown, use 0.98 as a default or 2.2 for a heat pump water heater

$Conversion\ Factor$ = 3,412 Btu/kWh

Table 354: Maximum and Minimum Temperatures per Weather Zone

Weather Zone	**Ambient Temperature (°F)**			
	T			

Weather Zone	**Ambient Temperature (°F)**			
	$T_{ambientMAX}$ (Electric)		**$T_{ambientMIN}$ (Gas)**	
	Conditioned Space	**Unconditioned Space**	**Conditioned Space**	**Unconditioned Space**
9 Fayetteville	78	Not Applicable	70	4.3
8 Fort Smith				13.5
7 Little Rock				12.1
6 El Dorado				27.8

For gas, peak day demand savings were calculated using the following formula:

$$Demand\ Pipe\ Insulation\ Savings\ (Therms/day) = (U_{pre} - U_{post}) \times A \times (T_{Pipe} - T_{ambientMIN}) \times \left(\frac{1}{E_t}\right) \times \frac{1}{Conversion\ factor} \times 24\ hr/day \quad \textbf{(284)}$$

Where:

U_{pre} = 1/(2.03 + 1.85)

U_{post} = 1/(1.85 + 2.03 + $R_{Additional}$)

$R_{Additional}$ = R-value of additional insulation that exceeds IECC standard

A = Surface area in square feet (for a length of pipe = $2\pi rL$) with L and r in feet

T_{Pipe} (°F) =Average temperature of the pipe; default value = 90 °F (average temperature of pipe between water heater and the wall)

$T_{ambientMIN}$ (°F) =For water heaters not installed in conditioned space, use the minimum annual ambient temperatures in Table 354; for water heaters inside the building envelope, use an average ambient temperature of 70 °F

E_t = Thermal efficiency; if unknown, use 0.8 as a default (Not to be confused with the Energy Factor (EF))

$Conversion\ factor$ = 100,000 Btu/therm

For example, energy savings for water heater pipe insulation adding an additional 1.85 R-value on a conventional electric resistance storage water heater in Weather Zone 8 (e.g. Fort Smith) in an unconditioned space would be:

U_{pre} = 0.26

$R_{Additional}$= 1.85

U_{post} = 0.17

Pipe Length = 8 feet

Pipe diameter = 1 inch

A = 2.1 sq ft (Pipe surface area$= 2\pi rL$)

T_{ambient}(°F) = 60.1 degrees F

T_{Pipe}(°F) = 90 degrees F

E_t = 98%

kWh per year = 14.8 kWh

kW = 0, since no peak savings are available on hot water heaters in unconditioned space for electric.

3.3.5 Low-Flow Showerheads

Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads at the following commercial building types: hospitals and nursing homes, lodging facilities, commercial facilities (offices or other commercial buildings in which showers are provided for employees), fitness centers, and schools.[500]

Baseline and Efficiency Standards

The savings values for low-flow showerheads are for the retrofit of existing operational showerheads with a flow rate of 2.5 gallons per minute (GPM) or higher.[501] Facilities that use both gas and electric water heaters are eligible for this measure.

The baseline showerhead has an average flow rate of 2.5 GPM based on the current DOE standard. To qualify for the deemed savings, replacement showerheads must have a flow rate of 2.0 GPM or less.[502]

Additional Requirement for Contractor-Installed Showerheads

Existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. Low-flow shower heads that are easily tampered with should not be used. Removed showerheads shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Table 355: Low-Flow Showerhead – Baseline and Efficiency Standards

Measure	New Showerhead Flow Rate [503]	Existing Showerhead Baseline Flow Rate
2.0 gpm showerhead	2.0 gpm	2.5 gpm
1.75 gpm showerhead	1.75 gpm	2.5 gpm
1.5 gpm showerhead	1.5 gpm	2.5 gpm

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[500] This measure draws from multiple sources, including the residential low flow showerhead measure and commercial faucet aerator measure. Information specific to hot water use in commercial market sectors was drawn from CLEAResult, Inc. draft white paper: *Work Papers for Low Flow Shower Heads with Gas or Electric Water Heaters: Savings Calculation Methodology for Application in Arkansas Energy Efficiency Programs*, February 2014.

[501] 10 CFR Part 430, Energy Conservation Program for Consumer Products: Test Procedures and Certification and Enforcement Requirements for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances; Final Rule, March 1998. Online.Available: http://www.regulations.gov/#!documentDetail;D=EERE-2006-TP-0086-0003.

[502] The U.S. Environmental Protection Agency (EPA) WaterSense Program has a thorough specification for showerheads that meet a maximum flow rate of 2.0 gpm. The specification is available on the EPA website at: www.epa.gov/WaterSense/partners/showerhead_spec.html

[503] All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

Estimated Useful Life (EUL)

The estimated useful life (EUL) of this measure is 10 years.[504]

Deemed Savings Calculations

Energy and demand savings are estimated as functions of the reduction in daily water use (ΔV) attributable to installation of low flow showerheads in a given commercial building type. Reduction in water use and deemed savings calculations make use of the data provided by building type in Table 356 and by weather zone in Table 357

Table 356: Showers per Day (per Showerhead) and Days of Operation by Building Type

Building Type	N	Days/Year
Hospital/Nursing Home	0.89	365
Hospitality	1.25	365
Commercial	0.97	250
Fitness Center	19.94	365
School	1.32	200

Table 357: Average Inlet Water Temperature (T_{supply}) and Hot Water Fraction (F_{HW}) by Weather Zone

Weather Zone	T_{supply} (°F)	F_{HW} (%)
9 Fayetteville	65.6	72.4%
8 Fort Smith	66.1	72.2%
7 Little Rock	67.8	71.3%
6 El Dorado	70.1	69.9%

Estimated Hot Water Usage Reduction

Reduction in annual hot water usage is estimated based on the typical duration of a shower and the expected number of showers per year for an installed showerhead in a given facility.

Reduction in daily hot water consumption is estimated on a per-showerhead basis using the following formula:

$$\Delta \boldsymbol{V} = \boldsymbol{U} \times \boldsymbol{N} \times (\boldsymbol{Q_B} - \boldsymbol{Q_P}) \times \boldsymbol{F_{HW}}$$

(285)

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[504] Database for Energy Efficient Resources, 2008.

Where:

ΔV = Reduction in daily hot water use in gallons per day (GPD)

U = Typical shower duration of 7.8 (minutes/shower)

N = Number of showers per day (per showerhead); (N) is a function of the commercial building type, values for N are provided in Table 359

Q_B = Baseline showerhead flow rate, 2.5 GPM

Q_P = Flow rate of installed showerhead (in GPM)

F_{HW} = Hot Water Fraction (share of water flowing through showerhead from the water heater, %)

The fraction of hot water is a function of the inlet water temperature (T_{supply}) the temperature of water from the hot water heater (T_{HW} = 120 °F), and the desired temperature at the showerhead (M_{ixed} = 105 °F).

Reduction in daily hot water usage is provided for reference in Table 358.

Table 358: Reduction in Daily Hot Water Usage, ΔV (GPD)

Flow Rate of Installed Showerhead	Weather Zone	Building Type				
		Hospital/ Nursing Home	Hospitality	Commercial (General) – Employee Shower	Fitness Center	Schools
2.0 GPM	Fayetteville	2.51	3.53	2.74	56.30	3.73
	Fort Smith	2.51	3.52	2.73	56.15	3.72
	Little Rock	2.47	3.48	2.70	55.45	3.67
	El Dorado	2.43	3.41	2.64	54.36	3.60
1.75 GPM	Fayetteville	3.77	5.29	4.11	84.45	5.59
	Fort Smith	3.76	5.28	4.10	84.22	5.58
	Little Rock	3.71	5.21	4.05	83.17	5.51
	El Dorado	3.64	5.11	3.97	81.54	5.40
1.5 GPM	Fayetteville	5.03	7.06	5.48	112.61	7.45
	Fort Smith	5.01	7.04	5.46	112.29	7.43
	Little Rock	4.95	6.95	5.39	110.89	7.34
	El Dorado	4.85	6.82	5.29	108.72	7.20

Energy Savings

The deemed energy savings are calculated as follows:

$$Energy\ Savings\ = \frac{\rho \times C_P \times \Delta V \times \left(T_{HW} - T_{Supply}\right) \times \left(\frac{1}{E_t}\right)}{Conversion\ Factor} \times \frac{days}{year}$$

(286)

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb·°F

ΔV = gallons saved per day (GPD, calculated from Equation (285) and identified in Table 358)

T_{HW} = Temperature to which water is heated in the water heater, 120°F

T_{Supply}= Average inlet water temperature (water mains temperature), from Table 357

E_t = Thermal efficiency of water heater (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.80 for natural gas water heaters[505]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/therm for gas water heating

$days/year$ = annual operating days for the building type in which the retrofit is being implemented (see Table 359)

Demand Savings

The deemed demand savings are calculated as follows:

$$Demand\ Savings\ = \frac{\rho \times C_P \times \Delta V \times \left(T_{HW} - T_{Supply}\right) \times \left(\frac{1}{E_t}\right)}{Conversion\ Factor}\ x\ P$$

(287)

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[505] Default values based on median recovery efficiency of commercial water heaters by fuel type in the AHRI database as cited in previous iterations of the AR TRM. Online: available at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Where:

ρ = Water density = 8.33 lb/gallon

C_P = Specific heat of water = 1 Btu/lb·°F

ΔV = gallons saved per day (GPD, calculated from the above equation or taken from Table 358)

T_{HW} = Temperature to which water is heated in the water heater, 120°F

T_{Supply} = Average inlet water temperature (water mains temperature), from Table 357

E_t = Thermal efficiency of the water heater (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.80 for natural gas water heaters[506]

$Conversion\ Factor$ = 3,412 Btu/kWh for electric water heating or 100,000 Btu/therm for gas water heating

P = gas and electric peak coincidence factors, as provided for each building type in Table 359

Electric peak coincidence factors are derived from AHSRAE.[507] The peak day therm ratio from Appendix G for residential gas water heater replacement (0.003) is adopted for peak gas savings. However, that multiplier is for annual energy savings, so it is multiplied by operating days for each building type to arrive at appropriate gas peak coincidence factors.

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[506] Default values based on median recovery efficiency of commercial water heaters by fuel type in the AHRI database as cited in previous iterations of the AR TRM. Online: available at https://www.ahridirectory.org/ahridirectory/pages/cwh/defaultSearch.aspx

[507] For all building types except 24-Hour Fitness Centers, derived from *ASHRAE Handbook 2011. HVAC Applications.* American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The peak factor is the ratio of the gallons of hot water used during the peak times of 3pm to 6pm, to the total amount of hot water used during the day. 24-Hour Fitness Center is assigned the same value as Commercial.

Table 359: Parameters for Annual Energy and Peak Demand Savings Calculations

Parameter	Description	Value
U	Baseline shower duration[508] (min/shower)	7.8
N	Number of showers per day per showerhead[509] 1. Hospital, Nursing Home 2. Lodging 3. Commercial 4. Fitness Center 5. Schools	 0.89 1.25 0.97 19.94 1.32
Q_B	Average baseline flow rate of showerhead (GPM)	2.5
Q_P	Flow rate of installed showerhead (GPM)	≤ 2.0
F_{HW}	Share of water flowing through showerhead coming from the water heater (%) Zone 9: Fayetteville Zone 8: Fort Smith Zone 7: Little Rock Zone 6: El Dorado	 72.4 72.2 71.3 69.9
ρ	Density of water (lb/gal)	8.33
Cp	Heat capacity of water (Btu/lb-°F)	1
T_{HW}	Temperature to which water is heated by the water heater (°F)[510]	120

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[508] Hendron, R., & Engebrech, C. 2010, "*Building America Research Benchmark Definition, Updated December 2009, Technical Report NREL/TP-550-47246,* January. National Renewable Energy Laboratory The average shower duration taken from Table 12, p. 20.

[509] Primary source is Northwest Power and Conservation Council ProCost V2.3. The number of showers per day per showerhead is back-calculated for hospitals and nursing homes, lodging and commercial building types, coefficients from annual minutes per showerhead estimates. N = (Minutes/year) x (year/days) x (Shower/minutes) = Showers/day. For fitness centers, minutes per year were taken from informal telephone survey of Fitness Centers in the Northwest, conducted by Northwest Power and Conservation Council Regional Technical Forum staff in June, 2013. The estimate for schools is derived from Water consumption from Planning and Management Consultants, Ltd., Aquacraft, Inc. and John Olaf Nelson, Water Resources Management. "*Commercial and Institutional End Uses of Water,"* American Water Works Association Research Foundation, 2000.

[510] ASHRAE Handbook 2011. HVAC Applications. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE), Inc., Atlanta, GA.

Parameter	Description	Value	
T_{supply}	Average supply (cold) water temperature (ºF)		
	Zone 9: Fayetteville	65.6	
	Zone 8: Fort Smith	66.1	
	Zone 7: Little Rock	67.8	
	Zone 6: El Dorado	70.1	
E_t	Thermal Efficiency of hot water heater:		
	Conventional Electric Storage Water Heater	0.98	
	Heat Pump Water Heater (COP)	2.2	
	Gas Storage Water Heater	0.80	
$Days/year$	Annual building type operating days for the applications:[511]		
	1. Hospital, Nursing Home	365	
	2. Lodging	365	
	3. Commercial	250	
	4. Fitness Center	365	
	5. School	200	
P	Peak Factor:	Gas[512]	Electric[513]
	1. Hospital, Nursing Home	$8.2\ e^{-6}$	0.03
	2. Lodging	$8.2\ e^{-6}$	0.02
	3. Commercial	$1.2\ e^{-5}$	0.08
	4. Fitness Center	$8.2\ e^{-6}$	0.08
	5. School	$1.5\ e^{-5}$	0.05

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[511] All values except Fitness Center from Osman , S. & Koomey, J. Lawrence Berkeley National Laboratory 1995. *Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting.* December 1995. Value for Fitness Center based on observation.

[512] See Appendix G for peak rationale.

[513] Derived from *ASHRAE Handbook 2011. HVAC Applications.* American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The peak factor is the ratio of the gallons of hot water used during the peak times of 3 pm to 6pm, to the total amount of hot water used during the day.

Example energy and demand savings calculations are provided for a 2.0 GPM showerhead installation in a hospital in Weather Zone 9 (e.g. Fayetteville) with a conventional gas storage water heater.

$$Energy\ Savings\ = \frac{8.33\frac{lb}{gal} \times 1\frac{\mathrm{Btu}}{\mathrm{lb}\cdot{}^{0}\ \mathrm{F}} \times 2.51\ \mathrm{GPD} \times (120 -\ 65.6) \times \left(\frac{1}{0.80}\right)}{100{,}000\ Btu/therm}\ x\ 365\frac{days}{yr}$$

$$= 5.2\ therms/yr.$$

$$Peak\ Gas\ Savings\ = \frac{8.33\frac{lb}{gal} \times 1\frac{\mathrm{Btu}}{\mathrm{lb}\cdot{}^{0}\ \mathrm{F}} \times 2.51\ \mathrm{GPD} \times (120 -\ 65.6) \times \left(\frac{1}{0.80}\right)}{100{,}000\ Btu/therm}\ x\ 8.2x10^{-6}$$

$$=4.2x10^{-5}\ therms/day$$

3.4 Motors

3.4.1 Electronically Commutated Motors for Refrigeration and HVAC Applications

Measure Description

An electronically commutated motor (ECM) is a fractional horsepower direct current (DC) motor used most often in commercial refrigeration applications such as display cases, walk-in coolers/freezers, refrigerated vending machines, and bottle coolers. ECMs can also be used in HVAC applications, primarily as small fan motors for packaged terminal units or in terminal air boxes. ECMs generally replace shaded pole (SP) or permanent split-capacitor (PSC) motors and offer energy savings of at least 50 percent.

Estimated Useful Life (EUL)

In accordance with DEER 2008, the estimated useful life (EUL) is 15 years.

Baseline and Efficiency Standards

The standard motor type for this application is a shaded pole or permanent split-capacitor motor.

Any ECM up to 746 W in size will meet the minimum requirements for both retrofit and new construction installations.

Calculation of Deemed Savings

Measure/Technology Review

The measure is designed to be flexible for various sized motors for both HVAC and refrigeration application. The minimum information needed is rated wattage for both the base motor and replacement ECM as well as application type (HVAC or refrigeration). Variables related to operation such as COP, phase, and power factor are added in to allow for customization as needed based on application.

Unit Electrical Measure Savings

Total demand and energy savings for replacing an existing evaporator fan shaded-pole motor with a higher-efficiency, electronically-commutated motor are represented by the following equation:

Deemed energy savings should be calculated by the following formula for refrigeration and HVAC applications:

$$kWh_{Savings} = (kW_{Base} - kW_{ECM}) * Hrs * DC * \left(1 + \frac{1}{COP}\right)$$

(288)

Where:

kW_{Base}= Power of the motor being replaced; use known wattage of motor, or if unknown, use 132 W (SP motors)[514] or 72 W (PSC motors)[515]

kW_{ECM} = Power of the replacement EC motor; use known wattage of motor, or if unknown, use 40 W[516]

The motor's power for either Base or ECM can be calculated using the following equation if power is not known. The values for rated wattage and phase can be found on motor's nameplate:

$$kW_{Motor} = \frac{Volts \times Amperage}{1000} * \sqrt{Phase} * PowerFactor$$

(289)

Hrs = Hours of yearly operation, use 8,760 hrs for refrigeration and 4,386 for HVAC

DC = Duty cycle, only use a value of 0.94 if the application of the motor being replaced is for a freezer refrigeration. This is because the freezer will complete 4 20-min defrost cycles per day where the evaporator fan will not be used. Use a value of 1 if the application is for a cooler refrigeration or HVAC.

$PowerFactor$ = Power factor of the motor, if not known an average value of 0.55 can be used for ECM in refrigeration, 0.7 for ECM in HVAC, and 0.85 for base motor in both applications.[517]

COP = Coefficient of Performance for the motors operation based on application. COP value depends on the end temperature of the refrigeration process. The COP values to use for refrigeration analysis are 1.3 for freezers and 2.5 for coolers[518]. For HVAC, use the EER value from install spec sheet and the conversion COP = EER/3.412.

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[514] http://www.fishnick.com/publications/appliancereports/refrigeration/GE_ECM_revised.pdf

[515] The Massachusetts TRM specifies a load factor of 54% for SP motors and a load factor of 29% for PSC motors, as specified by National Resource Management (NRM). Multiplying the 132 W default value for SP motors by the ratio of PSC load factor to SP load factor results in a default PSC motor wattage of 72 watts.

[516] http://www.fishnick.com/publications/appliancereports/refrigeration/GE_ECM_revised.pdf

[517] http://www.ecw.org/sites/default/files/230-1.pdf

[518] PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, pp. 4-103 - 4-106.

Deemed demand savings should be calculated by the following formulas:

$$kW_{HVAC\ Savings} = (kW_{Base} - kW_{ECM}) \times CF \times \left(1 + \frac{1}{COP}\right)$$

(290)

$$kW_{Refrigeration\ Savings} = (kW_{Base} - kW_{ECM}) \times DC \times CF \times \left(1 + \frac{1}{COP}\right)$$

(291)

Where:

CF = Coincidence Factor, use values from Table 475 for HVAC applications; default value of 1.0 for refrigeration applications[519]

DC = Duty cycle, only use a value of 0.94 if the application of the motor being replaced is for a freezer refrigeration. This is because the freezer will complete four 20-min defrost cycles per day where the evaporator fan will not be used. Use a value of 1 if the application is for a cooler refrigeration of HVAC.

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[519] CF set to 1.0 for refrigeration applications based on annual run-time assumption of 8,760 hours

3.4.2 Premium Efficiency Motors

Measure Description

Currently a wide variety of NEMA premium efficiency motors from 1 to 500 hp are available. Deemed saving values for demand and energy savings associated with this measure must be for motors with an equivalent operating period (hours x Load Factor) over 1,000 hours.

Baseline and Efficiency Standards

Replace on Burnout

The EISA 2007 Sec 313[68] adopted the new federal standard and required that electric motors that are manufactured and sold in the United States meet the new standard by December 19, 2010. The standards can also be found in sections 431.25(c)-(f) of the Code of Federal Regulations (10 CFR Part 431).[10]

With these changes, any 1-500 hp motor bearing the “NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) has already adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

In addition to the new standards for 200-500 hp motors, additional motors in the 1-200 hp range are now included in the NEMA Premium standard. These new motors are referred to as “General Purpose Electric Motors (Subtype II)”. These additional types of motors include:

- U-Frame Motors
- Design C Motors
- Close-coupled pump motors
- Footless motors
- Vertical solid shaft normal thrust (tested in a horizontal configuration)
- 8-pole motors
- All poly-phase motors with voltages up to 600 volts other than 230/460 volts (230/460 volt motors are covered by EPAct-92)

Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EPAct), as listed in Table 360.

NEMA Premium Efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for both replace on burnout and early retirement projects exceeds that listed in Table 361.

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed. Where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 15 years.

Calculation of Deemed Savings

Actual motor operating hours are expected to be used to calculate savings. Every effort should be made to capture the estimated operating hours. Short and/or long term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 364.

Measure/Technology Review

Premium efficiency motors are a mature technology and a wealth of information exists on the measure. A summary of the key resources is included in Table 360.

Table 360: Premium Efficiency Motors – Review of Motor Measure Information

Resource	Notes
PG&E 2006[42]	Savings for common motor retrofits
Xcel Energy 2006[53]	Program level savings estimates for high-efficiency motors
DEER *2008*[63]	Savings and cost for common motor retrofits
KEMA 2010[24]	Motor savings included in comprehensive potential study
CEE[61]	Industrial motor efficiency initiative
RTF[79]	Savings for common motor retrofits
ITP[71]	Savings for common motor retrofits
NPCC 2010[38]	Market information and overview of savings potential
NEMA 2009[29]	Minimum efficiency levels for premium efficiency motors
MotorMaster+[73]	Comprehensive resource of motor efficiencies and tools to calculate savings
PacifiCorp 2009[44]	Motor savings included in comprehensive potential study

Note: Italic numbers are endnotes not footnotes. (See Section 4.4 Commercial Measure References)

Deemed electric motor demand and energy savings should be calculated by the following formulas:

Replace on Burnout (ROB)

$$kWh_{Savings} = Rated\ HorsePower \times Conversion\ Factor \times LF \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times Hrs$$

(292)

$$kW_{Savings} = Rated\ HorsePower \times Conversion\ Factor \times LF \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times CF$$

(293)

Where:

$Rated\ HorsePower$ = Nameplate horsepower data of the motor

$Conversion\ Factor$ = 0.746 kW/hp

$\boldsymbol{LF}$ = Estimated load factor for the motor; if load factor is not available, deemed load factors in Table 345 can be used

$\eta_{baseline}$ = Efficiencies listed in Table 361 should be used (in the case of rewound motors, in situ efficiency may be reduced by a percentage as found in Table 363)

η_{post} = Efficiency of the newly installed motor

$\boldsymbol{Hrs}$ = Estimated annual operating hours for the motor; if unavailable, annual operating hours in Table 364 can be used

CF = Coincidence Factor = 0.74[520]

Early Retirement (ER)

Annual kWh and kW savings must be calculated separately for two time periods:

1. The estimated remaining life (RUL, see Table 365) of the equipment that is being removed, designated the first N years, and
2. Years EUL - N through EUL, where EUL is 15 years.

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[520] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf Accessed May 2013.

For the first N years:

$$kWh_{Savings} = Rated\ HorsePower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times\ Hrs$$

(294)

$$kW_{Savings} = Rated\ HorsePower\ \times Conversion\ Factor\ \times LF\ \times \left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{post}}\right) \times\ CF$$

(295)

Where:

$Rated\ HorsePower$ = Nameplate horsepower data of the motor

$Conversion\ Factor$ = 0.746 kW/hp

$\boldsymbol{LF}$ = Estimated load factor for the motor; if load factor is not available, deemed load factors in Table 345 can be used

$\boldsymbol{\eta_{baseline}}$ = In situ efficiency of the baseline motor; if unavailable, efficiencies listed in Table 361 can be used (in the case of rewound motors, in situ efficiency may be reduced by a percentage as found in Table 363)

η_{post} =Efficiency of the newly installed motor

Hrs = Estimated annual operating hours for the motor; if unavailable, annual operational hours in Table 364 can be used

CF = Coincidence Factor = 0.74[521]

For Years EUL - N through EUL: Savings should be calculated exactly as they are for replace on burnout projects, referred to as $kWh_{SavingsROB}$.

Total lifetime savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations as follows:

$$Lifetime\ kWh\ savings\ for\ Early\ Retirement\ Projects = (kWh_{SavingsRUL}\ \times RUL) + \ [kWh_{SavingsROB}\ \times (EUL - RUL)]$$

(296)

Where:

RUL= The Remaining Useful Life of the equipment, in years, see Table 365

EUL = The Estimated Useful Life of the equipment, deemed at 15 years

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[521] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf. Accessed May 2013.

Table 361: Premium Efficiency Motors – Replace on Burnout Baseline Efficiencies by Motor Size; Also for use with $kWh_{savingsROB}$ when Calculated for Early Retirement Projects[522]

hp	$\eta_{baseline, Open Motors}$			$\eta_{baseline, Closed Motors}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	94.5	95.4	94.5	95.0	95.0	95.4
300	94.5	95.4	95.0	95.0	95.4	95.4
350	94.5	95.4	95.0	95.0	95.4	95.4
400	n/a	95.4	95.4	n/a	95.4	95.4
450	n/a	95.8	95.8	n/a	95.4	95.4
500	n/a	95.8	95.8	n/a	95.8	95.4

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[522] Federal Standards for Electric Motors, Table 1: Full Load Efficiencies for Standard Electric Motors, http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50. Accessed June 2013.

Table 362: Premium Efficiency Motors – Early Retirement Baseline Efficiencies by Motor Size[523]

hp	$\eta_{\text{baseline, Open Motors}}$			$\eta_{\text{baseline, Closed Motors}}$		
	6-Pole	**4-Pole**	**2-Pole**	**6-Pole**	**4-Pole**	**2-Pole**
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0
250	94.5	95.4	94.5	95.0	95.0	95.4
300	94.5	95.4	95.0	95.0	95.4	95.4
350	94.5	95.4	95.0	95.0	95.4	95.4
400	n/a	95.4	95.4	n/a	95.4	95.4
450	n/a	95.8	95.8	n/a	95.4	95.4
500	n/a	95.8	95.8	n/a	95.8	95.4

Table 363: Rewound Motor Efficiency Reduction Factors[524]

Motor Horsepower	**Efficiency Reduction Factor**
< 40	0.01
≥ 40	0.005

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[523] Federal Standards for Electric Motor Efficiency from the Federal Energy Policy Act of 1992 (EPACT). http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/e-pact92.pdf . Accessed June 2013.

[524] U.S. DOE, Preliminary Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 2.7.2 Impact of Repair on Efficiency." July 23, 2012. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/50. Download TSD at: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/em_preanalysis_tsdallchapters.pdf .

Table 364: Premium Efficiency Motors – Operating Hours, Load Factor

Building Type	Load Factor[525]	HVAC Fan Hours[526]					
College/University	0.75	4,581					
Fast Food Restaurant		6,702					
Full Menu Restaurant		5,246					
Grocery Store		6,389					
Health Clinic		7,243					
Lodging		4,067					
Large Office (>30k SqFt)		4,414					
Small Office (≤30k SqFt)		3,998					
Retail		5,538					
School		4,165					
Industrial Processing	**Load Factor[527]**	**Hours[528]**					
		Chem	**Paper**	**Metals**	**Petroleum Refinery**	**Food Production**	**Other**
1-5 hp	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20 hp	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50 hp	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100 hp	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200 hp	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500 hp	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000 hp		7,495	7,255	7,750	5,934	5,260	8,157
> 1,000 hp		7,693	8,294	7,198	6,859	6,240	2,601

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[525] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. Accessed May 2013.http://www.deeresources.com/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf .

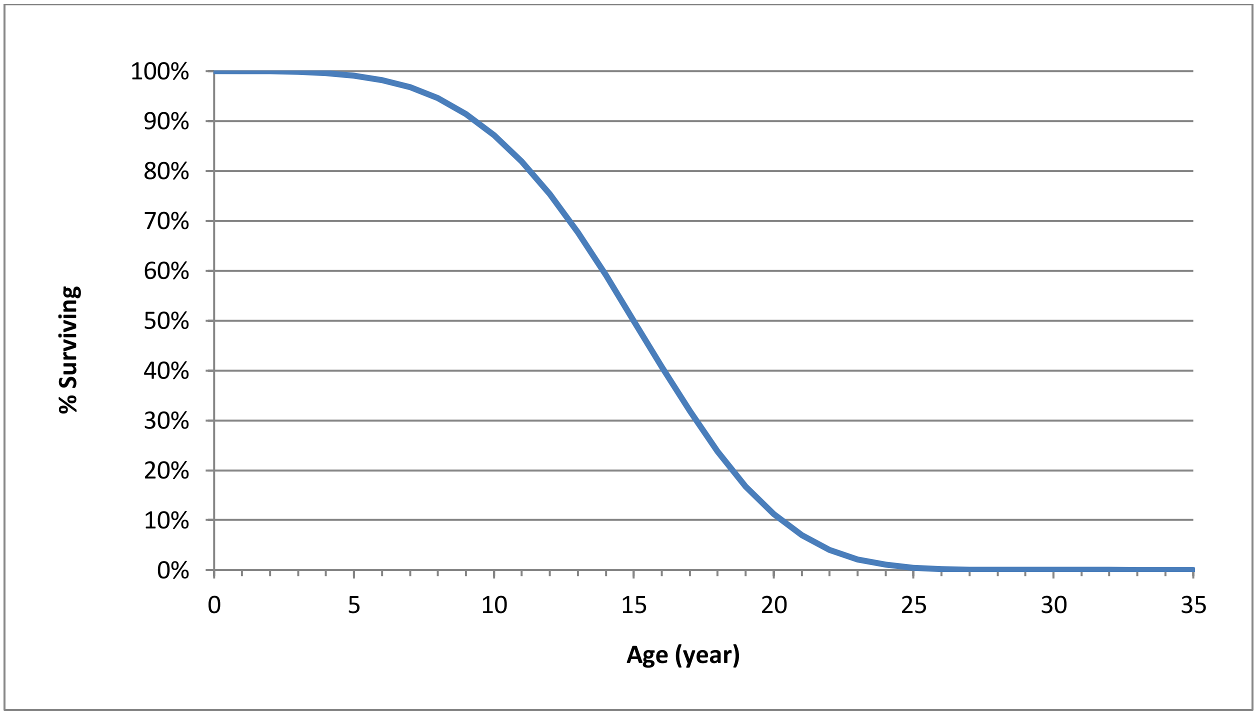
[526] Fan schedule operating hours taken as the average of operating hours from the Connecticut, Maine, and Pennsylvania Technical Reference Manuals: CL&P and UI Program Savings Documentation for 2008 Program Year, Connecticut Lighting & Power Company; Efficiency Maine Technical Reference User Manual No. 2007-1; Pennsylvania Utility Commission Technical Reference Manual June 2012.

[527] United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. Accessed May 2013. www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf .

[528] United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. Accessed May 2013. www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf .

Table 365: Premium Efficiency Motors - Remaining Useful Life (RUL) of Replaced Systems[529,530]

Age of Replaced System (Years)	RUL (Years)	Age of Replaced System (Years)	RUL (Years
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.5
8	7.3	17	2.2
9	6.5	18	1.9
10	5.7	19	0.0
11	5.0		
12	4.4		
13	3.8		



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[529] Because the motor EUL is 15 years, it is consistent for use with the RUL determined using the weibull distribution offered in the DOE’s Life Cycle Cost Analysis Spreadsheet, “lcc_cuac_hourly.xls”. http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

[530] Use of the early retirement baseline is capped at 18 years, representing the age at which 75 percent of existing equipment is expected to have failed. Systems older than 18 years should use the ROB baseline.

Figure 14: Survival Function for Premium Efficiency Motors[531]

The method used for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 14. The age of the system being replaced is found on the horizontal axis and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For more information regarding Early Retirement, see section 1.8 Early Retirement.

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[531] Source: Weibull distribution based on the Life Cycle Cost Analysis Spreadsheet, "lcc_cuac_hourly.xls". http://www1.eere.energy.gov/buildings/appliance_standards/standards_test_procedures.html.

3.5 Appliances

3.5.1 Solid-Door Refrigerators and Freezers

Measure Description

Commercial refrigerators and freezers are commonly found in restaurants and other food service industries. Reach-in, solid-door refrigerators and freezers are significantly more efficient than regular refrigerators and freezers due to better insulation and higher-efficiency components. These efficiency levels relate the volume of the appliance to its daily energy consumption.

Baseline and Efficiency Standards

Baseline efficiency for commercial solid door refrigerators and freezers are defined by federal minimum efficiency levels that went into effect on March 28, 2014 (see Table 366 below) Efficient units are defined by minimum efficiency levels for the ENERGY STAR® specifications effective March 27, 2017.

Table 366: Solid Door Refrigerators and Freezers – Efficiency Levels

Equipment Type	Efficiency Level	Maximum Daily Energy Consumption[532] (kWh/day)
Refrigerator	Baseline	0.05V + 1.36
Refrigerator	ENERGY STAR®	0<V<15, 0.022V + 0.97 15 <= V < 30 , 0.066V + 0.31 30 <= V < 50, 0.04V + 1.09 50 <= V, 0.024V + 1.89
Freezer	Baseline	0.22V + 1.38
Freezer	ENERGY STAR®	0 < V < 15, 0.21V + 0.9 15 <= V < 30 , 0.12V +2.248 30 <= V < 50, 0.285V - 2.703 50 = V, 0.142V + 4.445

The standard refrigerator/freezer efficiency is based on Table 367 which contains the baseline annual energy consumption, and demand, for solid-door refrigerators and freezers.

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[532] V is the volume of the refrigerator or freezer in cubic feet.

Table 367. Solid-Door Refrigerators and Freezers – Baseline Measure Information

Type	Size Range[533] (cubic ft.)	Annual Energy Consumption (kWh/unit)	Demand (kW/unit)
Refrigerator	0-15	770	0.09
	15-30	1,044	0.12
	30-50	1,409	0.16
	≥50	1,774	0.20
Freezer	0-15	1,708	0.20
	15-30	2,913	0.33
	30-50	4,519	0.52
	≥50	6,125	0.70

To qualify for this measure, new solid-door refrigerators and freezers must meet ENERGY STAR® minimum efficiency requirements. Table 368 summarizes the estimated performance information for qualifying units.

Table 368: Solid-Door Refrigerators and Freezers – Qualifying Measure Information

Type	Size Range[534] (cubic ft.)	Annual Energy Consumption (kWh/unit)	Demand (kW/unit)
Refrigerator	0-15	475	0.054
	15-30	836	0.095
	30-50	1,128	0.129
	≥50	1,303	0.149
Freezer	0-15	1,478	0.169
	15-30	2,135	0.244
	30-50	4,215	0.481
	≥50	5,251	0.599

---

[533] Solid-door refrigerators and freezers were evaluated for four different sizes or volumes (V), 15, 30, 50 and 70 cubic feet. The unit will be operated for 365 days per year.

[534] Ibid.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is 12 years.

Deemed Savings Values

Deemed measure savings for qualifying solid-door refrigerators and freezers are presented in Table 369.

Table 369: Solid Door Refrigerators and Freezers – Deemed Savings Values [535]

Type	**Size Range**[536] **(ft^3)**	**Annual Energy Savings (kWh/unit)**	**Demand Savings (kW/unit)**
Refrigerator	0-15	296	0.034
	15-30	208	0.024
	30-50	281	0.032
	≥50	471	0.054
Freezer	0-15	230	0.026
	15-30	778	0.089
	30-50	304	0.035
	≥50	874	0.100

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[535] Savings represent gross savings at meter.

[536] Solid-door refrigerators and freezers were evaluated for four different sizes or volumes (V), 15, 30, 50 and 70 cubic feet. The unit will be operated for 365 days per year.

3.6 Lighting

3.6.1 Light Emitting Diode (LED) Traffic Signals

Measure Description

This measure involves the installation of LED traffic signals, typically available in red, yellow, green, and pedestrian format, at a traffic light serving any intersection in retrofit applications. New construction applications are not eligible for this measure, as incandescent traffic signals are not compliant with the current federal standard[537], effective January 1, 2006.

Baseline & Efficiency Standards

For all retrofit projects, the baseline is a standard incandescent fixture.

Due to the increased federal standard for traffic signals, the ENERGY STAR® LED Traffic Signal specification was suspended effective May 1, 2007.[538] ENERGY STAR® chose to suspend the specification rather than revise it due to minimal additional savings that would result from a revised specification. Because the ENERGY STAR® specification no longer exists, the efficiency standard is considered to be an equivalent LED fixture for the same application. The equivalent LED fixture must be compliant with the federal standard. There is no current federal standard for yellow "ball" or "arrow" fixtures.

Table 370: Federal Standard Maximum Nominal Wattages[539] and Maximum Wattages[540]

Measure	Nominal Wattage	Maximum Wattage
12" Red Ball	17	11
12" Green Ball	15	15
8" Red Ball	13	8
8" Green Ball	12	12
12" Red Arrow	12	9
8" Green Arrow	11	11
Combination Walking Man/Hand	16	13
Walking Man	12	9
Orange Hand	16	13

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[537] Current federal standards for traffic and pedestrian signals can be found at the DOE website at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/32.

[538] Memorandums related to this decision can be found on the ENERGY STAR® website at: https://www.energystar.gov/index.cfm?c=archives.traffic_signal_spec.

[539] Nominal wattage is defined as power consumed by the module when it is operated within a chamber at a temperature of 25 °C after the signal has been operated for 60 minutes.

[540] Maximum wattage is the wattage at which power consumed by the module after being operated for 60 minutes while mounted in a temperature testing chamber so that the lensed portion of the module is outside the chamber, all portions of the module behind the lens are within the chamber at a temperature of 74 °C, and the air temperature in front of the lens is maintained at a minimum of 49 °C.

Typical incandescent and LED traffic signal fixture wattages can be found in the following table. These fixture wattages should be used in the absence of project specific fixture wattages.

Table 371: Incandescent/LED Traffic Signal Fixture Wattages

Measure	Incand. Wattage[541]	LED Wattage[542]
Replace 12” Red Incandescent Ball with 12” Red LED Ball	149	9
Replace 12” Yellow Incandescent Ball with 12” Yellow LED Ball		17
Replace 12” Green Incandescent Ball with 12” Green LED Ball		11
Replace 8” Red Incandescent Ball with 8” Red LED Ball	86	6
Replace 8” Yellow Incandescent Ball with 8” Yellow LED Ball		12
Replace 8” Green Incandescent Ball with 8” Green LED Ball		6
Replace 12” Red Incandescent Arrow with 12” Red LED Arrow	128	5
Replace 12” Yellow Incandescent Arrow with 12” Yellow LED Arrow		8
Replace 12” Green Incandescent Arrow with 12” Green LED Arrow		5
Replace Large (16”x18”) Incandescent Pedestrian Signal with LED Pedestrian Signal (with Countdown)	149	17
Replace Small (12”x12”) Incandescent Pedestrian Signal with LED Pedestrian Signal (with Countdown)	107	10
Replace Large (16”x18”) Incandescent Pedestrian Signal with LED Pedestrian Signal (without Countdown)	116[543]	6
Replace Small (12”x12”) Incandescent Pedestrian Signal with LED Pedestrian Signal (without Countdown)	68[544]	5

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[541] Northwest Power & Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37.

[542] Typical practice for estimating fixture wattages is to take an average of the three leading manufacturers: GE, Philips, and Sylvania. Of the three, GE is the only manufacturer providing LED traffic signals. Other manufacturers excluded from averages. http://www.gelightingsolutions.com/products--solutions/transportation-led-lighting/traffic-signals.

[543] Average high wattage A19, A21, and A23 incandescent fixture from Philips and Sylvania.

[544] Ibid.

Estimated Useful Life (EUL)

According to the Northwest Power & Conservation Council Regional Technical Forum, the estimated useful life (EUL) is 5 to 6 years, as shown in the following table.

Table 372: Estimated Useful Life by Measure

Measure	EUL[545] (Years)
Replace 12" Red Incandescent Ball with 12" Red LED Ball	6
Replace 12" Yellow Incandescent Ball with 12" Yellow LED Ball	
Replace 12" Green Incandescent Ball with 12" Green LED Ball	
Replace 8" Red Incandescent Ball with 8" Red LED Ball	
Replace 8" Yellow Incandescent Ball with 8" Yellow LED Ball	
Replace 8" Green Incandescent Ball with 8" Green LED Ball	
Replace 12" Red Incandescent Arrow with 12" Red LED Arrow	
Replace 12" Yellow Incandescent Arrow with 12" Yellow LED Arrow	
Replace 12" Green Incandescent Arrow with 12" Green LED Arrow	
Replace Large (16"x18") Incandescent Pedestrian Signal with LED Pedestrian Signal	5
Replace Small (12"x12") Incandescent Pedestrian Signal with LED Pedestrian Signal	

Measure Savings Calculation

$$kW_{savings} = \sum\left(\left[N_{fixt(i)}\ x\ \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)}\ x\ \frac{W_{fixt(i)}}{1000}\right]_{post}\right) x\ CF$$

(297)

$$kWh_{savings} = \sum\left(\left[N_{fixt(i)}\ x\ \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)}\ x\ \frac{W_{fixt(i)}}{1000}\right]_{post}\right) x\ AOH$$

(298)

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[545] Northwest Power & Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37. EUL is determined by LED Traffic Signal replacement schedule, which is set to precede earliest burnout. All fixtures will be replaced at the same time to minimize maintenance interruptions.

Where:

$N_{fixt(i),pre}$ = Pre-retrofit number of fixtures of type i.

$N_{fixt(i),post}$ = Post-retrofit number of fixtures of type i.

$W_{fixt(i),pre}$ = Rated wattage of pre-retrofit fixtures of type i (if unknown, use Table 371).

$W_{fixt(i),post}$ = Rated wattage of post-retrofit fixtures of type i (if unknown, use Table 371).

CF = Peak demand coincidence factor (Table 373).

AOH = Annual operating hours for specified measure type (Table 373).

Table 373: Coincidence Factor and Annual Operating Hours by Measure

Measure	CF[546]	AOH[547]
Replace 12" Red Incandescent Ball with 12" Red LED Ball	0.54	4,746
Replace 12" Yellow Incandescent Ball with 12" Yellow LED Ball	0.03	263
Replace 12" Green Incandescent Ball with 12" Green LED Ball	0.43	3,751
Replace 8" Red Incandescent Ball with 8" Red LED Ball	0.54	4,746
Replace 8" Yellow Incandescent Ball with 8" Yellow LED Ball	0.03	263
Replace 8" Green Incandescent Ball with 8" Green LED Ball	0.43	3,751
Replace 12" Red Incandescent Arrow with 12" Red LED Arrow	0.89	7,771
Replace 12" Yellow Incandescent Arrow with 12" Yellow LED Arrow	0.03	263
Replace 12" Green Incandescent Arrow with 12" Green LED Arrow	0.08	726
Replace Large (16"x18") Incandescent Pedestrian Signal with LED Pedestrian Signal	0.99	8,642
Replace Small (12"x12") Incandescent Pedestrian Signal with LED Pedestrian Signal	0.99	8,642

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[546] CF = AOH / 8,760 hours

[547] Northwest Power & Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37.

3.6.2 Lighting Controls

Measure Description

Automatic lighting controls save energy by switching off or dimming lights when they are not necessary. Some lighting control techniques, such as using photocell controls, can be coupled with a variety of control strategies, including daylighting controls, occupancy controls, timer controls, and time clocks.

Stepped Lighting Control Systems

When switching systems are used with entire circuits of lights, as opposed to individual light fixtures, the control protocol is usually described in terms of steps, with each "step" referring to a percentage of full lighting power. Stepped lighting control systems are a relatively inexpensive approach to controlling large individual spaces, but they can be distracting to occupants.

Continuous Dimming Control Systems

Continuous dimming control systems are designed to adjust electric lighting to maintain a designated light level. Continuous dimming systems eliminate distracting and abrupt changes in light levels, provide appropriate light levels at all times, and provide an increased range of available light level. Cost is the major disadvantage of this control.

Occupancy Sensors

Occupancy sensors use motion detection to control lights in response to the presence or absence of occupants in a space. Many different varieties of sensors are available, including passive infrared (PIR), Ultrasound detecting, dual-technology, and integral occupancy sensors. Occupancy sensors are most effective in spaces with sporadic or unpredictable occupancy levels.

Daylighting

Daylighting controls switch or dim electric lights in response to the presence or absence of daylight illumination in the space. Advanced daylighting controls incorporate occupancy and daylighting sensors into the same control.

Baseline and Efficiency Standards

IECC 2003 (Section 805.2) and IECC 2009 (Section 505.1) specify the conditions under which light reduction and automatic controls are mandatory for new construction and affected retrofit projects. See the Measure Baseline section under the lighting efficiency measure for a discussion of updated lighting fixture wattages.

There are no minimum efficiency requirements for lighting controls.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is eight years for Daylighting Sensors and eight years for Occupancy Sensors.

Calculation of Deemed Savings

Measure/Technology Review

There have been many in-depth studies performed on the energy savings associated with occupancy and daylighting controls. Research by various organizations – including the Illuminating Engineering Society (IES), Canada National Research Council (CNRC), New Buildings Institute (NBI), Lighting Research Center (LRC) and multiple utilities – was included in this review. A summary of the findings of these reports are located in Table 374 and Table 375.

Table 374: Lighting Controls – Energy Saving Estimates for Occupancy Sensors

Location	IES[548]	CNRC[549]	NBI[550]	LRC[551]
Break Room	22%	-	-	-
Classroom	45%	63%	25%	-
Conference Room	43%	-	-	-
Corridor	-	24%	-	-
Office	32%	44%	35-45%	43%
Restroom	41%	-	-	-

Table 375: Lighting Controls – Energy Saving Estimates for Daylighting Sensors

Location	CNRC	NBI	So Cal Edison[552]	LRC
Classroom	16%	40%	-	-
Corridor	25%	-	-	-
Office	22%	35-40%	74%	24-59%
Grocery Stores	-	40%	-	-
Big Box Retail	-	60%	-	-

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[548] IES HB-9-2000. *"Illuminating Engineering Society Lighting Handbook 9th Edition"*. 2000.

[549] Canada National Research Center, *"Energy Savings from Photosensors and Occupant Sensors/Wall Switches"*. September 2009.

[550] New Buildings Institute. 2010. http://buildings.newbuildings.org/.

[551] Lighting Research Center (LRC), Solid State Lighting Program. http://www.lrc.rpi.edu/researchareas/leds.asp.

[552] Southern California Edison, "*Energy Design Resources: Design Brief Lighting Controls*". February 2000.

Lighting energy savings can be calculated using the following formula. The kWh savings for each combination of fixture type, fixture location, building type, and refrigeration type must be calculated separately:

$$kW_{savings} = N_{fixt} \times \frac{W_{fixt}}{1000} \times CF \times IEF_D$$

(299)

$$kWh_{savings} = N_{fixt} \times \frac{W_{fixt}}{1000} \times (1 - PAF) \times AOH \times IEF_E$$

(300)

Where:

N_{fixt} = Number of fixtures

W_{fixt} = Rated wattage of post-retrofit fixtures (Appendix E in TRM Volume 3)

Note: If the fixture was retrofitted, use the installed fixture wattage; if fixture was not retrofitted, use the existing fixture wattage

PAF = Stipulated power adjustment factor based on control type (Table 376)

CF = Peak demand coincidence factor = 0.26[553]

AOH = Annual operating hours for specified building type (Table 382)

IEF_D = Interactive effects factor for demand savings (Table 383)

IEF_E = Interactive effects factor for energy savings (Table 383)

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[553] RLW Analytics, "*2005 Coincidence Factor Study*," Connecticut Energy Conservation Management Board. January 4, 2007. Default value applicable to all building types. This coincidence factor is a combination of the savings factor and peak coincidence factor.

Table 376: Lighting Controls – Power Adjustment Factors[554]

Control Type	Power Adjustment Factor (PAF)
No controls measures	1.00
Daylighting Control – Continuous Dimming	0.70
Daylighting Control – Multiple Step Dimming	0.80
Daylighting Control – ON/OFF (Indoor)	0.90
Daylighting Control – ON/OFF (Outdoor) [555]	1.00
Occupancy Sensor	0.70
Occupancy Sensor w/ Daylighting Control – Continuous Dimming	0.60
Occupancy Sensor w/ Daylighting Control – Multiple Step Dimming	0.65
Occupancy Sensor w/ Daylighting Control – ON/OFF	0.65

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[554] PAFs are adapted from ASHRAE Standard 90.1-1989, Table 6-3.

[555] ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

3.6.3 Lighting Efficiency

Measure Description

A variety of high-efficiency fixtures, ballasts and lamps exist in the market today, producing the same lighting level (in lumens) as their standard-efficiency counterparts while consuming less electricity. This measure provides energy and demand savings calculations for the replacement of commercial lighting equipment with energy efficient lamps or fixtures. The operating hours and demand factors for the different building types listed in this measure are based on a wide array of information available in the market.

Baseline & Efficiency Standard

The following sections explain the various codes, standards, and required processes to establish the applicability of the Lighting Efficiency savings calculation method.

State Commercial Energy Codes

Arkansas' state commercial energy code recognizes ASHRAE 90.1-2007[556] for commercial structures. These standards specify the maximum lighting power densities (LPDs) by building type (building area method) and interior space type (space-by-space method). LPDs apply to all new construction and major renovation projects. The ASHRAE 90.1-2007 LPDs for various building types are outlined in Appendix F of TRM Volume 3. Agricultural lighting for animals will utilize recognized industry standards unique to the requirements of that animal to determine the LPD for the building housing those animals.

High-Efficiency/Performance Linear Fluorescents

All installed 4-ft technologies must use electronic ballasts manufactured after November 2014[557] and high performance T8 lamps that are on the T8 Replacement Lamp[558] qualified products list developed by the Consortium for Energy Efficiency (CEE) as published on its website. This is a requirement for all 4-ft T8 system projects.

If CEE does not have efficiency guidelines for a T8 system (such as for 8-foot, 3-foot, 2-foot, and U-bend T8 products), the product must have higher light output or reduced wattage than its standard equivalent product (minimum efficacy of 75 mean lumens per watt), while also providing a CRI (color rendition index) greater than 80, and an average rated life of 24,000 hours at 3 hours per start. In addition, 2-foot and 3-foot ballasts must also use electronic ballasts manufactured after November 2014.

Other high performance systems, including but not limited to T5 and LED systems, are allowed.

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[556] Any references to any versions of this standard refer to the American National Standards Institute (ANSI) /American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America (IESNA) Standard 90.1

[557] Changes to the DOE Federal standards for electronic ballasts effective November 2014 met both the CEE performance specification and the NEMA Premium requirements, so CEE discontinued their specification and qualifying product lists. A legacy ballast list from January 2015 is still available.

[558] In March 2015, the CEE dropped the separate High Performance and Reduced Watt T8 lamp designations and product lists and created a single T8 Replacement Lamp qualified product list.

T12s are no longer an eligible baseline technology for 4 foot, 8 foot, and U-tube lamps.

Federal Efficacy Standards

The Energy Independence and Security Act (EISA) of 2007 mandates minimum efficacy standards for general service incandescent lamps, modified spectrum general service incandescent lamps, incandescent reflector lamps, fluorescent lamps and metal halide lamps.

Effective January 1, 2010, EISA increased minimum ballast efficacy factors and established pulse-start metal halides (PSMHs) as the new industry standard baseline for the metal halide technology (≤ 500 W). New construction projects must use PSMHs in metal halide applications.

Starting in 2012, baseline wattages for general service incandescent lamps (GSILs) should not exceed values specified by EISA. For convenience, Table 377 provides the lumens and wattages required to meet EISA standards for incandescent lamps.

Table 377: New Maximum Wattages for General Service Incandescent Lamps, 2012-2014

Old Standard Incandescent Wattage	New Maximum Wattage (EISA 2007)	Rated Lumens	Effective Date[559]
100	72	1490 - 2600	6/1/2012
75	53	1050 - 1489	6/1/2013
60	43	750 - 1049	6/1/2014
40	29	310 – 749	6/1/2014

The Energy Policy Act (EPAct) of 2005 and EISA of 2007 are two energy legislative rulings enacted to establish energy reduction targets for the United States. On July 14, 2009, the Department of Energy published a final rule for energy conservation standards for general service fluorescent lamps (GSFLs). These standards are shown in Table 378. As a result of this rule, all GSFLs manufactured in the United States, or imported for sale into the United States on or after July 14, 2012 (three years from the ruling date) must meet new, more stringent efficacy standards (measured in lumens per watt, LPW).

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[559] Adjusted from January to June assuming continued market availability for a period of 6 months after the standard effective date.

Table 378: Lighting Efficiency – Current Federal Efficiency Standards for GSFLs

Lamp Type	Nominal Lamp Wattage	Minimum Color Rendering Index (CRI)	Minimum Average Lamp Efficacy (Lumens/Watt, or LPW)
4-foot Medium Bi-Pin	> 35W ≤ 35 W	69 45	75.0 75.0
2-foot U-Shaped	> 35W ≤ 35W	69 45	68.0 64.0
8-foot Slimline	> 65W ≤ 65W	69 45	80.0 80.0
8-foot High Output	> 100W ≤ 100W	69 45	80.0 80.0

Facilities with 4-foot and 8-foot T12s or with 2-foot U-Shaped T12s are still eligible to participate in lighting retrofit projects, but an assumed electronic T8 baseline should be used in place of the existing T12 equipment. These T12 fixtures will remain in the standard wattage table with the label “T12 (T8 baseline)” and will include adjusted wattages assumptions consistent with a T8 fixture with an equivalent length and lamp count. T12 fixtures not specified above will remain an eligible baseline technology.

Table 379: Adjusted Baseline Wattages for T12 Equipment

T12 Length	**Lamp Count**	**Revised Lamp Wattage**	**Revised System Wattage**
48 inch-Std, HO, and VHO (4 feet)	1	32	31
	2	32	58
	3	32	85
	4	32	112
	6	32	170
	8	32	224
96 inch-Std (8 feet) 60/75W	1	59	69
	2	59	110
	3	59	179
	4	59	219
	6	59	330
	8	59	438*
96 inch-HO and VHO (8 feet) 95/110W	1	86	101
	2	86	160
	3	86	261
	4	86	319
	6	86	481
	8	86	638
2 ft. U-Tube	1	32	32
	2	32	60
	3	32	89
* 8 lamp fixture wattage approximated by doubling 4 lamp fixture wattage.			
Key: HO = high output, VHO = very high output			

Fixture Qualification Process – High Performance and Reduced Wattage T-8 Equipment:

CEE developed and previously maintained energy specifications for High Performance and Reduced Wattage T8 equipment. As of November 14, 2014, the Federal Standard increased causing CEE to discontinue their ballast specification. A legacy qualification list for CEE high performance and reduced wattage T8 specifications can be found at:

1) http://www.cee1.org/com/com-lt/com-lt-specs.pdf (High Performance products)
2) http://www.cee1.org/com/com-lt/lw-spec.pdf (Reduced Wattage products)

CEE compiles a list of approved lamps and ballasts for T8 systems that are eligible for incentives for retrofits which is available for download on CEE's website at http://library.cee1.org/content/commercial-lighting-qualifying-products-lists.

For ballasts manufactured on or after November 14, 2014, refer to the NEMA Premium Electronic Ballast Program qualification list available at http://www.nema.org/Technical/Pages/NEMA-Premium.aspx.

Fixture Qualification Process – CFL and LED Products:

CFL and LED products must be pre-qualified under one of the following options:

1) Product is on the ENERGY STAR® Qualified Product List or ENERGY STAR® Qualified Light Fixtures Product List (http://www.energystar.gov)
2) Product is on the Northeast Energy Efficiency Partnerships (NEEP) DesignLights Consortium™ (DLC) Qualified Products Listing (www.designlights.org)
3) Product is on the Consortium for Energy Efficiency's (CEE) Commercial Lighting Qualifying Products List (http://www.cee1.org/)
4) Exceptions to the qualifying product requirements are allowed for unlisted lamps and fixtures that have already been submitted to one of the organizations for approval. If the lamp or fixture does not achieve approval within the AR DSM program year, however, then the lamp or fixture must immediately be withdrawn from the program. If withdrawn, savings may be claimed up to the point of withdrawal from the program. For Agricultural uses where the fixture is designed for animal use, if an LED bulb does not meet qualifying requirements, the bulb can be utilized if a thorough review of the bulb is conducted and verified by the program evaluator.

Input Wattages

Input wattages for pre-retrofit and qualifying fixtures are included in the Standard Fixture Wattage Table (Appendix E). This is a relatively comprehensive list of both old and new lighting technologies that could be expected for inclusion in a project. If there are fixtures identified that are not included in this table, those fixtures should be submitted to the Independent Evaluation Monitor (IEM) for review and incorporation into subsequent TRM updates. Interim approval may be made for certain fixtures at the discretion of the IEM. However, there may be eligible products that are not on the list. If a product is not on the list, then manufacturer's data should be reviewed prior to accepting the product into a program. LED products should be approved by DLC, CEE or ENERGY STAR® before being recognized as an eligible product.

Estimated Useful Life (EUL)

Table 380: Estimated Useful Life by Lamp Type

Lamp Type	EUL (years)	Source[560]
Halogen	2	Based upon 5,000-hour manufacturer rated life and weighted-average 3,380 annual operating hours from Navigant U.S. Lighting Study. Rated life values assume the use of energy-efficient Halogen Infrared (IR) products.
High Intensity Discharge (HID)	16	Based upon 50,000 hour manufacturer rated life and weighted-average 3,205 annual operating hours from Navigant U.S. Lighting Study.
Integrated-Ballast Cold-Cathode Fluorescent Lamps (CCFL)	5	Based upon 25,000 hour manufacturer rated life and weighted-average 5,493 annual operating hours from Navigant U.S. Lighting Study.
Integrated-Ballast Compact Fluorescent Lamps (CFL)	2	Based upon 8,000 hour manufacturer rated life and weighted-average 3,253 annual operating hours from Navigant U.S. Lighting Study.
Linear LED Lamps[561]	15	Based upon 50,200 hour manufacturer rated life and weighted-average 3,260 annual operating hours from Navigant U.S. Lighting Study.[562]
LED Fixtures	15	Based upon 50,000 hour manufacturer rated life and weighted-average 3,260 annual operating hours from Navigant U.S. Lighting Study.
Linear Fluorescent Lamps (T5, T8)	9	Based upon 30,200 hour manufacturer rated life and weighted-average 3,211.[563]
Linear Fluorescent Fixtures/Ballasts (T5, T8)	16	Based upon 50,000 hour manufacturer rated life and weighted-average 3,211.
Modular CFL and CCFL	16	Based upon 60,000 hour manufacturer rated life and weighted-average 3,251 annual operating hours from Navigant U.S. Lighting Study.

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[560] Navigant Consulting, "U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate, Final Report." U.S. DOE. September 2002.

[561] Includes all lamp only replacements.

[562] Linear LED lamp taken from average LED lamp lifetime of all LED lamps from CEE T8 Qualifying Products List as of April 2017. Annual operating hours from Navigant U.S. Lighting Study (See Footnote 504). https://library.cee1.org/content/commercial-lighting-qualifying-products-lists

[563] Linear Fluorescent lamp life taken from average lamp lifetime of all fluorescent lamps from CEE T8 Qualifying Products List as of April 2017. Annual operating hours from Navigant U.S. Lighting Study (See Footnote 504). https://library.cee1.org/content/commercial-lighting-qualifying-products-lists

Calculation of Deemed Savings

New Construction:

$$kW_{savings} = \left(\left(SF \times \frac{LPD}{1000}\right) - \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right)\right) \times CF \times IEF_D$$

(301)

$$kWh_{savings} = \left(\left(SF \times \frac{LPD}{1000}\right) - \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right)\right) \times AOH \times IEF_E$$

(302)

$$therms_{penalty} = kWh_{savings} \times IEF_G$$

(303)

Where:

SF = Total affected square footage of the new construction facility

LPD = Maximum allowable power density by building type (W/ft^2) (Appendix F Table F1-F4)

$N_{fixt(i),post}$ = Post-retrofit # of fixtures of type i

$W_{fixt(i),post}$ = Rated wattage of post-retrofit fixtures of type i (Appendix E)

CF = Peak demand coincidence factor (Table 382)

AOH = Annual operating hours for specified building type (Table 382)

IEF_D = Interactive effects factor for demand savings (Table 383)

IEF_E = Interactive effects factor for energy savings (Table 383)

IEF_G = Interactive effects factor for gas heating savings (Table 384)

Retrofit with no existing controls:

$$kW_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times CF \times IEF_D$$

(304)

$$kWh_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times AOH \times IEF_E$$

(305)

$$therms_{penalty} = kWh_{savings} \times IEF_G$$

(306)

Retrofit with existing controls:

Note: For lighting systems with existing controls, no additional control savings should be claimed with the savings specified by the equations below.

$$kW_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times IEF_D \times CF_{controls}$$

(307)

$$kWh_{savings} = \sum\left(\left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{pre} - \left[N_{fixt(i)} \times \frac{W_{fixt(i)}}{1000}\right]_{post}\right) \times IEF_E \times AOH \times PAF$$

(308)

$$therms_{penalty} = kWh_{savings} \times IEF_G$$

(309)

Where:

$N_{fixt(i),pre}$ = Pre-retrofit number of fixtures of type i

$N_{fixt(i),post}$ = Post-retrofit number of fixtures of type i

$W_{fixt(i),pre}$ = Rated wattage of pre-retrofit fixtures of type i (Appendix E)

$W_{fixt(i),post}$ = Rated wattage of post-retrofit fixtures of type i (Appendix E)

CF = Peak demand coincidence factor (Table 382)

$CF_{controls}$ = Controls peak demand coincidence factor = 0.26[564]

AOH = Annual operating hours for specified building type (Table 382)

PAF = Power adjustment factor for specified control type (Table 376)

IEF_D = Interactive effects factor for demand savings (Table 383)

IEF_E = Interactive effects factor for energy savings (Table 383)

IEF_G = Interactive effects factor for gas heating savings (Table 384)

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[564] RLW Analytics, "*2005 Coincidence Factor Study,"* Connecticut Energy Conservation Management Board. January 4, 2007. Default value applicable to all building types. This coincidence factor is a combination of the savings factor and peak coincidence factor.

Operating Hours & Coincidence Factors (CF)

If the annual operating hours and/or CF for the specified building are not known, use the deemed average annual hours of operation and/or peak demand CF from Table 382.

Table 381 summarizes the general transferability ratings for the lighting end-use. Due to the low variability of schedules and weather for both indoor and outdoor lighting, there is a high degree of data transferability across regions and it is appropriate to assume very similar annual operating hours across different regions.[565] To the extent that utility system peak periods are similar, it is also appropriate to assume very similar peak CFs across different regions.

Table 381: Transferability of Data across Geographic Regions

Analysis Group	ScheduleVariability	WeatherVariability	TransferabilityRating
Lighting – Exterior	Low	Low	High
Lighting – Interior	Low	Low	High

Operating hours are the number of hours that a particular equipment type is in use over the course of a year. For the purpose of these recommendations, raw building lighting operating hour data were adjusted by Frontier Associates according to the percentage of wattage consumed by each space within a building. Subsequently, weighted average operating hours (AOH) were developed for a range of building types.

For facilities with multiple building types (i.e. office, warehouse, etc.), the building type and corresponding operating hours should be determined based on the space type that comprises the most (>50%) area at the facility. For example, if a building comprises of 80 percent warehouse space and 20 percent office space, the operating hours for a warehouse building type would be used for the energy savings calculations.

The CF for lighting is the ratio of the lighting kW demand during the utility's peak period (defined in Appendix G) to the connected lighting kW ($\sum(N_i \, xW_i/ 1000)$ as defined above. Other issues are automatically accounted for, such as diversity and load factor. A portion of the CF values were arrived at through secondary research. In the cases where acceptable values were not available through other sources, Frontier Associates calculated values comprised of CF and building operating hour data available for the types of building spaces that would likely be found within that building type.

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[565] KEMA. *End-Use Load Data Update Project Final Report: Phase 1: Cataloguing Available End-Use and Efficiency Measure Load Data*. 2009. Prepared for the Northwest Power and Conservation Council and Northeast Energy Efficiency Partnerships, November.

Table 382: Annual Operating Hours (AOH) and Coincidence Factors (CF)[566]

Building Type	AOH	CF
All Building Types: Exit Signs	8,760	1.00
Education: k-12, w/o Summer Session	2,777	0.47
Education: College, University, Vocational, Day Care, and K-12 w/ Summer Session	3,577	0.69
Food Sales: Non 24-hour Supermarket/Retail	4,706	0.95
Food Sales: 24-hour Supermarket/Retail	6,900	0.95
Food Service: Fast Food	6,188	0.81
Food Service: Sit-down Restaurant	4,368	0.81
Health Care: Out-patient	3,386	0.77
Health Care: In-patient	5,730	0.78
Lodging (Hotel/Motel/Dorm): Common Areas	6,630	0.82
Lodging (Hotel/Motel/Dorm): Rooms	3,055	0.25
Manufacturing – 1 and 2 Shift[567]	4,547	0.64
Manufacturing – 3 Shift	6,631[568]	0.89[569]
Multi-family Housing: Common Areas	4,772	0.87
Nursing & Resident Care	4,271	0.78
Office[570,571]	3,227	0.54
Outdoor	3,996	0.00
Outdoor Athletic Fields	503[572]	0.00

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[566] Unless otherwise noted, deemed AOH and CF values are based on Frontier Associates on behalf of Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to Revise Existing Measurement & Verification Guidelines for Lighting Measures for Energy Efficiency Programs: Docket No. 39146." Public Utility Commission of Texas. Approved June 6, 2011. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp.

[567] The Cadmus Group, Inc, "*Entergy Energy-Efficiency Portfolio Evaluation Report 2014 Program Year*". April 1, 2015. Annual operating hours based on metering at a total of 35 manufacturing and retail buildings in Arkansas.

[568] UI and CL&P Program Savings Documentation for 2013 Program Year, United Illuminating Company. October 2012.

[569] DEER 2011 report. Average of coincidence factor for Manufacturing – Bio-Tech and Manufacturing – Light building types.

[570] The Cadmus Group, Inc, "*Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year*". March 14, 2014. Annual operating hours based on metering 139 circuits at 18 office buildings in Arkansas.

[571] The Cadmus Group, Inc, "*Entergy Energy-Efficiency Portfolio Evaluation Report 2014 Program Year*". April 1, 2015. Annual operating hours based on metering at an additional nine office buildings in Arkansas.
572 Determined from literature review of past projects completed in various jurisdictions throughout the United

Building Type	AOH	CF
Parking Structure	7,884	1.00
Public Assembly	2,638	0.56
Public Order and Safety	3,472	0.75
Religious	1,824	0.53
Retail: Excluding Malls & Strip Centers	3,668	0.69[573]
Retail: Enclosed Mall	4,813	0.93
Retail: Strip Shopping & Non-enclosed Mall	3,965	0.90
Service (Excluding Food)	3,406	0.90
Warehouse: Non-refrigerated	3,501	0.77
Warehouse: Refrigerated	3,798	0.84

Interactive Effects

Lighting in air conditioned and refrigerated spaces adds heat to the space, increasing the cooling requirement during the cooling season and decreasing the heating requirement during the heating season. The decrease in waste heat from lighting mitigates these effects, thus reducing electricity used for cooling and increasing electricity or gas used for heating.

Deemed interactive effects factors for both demand and energy savings are presented in Table 383 and Table 384. These factors represent the percentage increase or decrease in energy savings for the refrigeration system's electric load attributed to the heat dissipated by the more efficient lighting system. For example, a factor of 1.20 indicates a 20% savings. The methodology for applying these Interactive Effects Factors to calculate savings is discussed in the

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States

[573] The Cadmus Group, Inc, "*Entergy Energy-Efficiency Portfolio Evaluation Report 2014 Program Year".* April 1, 2015. Annual operating hours based on metering at a total of 35 manufacturing and retail buildings in Arkansas.

Calculation of Deemed Savings section.

A detailed description of the derivation of interactive effects is available in Appendix I.

Table 383: Commercial Conditioned and Refrigerated Space Interactive Effects Factors

Building Type	Temperature Description	Heating Type	IEF_D	IEF_E
All building types (Except Outdoor & Parking Structure)	Air Conditioned Space – Normal Temps. (> 41°F)	Gas	1.20	1.09
		Electric Resistance		0.87
		Heat Pump		1.02
		Heating Unknown [574]		0.98
	Refrigerated Space – Med. Temps. (33-41°F)	All	1.25	1.25
	Refrigerated Space – Low Temps. (-10-10°F)	All	1.30	1.30

Table 384: Commercial Conditioned Space Gas Heating Penalty

Building Type	Heating Type	IEF_G (Therms/kWh)
All building types (Except Outdoor & Parking Structure)	Gas	-0.008
	Heating Unknown[575]	-0.004

Note that the interactive effects for demand (kW), energy (kWh) and natural gas (therms) should be utilized for all programs and installations of lamps covered by this measure.

Annual kW, Annual kWh, and Lifetime kWh Savings Calculation Example for GSILs

A 12 watt omni-directional LED is installed in an office in program year (PY) 2017. In July 2014, due to First Tier EISA 2007 standards going into effect, the baseline changed to 43 watts. In January 2023, due to Second Tier EISA 2007 standards going into effect, the baseline changes again to 20 watts. Necessary inputs for calculating the kWh savings include the EUL (9 years), IEF_D (1.2 for all standard heating/cooling types), IEF_E (0.98 for unknown heating/cooling type), summer coincidence factor (0.54), and Hours of Use per Year (3,227 hours for Office). All kWh values are rounded to the second decimal place.

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[574] These values should be used for programs where heat type cannot be determined.

[575] Ibid.

PY 2017 through PY 2022 Savings: From January 2017 to December 2022, the baseline is 43 watts. 2023 – 2017 is 7 years.

$$2017\ to\ 2022\ kW\ Savings\ (for\ each\ year) = \left(\frac{[43-12]}{1000}\right) \times 0.54 \times 1.2 = 0.0201\ kW$$

$$Cumulative\ 2016\ to\ 2022\ kWh\ Savings = \left(\frac{[43-12]}{1000}\right) \times 3{,}227 \times 0.98 \times 6 = 588.22\ kWh$$

(310)

PY 2023 through PY 2025 Savings: In January 2023, the baseline changes to the 2nd Tier EISA 2007 standard. The baseline wattage changes from 43 watts to 20 watts. The remaining measure life is 3 years.

$$2023\ to\ 2025\ kW\ Savings\ (for\ each\ year) = \left(\frac{[20-12]}{1000}\right) \times 0.54 \times 1.2 = 0.0052\ kW$$

$$Cumulative\ 2023\ to\ 2025\ kWh\ Savings = \left(\frac{[20-12]}{1000}\right) \times 3{,}227 \times 0.98 \times 3 = 75.90\ kWh$$

(311)

Lifetime kWh Savings:

$$588.22 + 75.90 = 64.12\ kWh\ lifetime\ savings$$

All other technologies are currently available and there is no reason to anticipate that a fixture would not be able to be replaced with a like fixture. Therefore, a dual baseline should not be applied to any fixture type other than an EISA compliant GSILs.

3.7 Other

3.7.1 Plug Load Occupancy Sensors

Measure Description

Plug load occupancy sensors are devices that control low wattage devices (<150 watts) using an occupancy sensor. Common applications are computer monitors, desk lamps, printers, and other desktop equipment. Three wattage tiers were analyzed based on available products in the market: 25, 50, and 150 watt.

Baseline and Efficiency Standards

Table 385 contains the baseline annual energy consumption and demand for plug loads.

Table 385: Plug Load Without Occupancy Sensors– Baseline Data

Size (watts)	Annual Energy Consumption[576] (kWh/ unit)	Annual Operating Hours	Demand (kW/unit)
25	110	4,400	0.025
50	220	4,400	0.05
150	555	3,700	0.15

Note: Italic numbers are endnotes not footnotes.

Table 386 contains the annual energy consumption and demand for plug load occupancy sensors.

Table 386: Plug Load Occupancy Sensors – Minimum Requirements

Size (watts)	Annual Energy Consumption[577] (kWh/ unit)	Annual Operating Hours	Demand[1] (kW/ unit)
25	45	1452	0.025
50	91	1452	0.050
150	234	1250	0.150

Note: Italic numbers are endnotes not footnotes.

Estimated Useful Life (EUL)

According to DEER 2008, the estimated useful life (EUL) is eight years.

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[576] Nexant's proprietary analysis results from multiple resources.

[577] Ibid.

Deemed Savings Values

Deemed measure costs and savings for various sized plug load occupancy sensors are provided in Table 387.

Table 387: Plug Load Occupancy Sensors – Unit Measure Savings

Measure	Demand Savings[1] (kW/ unit)	Annual Energy Savings[1] (kWh/ unit)
25 watt sensor	0.000	65
50 watt sensor	0.000	129
150 watt sensor	0.000	321

Note: Italic numbers are endnotes not footnotes.

Calculation of Deemed Savings

Four resources contained information on plug load occupancy sensors. The energy savings and amount of equipment controlled per sensor varied widely. The values for energy and demand savings are given in Table 388.

Table 388: Review of Plug Load Occupancy Sensor Measure Information

Available Resource	Type	Size	Annual Energy Saving (kWh/unit)	Demand Savings (kW/unit)
PG&E 2003[40]	Plug load occupancy sensor	150	300	0.124
Quantec 2005[47]	Power strip occupancy sensor	N/A	27	0.012
DEER 2005[65]	Plug load occupancy sensor	50	143	0.051
KEMA 2010[24]	Plug load occupancy sensor	50	221	0.025
NPCC 2005[37]	Cubicle occupancy sensor	25	55	0.025
PacifiCorp 2009[44]	Unitary savings included in comprehensive potential study		196	0.00

Note: Italic numbers are endnotes not footnotes. (See Section 4.4 Commercial Measures References)

3.7.2 Advanced Power Strips

Measure Description

This measure involves the installation of a multi-plug Advanced Power Strip (APS) that has the ability to automatically disconnect specific loads depending on the power draw of a specified or "master" load. A load sensor in the strip disconnects power from the control outlets when the master power draw is below a certain threshold. The energy savings calculated for this measure are derived by estimating the number of hours that devices in typical office workstations are in "off" or "standby" mode and the number of watts consumed by each device in each mode. When the master device (i.e. computer) is turned off, power supply is cut to other related equipment (i.e. monitors, printers, speakers, etc.), eliminating these loads.

Commercial deemed savings were developed based on reported plug load electricity consumption. The assumed mix of peripheral electronics, and related data, are presented in the following table.

Table 389 shows the assumed number of hours each device is typically in "off" mode. Given the assumption that the master device, a desktop computer, will only be in off mode during non-work hours, watts consumed by devices in standby-mode are not counted toward energy savings for a commercial APS. Workday and weekend day watts consumed in off mode are a function of hours multiplied by estimated watt consumption.

There are two deemed savings paths available: Savings can be estimated as follows: 1) per APS for an average complete system or 2) by individual peripheral device.

Table 389: Peripheral Watt Consumption Breakdown

Peripheral Device	Workday Daily Off Hours[578]	Weekend Daily Off Hours	Off Power (W)[579,580]	Workday (W-hr) [A]	Weekend (W-hr) [B]
Coffee Maker	16	24	1.14	18.24	27.36
Computer: Desktop	16	24	3.3	52.80	79.20
Computer: Laptop	16	24	4.4	70.40	105.60
Computer Monitor: CRT	16	24	1.5	24.00	36.00
Computer Monitor: LCD	16	24	1.1	17.60	26.40
Computer Speakers	16	24	2.3	36.80	55.20
Copier	16	24	1.5	24.00	36.00
External Hard Drive	16	24	3.0	48.00	72.00
Fax Machine: Inkjet	16	24	5.3	84.80	127.20
Fax Machine: Laser	16	24	2.2	35.20	52.80
Media Player: Blu-Ray	16	24	0.1	1.60	2.40
Media Player: DVD	16	24	2.0	32.00	48.00
Media Player: DVD-R	16	24	3.0	48.00	72.00
Media Player: DVD/VCR	16	24	4.0	64.00	96.00
Media Player: VCR	16	24	3.0	48.00	72.00
Microwave	16	24	3.08	49.28	73.92

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[578] Commercial hours of operation based on typical 8-hour workday schedule.

[579] New York State Energy Research and Development Authority (NYSERDA), "Advanced Power Strip Research Report". August 2011.

[580] Standby Power Summary Table, Lawrence Berkeley National Laboratory. http://standby.lbl.gov/summary-table.html.

Peripheral Device	**Workday Daily Off Hours**[578]	**Weekend Daily Off Hours**	**Off Power (W)**[579,580]	**Workday (W-hr) [A]**	**Weekend (W-hr) [B]**
Modem: Cable	0	24	3.8	0.00	91.20
Modem: DSL	0	24	1.4	0.00	33.60
Multi-Function Printer: Inkjet	16	24	5.26	84.16	126.24
Multi-Function Printer: Laser	16	24	3.12	49.92	74.88
Phone with Voicemail	16	24	2.92	46.72	70.08
Printer: Inkjet	16	24	1.3	20.80	31.20
Printer: Laser	16	24	3.3	52.80	79.20
Router	16	24	1.7	27.20	40.80
Scanner	16	24	2.1	33.60	50.40
Television: CRT	16	24	1.6	25.60	38.40
Television: LCD	16	24	0.5	8.00	12.00
Television: Plasma	16	24	0.6	9.60	14.40
Television: Projection	16	24	7.0	112.00	168.00

Baseline & Efficiency Standard

The baseline case is the absence of an APS, where peripherals are plugged into a traditional surge protector or wall outlet. The baseline assumes a typical mix of office equipment, shown in Table 389.

Estimated Useful Life (EUL)

The estimated useful life (EUL) is 10 years according to the New York State Energy Research and Development Authority (NYSERDA) Advanced Power Strip Research Report from August 2011.[581]

Calculation of Deemed Savings

Energy Savings

Energy savings for a 7-plug APS in use in a commercial setting are calculated using the following algorithm, where kWh saved are calculated and summed for all peripheral devices:

$$\Delta kWh = \frac{\sum(Workdays * \ A_i) + \sum\big((365 - Workdays) * \ B_i\big)}{1{,}000} \tag{312}$$

Where:

$Workdays =$ Average number of workdays per year[582] = 240 days

$A =$ Watt-hours/day consumed in the “off” mode per workday

$B =$ Watt-hours/day consumed in the “off” mode per weekend day

$1{,}000 =$ Constant to convert watts to kilowatts

Demand Savings

No demand savings are awarded for this measure due to the assumption that typical office equipment will be operating throughout the workday.

Deemed Savings Values

Energy savings from an APS in an office setting are estimated to be 71.4 kWh using the above equation and assuming six unique peripheral devices. Energy savings per peripheral device are also available in the following table.

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[581] New York State Energy Research and Development Authority (NYSERDA): Advanced Power Strip Research Report, p. 30. August 2011.

[582] Assuming 50 working weeks, deducting 2 weeks for federal holidays and another 2 weeks for vacation; 48 weeks x 5 days/week = 240 days

Table 390: Deemed Savings for Commercial APS (per Peripheral Device)

Peripheral Device	kWh Savings
Coffee Maker	7.8
Computer: Desktop	22.6
Computer: Laptop	30.1
Computer Monitor: CRT	10.3
Computer Monitor: LCD	7.5
Computer Speakers	15.7
Copier	10.3
External Hard Drive	20.5
Fax Machine: Inkjet	36.3
Fax Machine: Laser	15.0
Media Player: Blu-Ray	0.7
Media Player: DVD	13.7
Media Player: DVD-R	20.5
Media Player: DVD/VCR	27.4
Media Player: VCR	20.5
Microwave	21.1
Modem: Cable	11.4
Modem: DSL	4.2
Multi-Function Printer: Inkjet	36.0
Multi-Function Printer: Laser	21.3
Phone with Voicemail	20.0
Printer: Inkjet	8.9
Printer: Laser	22.6
Router	11.6
Scanner	14.4
Television: CRT	10.9
Television: LCD	3.4
Television: Plasma	4.1
Television: Projection	47.9
Average APS: Small Business Whole System[583]	**61.2**

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[583] Assuming Computer Monitor: LCD, Computer Speakers, Modem: Average, Printer: Average, and Scanner. Computer not included because it is assumed to be the controlling load. This average value is meant to apply to a typical small business application and should not be applied in other applications. For other applications, calculate the savings for each individual equipment type. kWh savings = 7.5 + 15.7 + [(11.4 + 4.2) ÷ 2] + [(8.9 + 22.6) ÷ 2] + 14.4 = 61.2 kWh.

3.7.3 Computer Power Management

Measure Description

Computer Power Management (CPM) is the automated control of the power, or "sleep" settings of network desktop and notebook computer equipment. CPM involves using built-in features or add-on software programs to switch off displays and enable computers to enter a low power setting called sleep mode during periods of non-use. This measure applies to both ENERGY STAR® and conventional computer equipment, and assumes that the same computer equipment is being used before and after CPM settings are activated. The power draw of a computer is assumed to be roughly equivalent during active and idle periods, so for the purposes of calculating savings, we will combine the terms active and idle as "active/idle" throughout the document.

Baseline and Efficiency Standards

The baseline conditions are the estimated number of hours that the computer spends in idle and sleep mode before the power settings are actively managed. The efficient conditions are the estimated number of hours that the computer spends in active/idle and sleep mode after the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used.

Estimated Useful Life (EUL)

The EUL of this measure is based on the useful life of the computer equipment which is being controlled. Computer technology may continue to function long after technological advances have diminished the usefulness of the equipment. The EUL for Computer Power Management is 4 years.[584]

Calculation of Deemed Savings

Deemed demand and annual savings are based on the ENERGY STAR® Low Carbon IT Savings calculator. The coincidence factor, default equipment wattages in Table 391, and the active/idle and sleep hours are taken from assumptions in the ENERGY STAR® calculator with all equipment set to enter sleep mode after 15 minutes of inactivity.

$$kWh_{savings} = \frac{W_{active/idle}\left(hours_{active/idle_{pre}} - hours_{active/idle_{post}}\right) + W_{sleep}\left(hours_{sleep_{pre}} - hours_{sleep_{post}}\right)}{1{,}000}$$

(313)

$$kW_{savings} = \frac{(W_{active/idle} - W_{sleep}) * CF}{1{,}000}$$

(314)

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[584] The Regional Technical Forum, Measure workbook for Commercial: Non-Res Network Computer Power Management. http://rtf.nwcouncil.org/measures/measure.asp?id=95. Accessed August 2013.

Where:

$W_{active/idle}$ = total wattage of the equipment, including computer and monitor, in active/idle mode; see Table 391

$hours_{active/idle_{pre}}$ = annual number of hours the computer is in active/idle mode before computer management software is installed = 6,293

$hours_{active/idle_{post}}$ = annual number of hours the computer is in active/idle mode after computer management software is installed = 1,173

W_{sleep} = total wattage of the equipment, including computer and monitor, in sleep mode; see Table 391

$hours_{sleep_{pre}}$ = annual number of hours the computer is in sleep mode before computer management software is installed = 0

$hours_{sleep_{post}}$ = annual number of hours the computer is in sleep mode after computer management software is installed = 5,120

CF = Coincidence Factor[585] = 0.25

1,000 = Conversion factor

Table 391: Computer Power Management - Equipment Wattages

Equipment	W_{sleep}	$W_{active/idle}$
Conventional LCD Monitor	1	32
Conventional Computer	3	69
Conventional Notebook (including display)	2	21

Table 392: Computer Power Management - Deemed Savings Values

Equipment	kWh savings	kW savings
Conventional LCD Monitor	158.72	0.008
Conventional Computer	337.92	0.017
Conventional Notebook (including display)	97.28	0.005

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[585] The coincidence factor is the percentage of time the computer is assumed to be not in use during the hours 3pm to 6pm from the ENERGY STAR® calculator modeling study.

3.7.4 Beverage and Snack Machine Controls

Measure Description

This measure involves the installation of a beverage or snack machine control on an existing refrigerated beverage vending machine, refrigerated glass-front reach-in cooler, or non-refrigerated snack machine with a lighted display and no existing controls. Applicable control types include occupancy or schedule-based controls installed on the unit that will reduce energy consumption by powering down the refrigeration and lighting systems when the control does not detect human activity and by reducing the refrigeration process, while still maintaining product quality.

Baseline and Efficiency Standards

The baseline for this measure is an existing 120-volt single phase refrigerated or non-refrigerated beverage vending machine, refrigerated reach-in cooler, or non-refrigerated snack machine with a lighted display and no existing controls. Current federal regulations specify that refrigerated bottled or canned beverage vending machines manufactured on or after August 31, 2012 must meet increased energy conservation standards.[586,587] Therefore, any vending machine occupancy controls installed on refrigerated beverage vending machines must be installed on machines that were manufactured and purchased before August 31, 2012 to be eligible for this measure.

Estimated Useful Life (EUL)

The estimated useful life (EUL) for this measure for occupancy-based vending controls is five years.[588] The EUL for schedule-based controls is ten years.[589]

Calculation of Deemed Savings

Deemed Savings Values

Table 393: Occupancy-based Controls – Energy and Demand Savings by Machine Type

Machine Type	Annual Energy Savings (kWh/unit)	Peak Demand Savings (kW/unit)
Refrigerated beverage vending machine	1,612	0.030
Refrigerated glass-front reach-in cooler	1,209	0.035
Non-refrigerated snack vending machine	343	0.006

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[586] U.S. DOE. Refrigerated Beverage Vending Machines: Standards and Test Procedures. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/24.

[587] Refrigerated bottled or canned beverage vending machines manufactured on or after August 31, 2012 must meet the energy conservation standards specified in the Code of Federal Regulations, 10 CFR 421.296. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-292.pdf

[588] Database for Energy Efficiency Resources (DEER) 2014. Used value specified for Vending Machine Controllers.

[589] Energy & Resource Solutions (ERS), “Measure Life Study”. Prepared for the Massachusetts Joint Utilities. November 17, 2005. Used median value specified for Novelty Cooler Shutoff.

Table 394: Schedule-based Controls – Energy and Demand Savings by Machine Type

Machine Type	Annual Energy Savings (kWh/unit)	Peak Demand Savings (kW/unit)
Refrigerated beverage vending machine	Use energy savings algorithms with site-specific annual operating hours	0
Refrigerated glass-front reach-in cooler		0
Non-refrigerated snack vending machine		0

Energy Savings

The following energy savings estimates align conservatively with various other vending miser energy savings studies.[590,591,592] Additionally, in comparing to savings calculation methodologies for schedule-based controls from other TRMs, the energy savings factors defined in this measure produce energy savings that are more in line with expected savings percentages. This is likely due to the exclusion of a morning start-up penalty, used to represent the additional energy required to return to typical operating temperatures, from some TRMs.[593]

$$kWh_{Savings} = W_{CL} \times \frac{1\ kW}{1000\ W} \times AOH \times \ ESF$$

(315)

Where:

W_{CL} = Connected load of controlled beverage or snack machine; if unknown, use default values from Table 395

AOH = Annual Operating Hours = 8,760 hours for occupancy-based controls; for schedule-based controls, assume one less hour than the number of hours that the installation location is closed per day

ESF = Energy Savings Factor (Table 396)

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[590] Deru, M., et. al. 2003, "*Analysis of NREL Cold-Drink Vending Machines for Energy Savings*". June. National Renewable Energy Laboratory (NREL). http://www.nrel.gov/docs/fy03osti/34008.pdf

[591] Foster-Miller, Inc., "Vending Machine Energy Efficiency Device Engineering Evaluation and Test Report". June 1, 2000. Bayview Technology Group, Inc. http://www.energymisers.com/downloads/FosterMillerReportVMEnergyNoCover.pdf

[592] Ritter, J & Hugghins, J. 2000 Joel Hugghins, "Vending Machine Energy Consumption and Vending Miser Evaluation". October 31. Texas A&M Energy Systems Laboratory. http://repository.tamu.edu/bitstream/handle/1969.1/2006/ESL-TR-00-11-01.pdf

[593] Select Energy Services, Inc., "Analysis of Cooler Control Energy Conservation Measures: Final Report. March 3, 2004. Submitted to NSTAR Electric.

Table 395: Default Connected Load by Machine Type

Machine Type	Connected Load (W)
Refrigerated beverage vending machine	400
Refrigerated glass-front reach-in cooler	460
Non-refrigerated snack vending machine	85

Table 396: Energy Savings Factor by Machine Type[594]

Machine Type	ESF
Refrigerated beverage vending machine	46%
Refrigerated glass-front reach-in cooler	30%
Non-refrigerated snack vending machine	46%

Demand Savings

Metered data from a Sacramento Municipal Utility District (SMUD) program evaluation found an average demand impact of 0.030 kW/unit using a peak definition of 2 PM to 6 PM.[595] This impact equates to a 7.5% demand reduction, using the USA Technologies, Inc. controlled load estimate of 400 W for refrigerated beverage vending machines. Assuming a comparable load reduction for other equipment types, this measure estimates an average demand impact of 0.035 kW/unit for refrigerated reach-in coolers and 0.006 kW/unit for non-refrigerated snack vending machines.

No demand savings are claimed for schedule-based beverage and snack machine controls because energy savings typically occur during off-peak hours.

$$kW_{Savings} = W_{CL} \times \frac{1\ kW}{1000\ W} \times DSF$$

(316)

Where:

W_{CL} = Connected load of controlled beverage or snack machine; if unknown, use default values from Table 395

DSF = Demand Savings Factor = 7.5% (occupancy controls); 0% (schedule controls)

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[594] Product data sheets from USA Technologies, Inc. http://www.energymisers.com.

[595] Chappell, C., et. al. 2002 "Does It Keep The Drinks Cold and Reduce Peak Demand?: An Evaluation of a Vending Machine Control Program". Heschong Mahone Group, Sacramento Municipal Utility District (SMUD), RLW Analytics, Inc., and American Council for an Energy-Efficient Economy (ACEEE). http://aceee.org/proceedings-paper/ss02/panel10/paper05

3.7.5 Door Heater Controls for Refrigerated Display Cases (Retrofit Only)

Measure Description[596]

This measure refers to the installation of anti-sweat door heater controls on glass doors for reach-in commercial refrigerators and freezers. The added control reduces both heater operation time and cooling load.

Baseline and Efficiency Standards

Qualifying equipment includes any controls that reduce the run time of door and frame heaters for refrigerated cases. The baseline efficiency case is a cooler or freezer door heater that operates 8,760 hours per year without any controls. The high efficiency case is a cooler (medium temperature) or freezer (low temperature) door heater connected to a heater control system. There are no state or federal codes or standards that govern the eligibility of equipment.

Estimated Useful Life (EUL)

The estimated useful life (EUL) is 12 years as defined in the DEER database.[597]

Deemed Savings Values

Annual and Peak Energy Savings

Annual and peak energy savings due to anti-sweat door heater controls in medium and low temperature refrigerated cases for various Arkansas locations are provided in the following table. Savings provided in the table are per linear foot of glass door controlled heater.

Table 397: Anti-Sweat Heater Controls – Savings per Linear Foot of Case by Location

Weather Zone	Med-Temperature		Low-Temperature	
	Annual kWh/ft. Savings	kW/ft. Savings	Annual kWh/ft. Savings	kW/ft. Savings
El Dorado	184	0.0025	427	0.0094
Fayetteville	219	0.0029	508	0.0112
Fort Smith	215	0.0029	499	0.0110
Little Rock	198	0.0026	459	0.0101

Calculation of Deemed Savings

A door heater controller senses dew point (DP) temperature in the store and modulates power supplied to the heaters accordingly. DP inside a building is primarily dependent on the moisture content of outdoor ambient air. Because the outdoor DP varies between weather zones, weather data from each weather zone must be analyzed to obtain a DP profile.

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[596] This work paper includes definitions and standards from the PG&E work paper “Anti-Sweat Heat (ASH) Controls” from May 2009.

[597] California’s Database for Energy Efficiency Resources (DEER 2008).

Indoor dew point (t_{d-in}) is related to outdoor dew point (t_{d-out}) according to the following equation. Indoor dew point was calculated at each location for every hour in the year.[598]

$$t_{d-in} = 0.005379 \times t_{d-out}^2 + 0.171795 \times t_{d-out} + 19.870006$$

(317)

In the base case, the door heaters are all on and have a duty of 100% irrespective of the indoor DP temperature. For the post retrofit case, the duty for each hourly reading was calculated by assuming a linear relationship between indoor DP and duty cycle for each bin reading. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89°F or lower DP and all on (duty cycle of 100%) at 52.87°F or higher DP for a typical supermarket. Between these values, the door heaters' duty cycle changes proportionally:

$$Door\ Heater\ ON\% = \frac{t_{d-in} - All\ OFF\ Setpt\ (42.89°F)}{All\ ON\ Setpt\ (52.87°F) - All\ OFF\ Setpt\ (42.89°F)}$$

(318)

Because the controller only changes the run-time of the heaters, instantaneous door heater power (kW_{ASH}) as a resistive load remains constant per linear foot of door heater at:

$$kW_{ASH} = \frac{kW}{ft} \times L_{DH}$$

(319)

Where kW/ft. = 0.0368 for medium temperature and 0.0780 for low temperature applications.

Door heater energy consumption for each hour of the year is a product of power and run-time:

$$kWh_{ASH-Hourly} = kW_{Ash} \times Door\ Heater\ ON\% \times 1\ hour$$

(320)

Total annual door heater energy consumption $\left(kWh_{ASH}\right)$ is the sum of all hourly reading values:

$$kWh_{ASH} = \sum kWh_{ASH-Hourly}$$

(321)

Energy savings were also estimated for reduced refrigeration loads using average system efficiency and assuming that 35% of the anti-sweat heat becomes a load on the refrigeration system.[599] The cooling load contribution from door heaters can be given by:

$$Q_{ASH}(ton) = 0.35 \times kW_{ASH} \times \frac{3{,}413\ \frac{Btu/h}{ton}}{12{,}000\ \frac{Btu/h}{ton}} \times Door\ Heater\ ON\%$$

(322)

The compressor power requirements are based on calculated cooling load and energy-efficiency

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[598] Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & Electric Company. May 29, 2009.

[599] Southern California Edison (SCE), 1999, *"A Study of Energy Efficient Solutions for Anti-Sweat Heaters."* Prepared for the Refrigeration Technology and Test Center (RTTC). December 14. https://www.sce.com/NR/rdonlyres/B1F7A3B4-719D-4CBB-87EB-E27F7CE7ECE0/0/Anti_Sweat_Heater_Report.pdf.

ratios obtained from the manufacturers' data. The compressor analysis is limited to the cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

The typical efficiency for a medium temperature case is 9 EER (1.33 kW/ton), and the typical efficiency for a low temperature case is 5 EER (2.40 kW/ton).[600]

Energy used by the compressor to remove heat imposed by the door heaters for each hourly reading is determined based on calculated cooling load and EER, as outlined below:

$$kWh_{Refrig-Hourly} = Q_{ASH} \times \frac{kW}{ton} \times 1\ hour$$

(323)

Total annual refrigeration energy consumption is the sum of all hourly reading values:

$$kWh_{Refrig} = \sum kWh_{Refrig-Hourly}$$

(324)

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of all hourly reading values:

$$kWh_{Total} = kWh_{Refrig} + kWh_{ASH}$$

(325)

Once the annual energy consumption (direct door heaters and indirect refrigeration) has been determined for the baseline and post-retrofit case, the total energy savings are calculated by the following equation:

$$Annual\ Energy\ Savings = \Delta kWh = kWh_{Total-Baseline} - kWh_{Total-Post\ Retrofit}$$

(326)

It is important to note that while there might be instantaneous demand savings as a result of the cycling of the door heaters, peak demand savings will only be due to the reduced refrigeration load. Peak demand savings was calculated by the equation shown below:

$$Peak\ Demand\ Savings = \Delta kW = \frac{kWh_{Refrig-Baseline} - kWh_{Refrig-Post\ Retrofit}}{8{,}760\ hr/yr}$$

(327)

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[600] Chapter 15 of the 2010 ASHRAE Handbook for Refrigeration

3.7.6 Refrigerated Case Night Covers

Measure Description

This measure applies to the installation of night covers on otherwise open vertical (multi-deck) and horizontal (coffin-type) low-temperature (L) and medium temperature (M) display cases to decrease cooling load of the case during the night. It is recommended that these film-type covers have small, perforated holes to decrease the build-up of moisture.

Cases may be either: Self Contained (SC) having both evaporator and condenser coils, along with the compressor as part of the unit or Remote Condensing (RC) where the condensing unit and compressor are remotely located. Refrigerated case categories[601] are as follows:

- Vertical Open (VO): Equipment without doors and an air-curtain angle ≥ 0° and < 10°
- Semivertical Open (SVO): Equipment without doors and an air-curtain angle ≥ 10° and < 80°
- Horizontal Open (HO): Equipment without doors and an air-curtain angle ≥ 80°

Baseline & Efficiency Standard

The baseline standard for this measure is an open low-temperature or medium temperature refrigerated display case (vertical or horizontal) that is not equipped with a night cover.

The efficiency standard for this measure is any suitable material sold as a night cover. The cover must be applied for a period of at least six hours per night.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2014), refrigerated case night covers are assigned an EUL of 5 years.[602]

Deemed Savings

Due to the relatively consistent summer dry-bulb temperature across the representative Arkansas weather zones, deemed savings values are only provided for the average dry-bulb temperature of 96°F.

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[601] U.S. DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment, Commercial Refrigeration Equipment, Washington DC, p3-15

[602] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Table 398: Refrigerated Case Night Covers – Deemed Savings Values (per Linear Foot)[603]

Case Description	Temperature Range (°F)	kWh Savings (kWh/ft.)	kW Savings (kW/ft.)
Vertical Open, Remote Condensing Medium Temperature	10 – 35 °F	112	0.00
Vertical Open, Remote Condensing Low Temperature	< 10 °F	209	0.00
Vertical Open, Self-Contained Medium Temperature	10 – 35 °F	182	0.00
Semivertical Open, Remote Condensing Medium Temperature	10 – 35 °F	83	0.00
Semivertical Open, Self-Contained Medium Temperature	10 – 35 °F	162	0.00
Horizontal Open, Remote Condensing Medium Temperature	10 – 35 °F	42	0.00
Horizontal Open, Remote Condensing Low Temperature	< 10 °F	94	0.00
Horizontal Open, Self-Contained Medium Temperature	10 – 35 °F	132	0.00
Horizontal Open, Self-Contained Low Temperature	< 10 °F	288	0.00

Calculation of Deemed Savings

The following outlines the assumptions and approach used to estimate demand and energy savings due to installation of night covers on open low- and medium-temperature, vertical and horizontal, display cases. Heat transfer components of the display case include infiltration (convection), transmission (conduction), and radiation. This deemed savings approach assumes that installing night covers on open display cases will only reduce the infiltration load on the case. Infiltration affects cooling load in the following ways:

- Infiltration accounts for approximately 80% of the total cooling load of open vertical (or multi-deck) display cases.[604]
- Infiltration accounts for approximately 24% of the total cooling load of open horizontal (coffin or tub style) display cases.[605]

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[603] Pacific Gas & Electric (PG&E), 2009, "*Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases),* May 29,.

[604] ASHRAE 2006. Refrigeration Handbook. Retail Food Store Refrigeration and Equipment. Atlanta, Georgia. pp. 46.1,. 46.5, . 46.10.

[605] Ibid.

Installing night covers for a period of 6 hours per night can reduce the cooling load due to infiltration. This was modeled by the U.S. Department of Energy (DOE) for Vertical and Semivertical cases.

Table 399: Vertical & Semivertical Refrigerated Case Savings

Case Type[606]	VO.RC.M	VO.RC.L	VO.SC.M	SVO.RC.M	SVO.SC.M
kWh per day- before Night Curtain	50.52	118.44	38.98	38.48	32.82
kWh per day - with Night Curtain	46.84	111.58	36.99	35.74	31.05
Percent kWh Savings per Day	7%	6%	5%	7%	5%
Annual kWh Savings	1,343	2,504	726	1,000	646
Test Case Length (ft.)	12	12	4	12	4

Table 400: Horizontal Refrigerated Case Savings

Case Type[607]	HO.RC.M	HO.RC.L	HO.SC.M	HO.SC.L
kWh per day- before Night Curtain[608]	15.44	34.23	16.06	35.02
kWh per day - with Night Curtain	14.05	31.15	14.61	31.87
Percent kWh Savings per Day[609]	9%	9%	9%	9%
Annual kWh Savings	507	1,124	528	1,150
Test Case Length (ft.)	12	12	4	4

While the DOE also modeled the energy consumption for horizontal open cases, there was not an efficient case modeled with a night cover. The 9% energy savings as found by Faramarzi & Woodworth-Szleper[6] was used to determine the post kWh per day.

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[606] U.S. DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment, Commercial Refrigeration Equipment, Washington DC, pp.5-43- 5-47, 5A-5, 5A-6

[607] U.S. DOE, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial Industrial Equipment, Commercial Refrigeration Equipment, Washington DC, pp. 5-48 - 5-51. The level AD3 was used for the baseline efficiency.

[608] Ibid.

[609] ASHRAE 1999 Effects of Low-E Shields on the Performance and Power Use of a Refrigerated Display Case. Faramarzi & Woodworth-Szleper, p.8

3.7.7 Strip Curtains for Walk-in Coolers and Freezers

Measure Description

This measure applies to the installation of strip curtains on walk-in coolers and freezers to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated space. The avoided infiltration depends on the efficacy of the installed strip curtains as infiltration barriers and on the efficacy of the supplanted infiltration barriers, if applicable.

The most likely applications for this measure are supermarkets, convenience stores, restaurants, and refrigerated warehouses.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2014), strip curtains are assigned an EUL of 4 years.[610]

Baseline & Efficiency Standard

The baseline standard for this measure is a walk-in cooler or freezer that previously had either no strip curtain installed or an ineffective strip curtain installed.

The efficiency standard for this measure is a strip curtain added to a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used for low temperature applications.

Calculation of Deemed Savings

$$\Delta \mathrm{kWh} = \frac{\Delta kWh}{sqft} \times A \tag{328}$$

$$\Delta kW_{peak} = \frac{\Delta kW}{sqft} \times A \tag{329}$$

The annual energy savings due to infiltration barriers is quantified by multiplying savings per square foot by area using assumptions for independent variables described in the protocol introduction. The source algorithm from which the savings per square foot values are determined is based on Tamm's equation[611] (an application of Bernoulli's equation) and the ASHRAE handbook.[612] To the extent that evaluation findings are able to provide more reliable site specific inputs assumptions, they may be used in place of the default per square foot savings using the following equation.

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[610] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

[611] Kalterveluste durch kuhlraumoffnungen. Tamm W,. Kaltetechnik-Klimatisierung 1966;18;142-144

[612] American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6

$$\frac{\Delta kWh}{sqft} = \frac{365 \times t_{open} \times (\eta_{new} - \eta_{old}) \times 20 \times CD \times A \times \left\{\left[\frac{(T_i - T_r)}{T_i}\right] \times g \times H\right\}^{0.5} \times [\rho_i \times h_i - \rho_r \times h_r]}{3{,}412 \frac{Btu}{kWh} \times COP_{adj} \times A}$$

(330)

The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8,760. This assumption is based on general observation that refrigeration is constant for food storage, even outside of normal operating conditions. This is the most conservative approach in lieu of a more sophisticated model.

$$\frac{\Delta kW_{peak}}{sqft} = \frac{\Delta kWh}{8{,}760}$$

(331)

The ratio of the average energy usage during Peak hours to the total annual energy usage is taken from the load shape data collected by ADM for a recent evaluation for the CA Public Utility Commission[613] in the study of strip curtains in supermarkets, convenience stores, and restaurants.

The default savings values are listed in Table 401. Default parameters used in the source equations are listed in Table 402 through Table 405. The source equations and the values for the input parameters are adapted from the 2006-2008 California Public Utility Commission's evaluation of strip curtains.[614] The original work included 8,760-hourly bin calculations. The values used herein represent annual average values. For example, the differences in the temperature between the refrigerated and infiltrating airs are averaged over all times that the door to the walk-in unit is open.

Table 401: Strip Curtain Calculation Assumptions

Term	Unit	Values	Source
$\frac{\Delta kWh}{ft^2}$, Average annual kWh savings per square foot of infiltration barrier	$\frac{\Delta kWh}{ft^2}$	Calculated	Calculated
$\frac{\Delta kW}{ft^2}$, Average kW savings per square foot of infiltration barrier	$\frac{\Delta kW}{ft^2}$	Calculated	Calculated
20, Product of 60 seconds per minute and an integration factor of 1/3	$\frac{sec}{min}$	20	4
g, Gravitational constant	$\frac{ft}{s^2}$	32.174	Constant
3,412, Conversion factor: number of Btus in one kWh	$\frac{Btu}{kWh}$	3,412	Conversion factor

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[613] http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf

[614] http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/2006-2008+Energy+Efficiency+Evaluation+Report.htm. The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units. The temperature and humidity of the infiltrating air and the COP of the units have been modified to reflect the PA climate.

Table 402: Strip Curtain Calculation Assumptions for Supermarkets

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains	*None*	0.88	0.88	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.00	0.58 0.00 0.00	1
C_d , Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli's law and actual observed infiltration rates	*None*	0.366	0.415	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	132	102	1
A, Doorway area	ft^2	35	35	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	71	67	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	37	5	1
ρ_i, Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.074	3
h_i, Enthalpy of the infiltrating air, based on 55% RH	$\frac{Btu}{lb}$	26.935	24.678	3
ρ_r, Density of the refrigerated air, based on 80% RH	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r, Enthalpy of the refrigerated air, based on 80% RH	$\frac{Btu}{lb}$	12.933	2.081	3
COP_{adj}, Time-dependent (weather dependent) coefficient of performance of the refrigeration system; based on nominal COP of 1.5 for freezers and 2.5 for coolers	*None*	3.07	1.95	1 and 2

Table 403: Strip Curtain Calculation Assumptions for Convenience Stores

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains	*None*	0.79	0.83	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.34	0.58 0.00 0.30	1
C_d , Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli's law and actual observed infiltration rates	*None*	0.348	0.421	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	38	9	1
A, Doorway area	ft^2	21	21	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	68	64	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	39	5	1
ρ_i, Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.075	3
h_i, Enthalpy of the infiltrating air, based on 55% RH	$\frac{Btu}{lb}$	25.227	23.087	3
ρ_r, Density of the refrigerated air, based on 80% RH	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r, Enthalpy of the refrigerated air, based on 80% RH	$\frac{Btu}{lb}$	13.750	2.081	3
COP_{adj}, Time-dependent (weather dependent) coefficient of performance of the refrigeration system; based on nominal COP of 1.5 for freezers and 2.5 for coolers	*None*	3.07	1.95	1 and 2

Table 404: Strip Curtain Calculation Assumptions for Restaurants

Term	Unit	Values		Source
		Cooler	Freezer	
η_{new}, Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains	*None*	0.80	0.81	1
η_{old}, Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.33	0.58 0.00 0.26	1
C_d, Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli's law and actual observed infiltration rates	*None*	0.383	0.442	1
t_{open}, Minutes walk-in door is open per day	$\frac{minutes}{day}$	45	38	1
A, Doorway area	ft^2	21	21	1
H, Doorway height	ft	7	7	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	70	67	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	39	8	1
ρ_i, Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.074	0.074	3
h_i, Enthalpy of the infiltrating air, based on 55% RH	$\frac{Btu}{lb}$	26.356	24.678	3
ρ_r, Density of the refrigerated air, based on 80% RH	$\frac{lb}{ft^3}$	0.079	0.085	3
h_r, Enthalpy of the refrigerated air, based on 80% RH.	$\frac{Btu}{lb}$	13.750	2.948	3
COP_{adj}, Time-dependent (weather dependent) coefficient of performance of the refrigeration system; based on nominal COP of 1.5 for freezers and 2.5 for coolers	*None*	3.07	1.95	1 and 2

Table 405: Strip Curtain Calculation Assumptions for Refrigerated Warehouses

Term	Unit	Values	Source
η_{new} , Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains	*None*	0.89	1
η_{old} , Efficacy of the old strip curtain with Pre-existing curtain with no Pre-existing curtain unknown	*None*	0.58 0.00 0.54	1
C_d , Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli's law and actual observed infiltration rates	*None*	0.425	1
t_{open} , Minutes walk-in door is open per day	$\frac{minutes}{day}$	494	1
A, Doorway area	ft^2	80	1
H, Doorway height	ft	10	1
T_i, Dry-bulb temperature of infiltrating air, Rankine = Fahrenheit + 459.67	$°F$	59	1 and 2
T_r, Dry-bulb temperature of refrigerated air, Rankine = Fahrenheit + 459.67	$°F$	28	1
ρ_i, Density of the infiltration air, based on 55% RH	$\frac{lb}{ft^3}$	0.076	3
h_i, Enthalpy of the infiltrating air, based on 55% RH	$\frac{Btu}{lb}$	20.609	3
ρ_r, Density of the refrigerated air, based on 80% RH	$\frac{lb}{ft^3}$	0.081	3
h_r, Enthalpy of the refrigerated air, based on 80% RH	$\frac{Btu}{lb}$	9.462	3
COP_{adj}, Time-dependent (weather dependent) coefficient of performance of the refrigeration system; based on nominal COP of 1.5 for freezers and 2.5 for coolers	*None*	1.91	1 and 2

Sources

1) The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.
2) For refrigerated warehouses, we used a bin calculation method to weight the outdoor temperature by the infiltration that occurs at that outdoor temperature. This tends to shift the average outdoor temperature during times of infiltration higher (e.g. from 54 °F year-round average to 64 °F). We also performed the same exercise to find out effective outdoor temperatures to use for adjustment of nominal refrigeration system COPs.
3) Density and enthalpy of infiltrating and refrigerated air are based on psychometric equations based on the dry bulb temperature and relative humidity. Relative humidity is estimated to be 55% for infiltrating air and 80% for refrigerated air. Dry bulb temperatures were determined through the evaluation cited in Source 1.
4) In the original equation (Tamm's equation) the height is taken to be the difference between the midpoint of the opening and the 'neutral pressure level' of the cold space. In the case that there is just one dominant doorway through which infiltration occurs, the neutral pressure level is half the height of the doorway to the walk-in refrigeration unit. The refrigerated air leaks out through the lower half of the door, and the warm, infiltrating air enters through the top half of the door. We deconstruct the lower half of the door into infinitesimal horizontal strips of width W and height dh. Each strip is treated as a separate window, and the air flow through each infinitesimal strip is given by 60 x CD x A x {[(Ti – Tr) / Ti] x g x ΔHNPL }^0.5 where ΔHNPL represents the distance to the vertical midpoint of the door. In effect, this replaces the implicit wh1.5 (one power from the area, and the other from ΔHNPL) with the integral from 0 to h/2 of wh'0.5 dh' which results in wh1.5/(3×20.5¬).[615].

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[615] For more information see:" Alereza et al, 2008, " Are They Cool(ing)?:Quantifying the Energy Savings from Installing / Repairing Strip Curtains," IEPEC Conference 2008 Conference Proceedings.

Deemed Savings Values

Table 406: Strip Curtains – Deemed Savings Values

Type	Pre-existing Curtains	Energy Savings $\frac{\Delta kWh}{ft^2}$	Demand Savings $\frac{\Delta kW}{ft^2}$
Supermarket - Cooler	Yes	37	0.0042
Supermarket - Cooler	No	108	0.0123
Supermarket - Cooler	Unknown	108	0.0123
Supermarket - Freezer	Yes	119	0.0136
Supermarket - Freezer	No	349	0.0398
Supermarket - Freezer	Unknown	349	0.0398
Convenience Store - Cooler	Yes	5	0.0006
Convenience Store - Cooler	No	20	0.0023
Convenience Store - Cooler	Unknown	11	0.0013
Convenience Store - Freezer	Yes	8	0.0009
Convenience Store - Freezer	No	27	0.0031
Convenience Store - Freezer	Unknown	17	0.0020
Restaurant - Cooler	Yes	8	0.0009
Restaurant - Cooler	No	30	0.0034
Restaurant - Cooler	Unknown	18	0.0020
Restaurant - Freezer	Yes	34	0.0039
Restaurant - Freezer	No	119	0.0136
Restaurant - Freezer	Unknown	81	0.0092
Refrigerated Warehouse	Yes	254	0.0290
Refrigerated Warehouse	No	729	0.0832
Refrigerated Warehouse	Unknown	287	0.0327

3.7.8 Door Gaskets for Walk-in and Reach-in Coolers and Freezers

Measure Description

This measure applies to the installation of door gaskets on walk-in coolers and freezers to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated space. Additionally, the reduction in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

The most likely applications for this measure are supermarkets, convenience stores, restaurants, and refrigerated warehouses.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2014), door gaskets are assigned an EUL of 4 years.[616]

Baseline & Efficiency Standard

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets.

The efficiency standard for this measure is a new better-fitting gasket. Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, reducing the cooling load. Decrease in moisture entering the refrigerated space also prevents frost on cooling coils.

Calculation of Deemed Savings

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

(332)

$$\Delta kW_{peak} = \frac{\Delta kWh/ft}{8760} \times L$$

(333)

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[616] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Table 407: Door Gasket Assumptions

Term	Unit	Values
$\frac{\Delta kWh}{ft}$, Annual energy savings per linear foot of gasket	$\frac{\Delta kWh}{ft}$	See Table 408
$\frac{\Delta kW}{ft}$, Demand savings per linear foot of gasket	$\frac{\Delta kWh/ft}{8760}$	See Table 408
L, Total gasket length	*ft.*	As Measured

Deemed Savings Values

The demand and energy savings assumptions are based on DEER 2005 and analysis performed by Southern California Edison (SCE) and an evaluation of PG&E direct install refrigeration measures for program year 2006-2008.[617,618]

Table 408: Door Gaskets Deemed Savings Values (per Linear Foot of Gasket)

Refrigerator Type Type	Walk-In or Reach In	
	$\frac{\Delta kW}{ft}$	$\frac{\Delta kWh}{ft}$
Cooler	0.0017	15
Freezer	0.0131	115

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[617] Southern California Edison (SCE). WPSCNRRN0013 – Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases & Solid Doors of Reach-in Coolers and Freezers. 2007.

[618] Commercial Facilities Contract Group, 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01.

3.7.9 Zero Energy Doors

Measure Description

This measure applies to the installation of zero energy doors for refrigerated cases. Zero energy doors eliminate the need for anti-sweat heaters to prevent the formation of condensation on the glass surface by incorporating heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate glass panes, and/or non-metallic frames.

This measure cannot be used in conjunction with anti-sweat heat (ASH) controls.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2014), zero energy doors are assigned an EUL of 12 years.[619]

Baseline & Efficiency Standard

The baseline standard for this measure is a standard vertical reach-in refrigerated cooler or freezer with anti-sweat heaters on the glass surface of the doors.

The efficiency standard for this measure is a reach-in refrigerated cooler or freezer with special doors installed to eliminate the need for anti-sweat heaters. Doors must have either heat reflective treated glass, be gas-filled, or both.

Calculation of Deemed Savings

The energy and demand savings from the installation of zero-energy doors are listed below:

$$kW_{savings} = kW_{door} \times BF \tag{334}$$

$$kWh_{savings} = kW_{savings} \times 8760 \tag{335}$$

Where:

kW_{door} = Connected load kW of a typical reach-in cooler or freezer door with a heater

BF = Bonus factor for reducing cooling load from eliminating heat generated by the door heater from entering the cooler or freezer

8760 = Annual operating hours

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[619] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Table 409: Assumptions for Savings Calculations

Variable	Calculation Parameters
kW_{door}[620]	Freezers: 0.245 Coolers: 0.131
BF[621]	Low-Temp (-35° - 0°F): 1.36 Medium-Temp (0° - 20°F): 1.22 High-Temp (21° - 45°F): 1.15

Deemed Savings Values

Table 410: Zero Energy Doors – Deemed Savings Values (per door)[622]

Equipment, Evaporator Temperature	kWh Savings	kW Savings
Freezer, Low-Temperature	2,919	0.333
Cooler, Medium-Temperature	1,400	0.160
Cooler, High-Temperature	1,320	0.151

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[620] Based on two manufacturers and metered data (cooler 50-130W, freezer 200-320W). Efficiency Vermont Commercial Master Technical Reference Manual No. 2005-37.

[621] Bonus factor (1+0.65/COP + 0.35 x 0.75 x 0.29/2.5) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discuss compressor efficiencies with Saturated Suction Temperatures of -20ºF, 20ºF, and 45ºF, respectively, and a condensing temperature of 90ºF, and manufacturers assumption that 65% of heat generated by door enters the refrigerated case. Efficiency Vermont Commercial Master Technical Reference Manual No. 2005-37.

[622] Temperature ranges based on Commercial Refrigeration Rebate Form, p, 3. Efficiency Vermont. https://www.efficiencyvermont.com/Media/Default/docs/rebates/forms/efficiency-vermont-commercial-refrigeration-rebate-form.pdf. and Energy Effiiciency Supermarket Refrigeration, Wisconsin Electric Power Company, July 23, 1993.

3.7.10 Evaporator Fan Controls

Measure Description

This measure applies to the installation of evaporator fan controls. As walk-in cooler and freezer evaporators often run continuously, this measure consists of a control system that turns the fan on only when the unit's thermostat is calling for the compressor to operate.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2014), evaporator fan controls are assigned an EUL of 16 years.[623]

Baseline & Efficiency Standard

The baseline standard for this measure is an existing shaded pole evaporator fan motor with no temperature controls with 8,760 annual operating hours.

The efficiency standard for this measure is an energy management system (EMS) or other electronic controls to modulate evaporator fan operation based on temperature of the refrigerated space.

Calculation of Deemed Savings

The energy savings from the installation of evaporator fan controls are a result of savings due to the reduction in operation of the fan. The energy and demand savings are calculated using the following equations:

$$kW_{savings} = \left[\left(kW_{evap} \times n_{fans}\right) - kW_{circ}\right] \times \left(1 - DC_{comp}\right) \times DC_{evap} \times BF$$

(336)

$$kWh_{savings} = kW_{savings} \times 8760$$

(337)

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[623] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Where:

kW_{evap} = Nameplate connected load kW of each evaporator fan = 0.123 kW (default) [624]

kW_{circ} = Nameplate connected load kW of the circulating fan = 0.035 kW (default) [625]

n_{fans} = Number of evaporator fans

DC_{comp} = Duty cycle of the compressor = 50% (default) [626]

DC_{evap} = Duty cycle of the evaporator fan = Coolers: 100%; Freezers: 94% (default) [627]

BF = Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running = Low Temp.: 1.5, Medium Temp.: 1.3, High Temp.: 1.2 (default) [628]

8760 = Annual hours per year

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[624] Based on a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts.

[625] Wattage of fan used by Freeaire and Cooltrol.

[626] A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (35%-65%), Control (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor.

[627] An evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day).

[628] Bonus factor (1+1/COP) assumes 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.

3.7.11 Commercial Kitchen Demand Ventilation Controls

Measure Description

This measure refers to the installation of a demand ventilation control (DVC) system on kitchen exhaust fans as part of a system retrofit. The added control optimizes performance and savings by decreasing air flow and reducing outdoor makeup air heating energy.

Baseline and Efficiency Standards

The baseline for this measure is a standard commercial kitchen ventilation system with single speed exhaust and makeup air unit (MAU) fans and a simple on/off control. The high efficiency case is a kitchen exhaust system that incorporates ventilation control by varying the rate of kitchen ventilation (exhaust and/or makeup air fans) based on the energy and effluent output from the cooking appliances. There are no state or federal codes or standards that govern the eligibility of equipment.

Estimated Useful Life (EUL)

The estimated useful life (EUL) is 15 years.[629]

Deemed Savings Values

Annual and peak energy savings reflect retrofitting kitchen ventilation systems with a demand control ventilation (DCV) system. The partially deemed energy savings for this measure are identified per exhaust fan rated horsepower (HP) for varying building types.

Table 411: Deemed Savings per Exhaust Fan HP by Building Type With or Without a Dedicated Makeup Air (MAU) Unit[630]

Building Type	Energy Savings (kWh/HP)		Demand Savings (kW/HP)		Gas Savings (Therms/HP)
	MAU	No MAU	MAU	No MAU	
Hotel, 24-Hr Restaurant	5,712	3,370	0.587	0.346	414
Casual Dining, Fast Food, Prison, University Dining	4,284	2,527	0.587	0.346	279
School, incl. summer sessions	2,144	1,265	0.587	0.346	173
School, no summer sessions	1,565	923	0	0	173

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[629] EUL is based on DEER 2014 for Variable Speed Drive controlled by CO2 sensor for HVAC-VSD-DCV.

[630] Deemed gas and electric values were calculated for Arkansas by applying field study results from “PGECOFST116 Demand Ventilation Controls. Revision #3. Commercial Kitchen Demand Ventilation Controls. Pacific Gas & Electric Company. June 18, 2012.” and WPSDGENRCC0019, Revision 0, Commercial Kitchen Ventilation Controls, San Diego Gas & Electric. June 15, 2012.

Calculation of Deemed Savings

The savings methodology applied follows that employed in the PG&E work paper[2] while also discounting the savings from a non-dedicated configured makeup air unit (MAU) system. Due to the variable exhaust, kitchen demand ventilation control systems must be paired with a variable flow makeup air system to maintain air balance. There are two methods of supplying variable flow makeup air. The first is to use variable speed fans in dedicated makeup air units. Alternately, some operations (without dedicated MAUs) link the kitchen demand ventilation control to the RTU outside air damper to draw in a proportional amount of outdoor air to the air being exhausted.

An $\text{MAU}_{\text{factor}}$[631] has been added to the electric energy and demand savings algorithm to account for this where 1.0 is a dedicated system and 0.57 is a non-dedicated system. The values applied in the algorithms were derived by averaging across the results from monitoring energy performance at 11 sites in California as shown in Table 412.

$$Annual\ \frac{\Delta kWh}{HP_{exhaust}} = \frac{kW}{HP_{exhaust}} \times Annual\ Hours\ \times MAU_{factor} \tag{338}$$

$$Annual\ \frac{\Delta kW}{HP_{exhaust}} = \frac{kW\ saved}{HP_{exhaust}} \times CF\ \times MAU_{factor} \tag{339}$$

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[631] Electric savings methodology defined in a memorandum dated 8/26/13 by CLEAResult for Kitchen Demand Ventilation Control.

Table 412: Derivation of kW Saved per HP and MAU$_{factor}$ based on field data results in California[632],[633]

Food Service Facility	Inst.	FS	Hotel	Groc.	Univ.	Univ.	Hotel	Hotel	QS	QS	QS	Avg.
Rated Exhaust Fan Horsepower (HP)	6	3	15	NA	8	20	21	14	3	4	2.5	**9.65**
Base Case Total Fan Power (kW)	7.3	3.9	14.0	6.3	12.7	12.0	27.9	12.1	4.7	5.2	2.9	**9.91**
Base Case MAU Fan Power (kW)	3.1	1.5	6.4	2.2	6.52	N/A	9	N/A	1.9	N/A	N/A	**4.37**
MAU/Total Fan Power	42%	38%	46%	35%	51%	N/A	32%	N/A	40%	N/A	N/A	**40.7%**
Measure Case Total Fan Power (kW)	1.9	2.1	5.3	1.23	5.8	6.6	10.7	5.2	2.9	2.0	1.4	**4.10**
Average Power Reduction (kW saved)	5.4	1.8	8.7	5.07	6.9	5.4	17.2	6.9	1.8	3.2	1.5	**5.81**
Average Power Saved per exhaust fan HP (kW/HP)	0.9	0.6	0.58	N/A	0.863	0.27	0.819	0.493	0.6	0.8	0.6	**0.652**

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[632] Inst – Institutional Cafeteria, FS – Full Service Dining, Groc. – Grocery, Univ. – University, QS – Quick Service Dining

[633] Electric savings methodology defined in a memorandum dated 8/26/13 by CLEAResult for Kitchen Demand Ventilation Control.

To determine the annual hours, four groups of applicable facilities were defined with conservative estimates on operation characteristics.

Table 413: Annual Hours of Use by Building Type[634]

Building Type	Hours Open	Hours/ Day	Days/ Year	Hours/ Year
Hotel, 24-Hr Restaurant	0:00 – 24:00	24	365	8,760
Casual Dining, Fast Food, Prison, University Dining	6:00 – 24:00	18	365	6,570
School, incl. summer sessions	6:00 – 18:00	12	274	3,288
School, no summer sessions	6:00 – 18:00	12	200	2,400

Gas savings for this measure is derived by applying the following algorithm.

$$Annual\ Gas\ Savings = \frac{Therms}{HP} = \frac{\%\ Fan\ Speed\ Reduction}{Avg\ HP} \times \frac{Annual\ Heating\ Load\ (kBtu)}{Eff_{heat}} \times \frac{1}{100\ \frac{kBtu}{therm}}$$

(340)

The Outdoor Air Load Calculator[635] by the Food Service Technology Center was used for Little Rock, Arkansas to determine the annual heating load based on the hours of operation as defined in Table 413. An outdoor makeup airflow rate at 11,200 cfm which is 80% of the average value of 14,000 cfm that was found from the PG&E field data was applied to the calculator.

Table 414: Heat Loads in Little Rock, Arkansas

Building Type	Annual Heat Load (kBtu)
Hotel, 24-Hr Restaurant	1,229,375
Casual Dining, Fast Food, Prison, University Dining	828,140
School, incl. summer sessions	514,147
School, no summer sessions	514,147

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[634] Electric savings methodology defined in a memorandum dated 8/26/13 by CLEAResult for Kitchen Demand Ventilation Control.

[635] Outdoor Air Calculator, http://www.fishnick.com/ventilation/oalc/oac.php

Table 415: Definition of Parameters for Savings Calculation.

Parameter	Description	Value	Source
Annual Hours	Daily Operating Hours	Table 413	AR TRM
kW/HP	Energy per rated exhaust fan motor horsepower	Table 412	
MAU factor	1 – Dedicated System 0.57 – No dedicated system	Value	PG&E Work Paper and SCE field studies.
Reduced Fan Speed	Average airflow reduction	26%	PG&E Work Paper and SCE field studies.
HP	Average rated exhaust fan horsepower	9.65	PG&E Work Paper and SCE field studies.
EFF_{heat}	Heating Efficiency	80%	AR TRM
CF	Coincidence Factor	0.9	

3.7.12 ENERGY STAR® Pool Pumps

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable speed pool pump. This measure applies to all commercial applications with a pump size up to 3 hp; larger sizes should be implemented through a custom program.

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that is basically two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[636] The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by the Arkansas Board of Health. Therefore, this measure does not apply to multi-speed pumps.

Baseline and Efficiency Standards

The baseline condition is a 0.5-3 horsepower (HP) standard efficiency single-speed pool pump.

The high efficiency condition is a 0.5-3 HP ENERGY STAR® certified variable speed or multi-speed pool pump.

Estimated Useful Life (EUL)

According to DEER 2014, the estimated useful life for this measure is 10 years.[637]

Deemed Savings Values

Deemed savings are per installed unit based on the pump horsepower.

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[636] Hunt, A. & Easley, S., 2012, "*Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.*" Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

[637] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

Table 416: ENERGY STAR® Variable Speed Pool Pumps – Deemed Savings Values

	Year-round Operation				Seasonal Operation (7 months)	
	24/7 Operation		Limited Hours[638]		Limited Hours[638]	
Pump HP	kW Savings	kWh Savings	kW Savings	kWh Savings	kW Savings	kWh Savings
0.5	0.43	2,968	0.43	1,992	0.43	1,161
0.75	0.56	3,472	0.56	2,285	0.56	1,332
1	0.83	4,114	0.83	2,743	0.83	1,599
1.5	1.17	5,618	1.17	3,745	1.17	2,183
2	1.34	6,418	1.34	4,279	1.34	2,494
2.5	1.51	6,907	1.51	4,578	1.51	2,669
3	1.98	8,632	1.98	5,755	1.98	3,355

Calculation of Deemed Savings

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator.[639]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES} \tag{341}$$

Where:

kWh_{conv}= Conventional single-speed pool pump energy (kWh)

kWh_{ES}= ENERGY STAR® variable speed pool pump energy (kWh)

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours_{conv} \times days}{EF_{conv} \times 1000} \tag{342}$$

$$hours_{conv} = \frac{V_{pool} \times PT}{PFR_{conv} \times 60} \tag{343}$$

$$kWh_{ES} = kWh_{HS} + kWh_{LS} \tag{344}$$

$$kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$$

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[638] Assumes typical hours for commercial pool operation are between the hours of 6am and 10pm.

[639] The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

(345)

$$kWh_{LS} = \frac{PFR_{LS} \times 60 \times hours_{LS} \times days}{EF_{LS} \times 1000}$$

(346)

$$PFR_{LS} = \frac{V_{pool}}{t_{turnover} \times 60}$$

(347)

Where:

kWh_{HS} = ENERGY STAR® variable speed pool pump energy at high speed (kWh)

kWh_{LS} = ENERGY STAR® variable speed pool pump energy at low speed (kWh)

$hours_{conv}$ = Conventional single-speed pump daily operating hours (Table 184)

$hours_{HS,VS}$ = ENERGY STAR® variable speed pump high speed daily operating hours = 24/7 Operation: 6 hours; Limited Hours: 4 hours

$hours_{LS,VS}$ = ENERGY STAR® variable speed pump low speed daily operating hours = 24/7 Operation: 18 hours; Limited Hours: 12 hours

$days$ = Operating days per year = Year-round Operation: 365 days; Seasonal Operation: 7 months x 30.4 days/month = 212.8 days (default)

PFR_{conv} = Conventional single-speed pump flow rate (gal/min) (Table 184)

$PFR_{HS,VS}$ = ENERGY STAR® variable speed pump high speed flow rate = 50 gal/min (default)

$PFR_{LS,VS}$ = ENERGY STAR® variable speed pump low speed flow rate (gal/min) = 45.8 (default)

EF_{conv} = Conventional single-speed pump energy factor (gal/W·hr) (Table 184)

$EF_{HS,VS}$ = ENERGY STAR® variable speed pump high speed energy factor = 3.75 gal/W·hr (default)

$EF_{LS,VS}$ = ENERGY STAR® variable speed pump low speed energy factor = 4.33 gal/W·hr (default)

V_{pool} = Pool volume = 22,000 gal (default)

PT = Pool turnovers per day = 24/7 Operation: 3; Limited Hours: 2[640]

$t_{turnover,VS}$ = Variable speed pump time to complete 1 turnover = 8 hours[640]

60 = Constant to convert between minutes and hours

1000 = Constant to convert W to kW

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[640] Arkansas Board of Health, Rules and Regulations Pertaining to Swimming Pools and Other Related Facilities. http://www.healthy.arkansas.gov/aboutadh/rulesregs/swimmingpools.pdf

Table 417: Conventional Pool Pumps Assumptions

Pump HP	$hours_{conv,}$ limited hours	$hours_{conv,}$ 24/7 Operation	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
0.5	14.7	22.0	50.0	2.71
0.75	13.8	20.8	53.0	2.57
1	12.2	18.3	60.1	2.40
1.5	11.4	17.1	64.4	2.09
2	11.2	16.8	65.4	1.95
2.5	10.7	16.1	68.4	1.88
3	10.0	15.0	73.1	1.65

Demand savings can be derived using the following:

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \left(\frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right)\right] \times \frac{CF}{days}$$

(348)

Where:

CF = Coincidence factor[641] = 1

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[641] Assumes that 100% of commercial pool pumps will be operating during summer peak period.

3.7.13 High Speed Doors for Cold Storage Facilities

Measure Description

This measure involves the installation of energy efficient industrial high-speed doors. High-speed doors are flexible doors composed of a soft material that can either roll up or bi-part for instant access to a facility.

Baseline and Efficiency Standards

The baseline case is an industrial door used to separate areas with differing conditioned spaces.

Estimated Useful Life

The estimated useful life (EUL) of this measure is 15 years.

Calculation of Deemed Savings

Energy Savings

High speed door energy savings are calculated using the following formulas:

$$Q_W = N \times 88 \times L_O \times W_O \times CD_W \times WS \times WD$$

(349)

$$Q_T = N \times 60 \times CD_T \times L_O \times W_O \times \sqrt{2 \times g \times \Delta H_{NPL} \times \left(\frac{T_E - T_I}{T_E + 460}\right)}$$

(350)

$$Q_P = N \times 136.8 \times CD_P \times L_O \times W_O \times \sqrt{2 \times gc \times \frac{\Delta P}{\rho_I}}$$

(351)

$$Q_{infiltration} = Q_W + Q_T + Q_P$$

(352)

$$q_c = \left[1.08 \times Q_{infiltration} \times (T_E - T_I)\right] + \left[4{,}840 \times Q_{infiltration} \times (W_E - W_I)\right]$$

(353)

$$q_{insulation} = \left(\frac{1}{R_{old}} - \frac{1}{R_{new}}\right) \times L_O \times W_O \times (T_E - T_I)$$

(354)

$$t_{door} = \left(\frac{1}{speed_{old}} - \frac{1}{speed_{new}}\right) \times \frac{L_O \times 12 \times Opens}{24 \times 60}$$

(355)

$$t_{open} = \frac{t_{door} \times AOH \times AOD}{60 \times 365}$$

(356)

$$t_{closed} = \frac{(60 - t_{door}) \times AOH \times AOD}{60 \times 365}$$

(357)

$$kWh_{savings} = \frac{q_c \times t_{open} + q_{insulation} \times t_{closed}}{\varepsilon_C \times 3{,}412}$$

(358)

Where:

Q_W = Wind effect air flowrate (cfm)

N = Number of openings

88 = Conversion factor to convert miles per hour to feet per minute

L_O = Length of opening (ft)

W_O = Width of opening (ft.)

CD_W = Surface-averaged wind pressure coefficient = 0.35[642]

WS = Average local wind speed (mph) (Table 418)

WD = Directional frequency of wind (%) (Table 419)

Q_T= Thermal effect air flowrate in cooling mode (cfm)

60 = Conversion factor to convert feet per second to feet per minute

460 = Conversion factor to convert to absolute temperature in degrees Rankine

CD_T = Discharge coefficient due to thermal forces = 0.65[643]

g = Local acceleration of gravity = 32.174 ft./s^2 at sea level

ΔH_{NPL} = Difference between the height of the opening and the height of the neutral pressure level (NPL) (ft) = one-half the height of the aperture[644]

T_I = Interior temperature (°F), if unknown, assume 40°F for medium-temperature coolers and 0°F for low-temperature freezers

T_E = Exterior temperature (°F) (Table 420)

Q_P= Building pressurization effect (mechanical ventilation system) air flowrate (cfm)

136.8 = Pressure unit conversion factor

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[642] Determined as a wind-induced average indoor-outdoor pressure difference using average values for local wind pressure coefficients and internal wind-induced pressure coefficients. ASHRAE Handbook 2013 Fundamentals, Chapter 24, p. 24.4-5

[643] Default discharge coefficient for unidirectional flow. ASHRAE Handbook 2013 Fundamentals, Chapter 16, p. 16.13

[644] Estimation of ΔH_{NPL} as one-half the height of the aperture. ASHRAE Handbook 2013 Fundamentals, Chapter 16, p. 16.13

CD_P = Discharge coefficient due to mechanical forces = 0.65[645]

gc = Gravitational proportionality constant = 32.174 lbm-ft/s^2·lbf

ΔP = Building pressurization by mechanical systems (iwc) = 0 for spaces with neutral pressurization (default), 0.01 for spaces with positive or negative pressurization

ρ_I = Interior density of air (lbm/ft^3) = 0.075[646]

$Q_{infiltration}$ = Total infiltration air flowrate (cfm)

q_c = Annual cooling heat transfer rate (Btu/hr)

1.08 = Conversion factor to convert cubic feet to pounds of water and minutes to hours

4,840 = Latent heat conversion factor

W_E = Exterior humidity ratio ($lbm_{water}/lbm_{dry\ air}$) (Table 420)

Demand Savings

Peak demand savings are assumed to be equal to the average hourly demand.

$$\mathbf{kW_{savings}} = \frac{\mathbf{kWh_{savings}}}{\mathbf{8,760}}$$

(359)

W_I = Interior humidity ratio ($lbm_{water}/lbm_{dry\ air}$) = for medium-temperature coolers use 0.0048, and for low-temperature freezers use 0.0008[647]

$q_{insulation}$ = insulation heat transfer rate (Btu/hr)

R_{old} = R-value of the old door (ft^2·°F·h/Btu)

R_{new} = R-value of the new door (ft^2·°F·h/Btu)

t_{door} = reduced time that the door stays open (min/hr)

$speed_{old}$= opening and closing speed of the old door (in/s)

$speed_{new}$= opening and closing speed of the new door (in/s)

12 = Conversion factor to convert feet to inches

$Opens$= number of time the door opens per day

24 = Conversion factor to convert days to hours

t_{open}= time that the door remains open (hr)

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[645] Default discharge coefficient for unidirectional flow. ASHRAE Handbook 2013 Fundamentals, Chapter 1, p. 16.13

[646] Property of air, ASHRAE Handbook 2013 Fundamentals, Chapter 1, p. 1.2

[647] Assuming 90% relative humidity at 40 and 0 °F

AOH = annual operating hours of the facility (hr) = for medium-temperature coolers use 5,000, and for low-temperature freezers use 7,000

AOD = annual operating days of the facility (days), if unknown, assume 52 weeks/year × 5 days/week = 260 days/year

365 = Conversion factor to convert years to days

t_{closed} = time that the door remains closed (hr)

ε_C = Cooling HVAC system efficiency = for medium-temperature coolers use 2.5 COP, and for low-temperature freezers use 1.5 COP[648]

$3{,}412$ = Conversion factor to convert BTU to kWh

Table 418: Average Wind Speed by Weather Zone

Weather Zone	Average Wind Speed (mph)
9 Rogers	7.703
9 Fayetteville	6.511
8 Fort Smith	7.475
7 Little Rock	7.095
6 El Dorado	5.376

Table 419: Directional Frequency of Wind by Weather Zone

Weather Zone	North (%)	South (%)	East (%)	West (%)
9 Rogers	16.4	40.0	22.8	20.9
9 Fayetteville	18.3	48.7	18.4	14.7
8 Fort Smith	17.3	12.6	50.1	20.0
7 Little Rock	23.2	29.2	25.5	22.1
6 El Dorado	24.5	33.8	23.3	18.4

Table 420: Average Annual Exterior Temperature by Weather Zone

Weather Zone	Average Annual Temperature (°F)
9 Rogers	57.8
9 Fayetteville	59.6
8 Fort Smith	60.1
7 Little Rock	61.8
6 El Dorado	64.1

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[648] Default assumptions from 3.7.7 Strip Curtains for Walk-in Coolers and Freezers

Table 421: Average Humidity Ratio by Weather Zone

Weather Zone	Average Humidity Ratio ($lbm_{water}/lbm_{dry\ air}$)
9 Rogers	0.00790
9 Fayetteville	0.00902
8 Fort Smith	0.00927
7 Little Rock	0.00978
6 El Dorado	0.01077

Demand Savings

Peak demand savings are assumed to be equal to the average hourly demand.

$$\boldsymbol{kW_{savings} = \frac{kWh_{savings}}{8,760}}$$

(360)

Where:

8,760 = Operating hours of cold storage facility

Annual kW and kWh Savings Calculation Example for High Speed Doors

One door with a width of 8.5 feet and a length of 13.5 feet faces east. The Fayetteville values are used for the average wind speed (6.511 mph), the directional frequency of wind (east 0.184), the average exterior temperature (59.6°F), and the average exterior humidity ratio ($lbm_{water}/lbm_{dry\ air}$). The default wind pressure coefficient and discharge coefficients defined above are used. The local acceleration due to gravity, the gravitational proportionality constant, and the interior density of air values defined above are used. The difference between the height of the opening and the height of the NPL is assumed to be half the height of the building, or 10.5 feet. The facility is assumed to be a medium-temperature cooler, yielding a default interior temperature of 40°F, an interior humidity ratio of 0.0048 $lbm_{water}/lbm_{dry\ air}$, an HVAC efficiency of 2.5 COP, and operating time of 5000 hours.

An assumed value of 0 iwc is used for a building with neutral pressurization. The R-value of the new door is 5 $ft^2 \cdot °F \cdot h/Btu$, and the R-value of the old door is 0.8 $ft^2 \cdot °F \cdot h/Btu$. The speed of the old door is 10 in/s, and the speed of the new door is 50 in/s. The door opens 100 times per day. The facility operates 260 days out of the year.

$$Q_W = N \times 88 \times L_O \times W_O \times CD_W \times WS \times WD = 1 \times 88 \times 13.5 \times 8.5 \times 0.35 \times 6.511 \times 0.184$$
$$= 4{,}234.2\ cfm$$

(361)

$$Q_T = N \times 60 \times CD_T \times L_O \times W_O \times \sqrt{2 \times g \times \Delta H_{NPL} \times \left(\frac{T_E - T_I}{T_E + 460}\right)}$$
$$= 1 \times 60 \times 0.65 \times 13.5 \times 8.5 \times \sqrt{2 \times 32.174 \times \frac{13.5}{2} \times \left(\frac{59.6 - 40}{59.6 + 460}\right)}$$
$$= 18{,}114.7\ cfm$$

(362)

$$Q_P = N \times 136.8 \times CD_P \times L_O \times W_O \times \sqrt{2 \times gc \times \frac{\Delta P}{\rho_I}}$$
$$= 1 \times 136.8 \times 0.65 \times 13.5 \times 8.5 \times \sqrt{2 \times 32.174 \times \frac{0}{0.075}} = 0\ cfm$$

(363)

$$Q_{infiltration} = Q_W + Q_T + Q_P = 4{,}234.2 + 18{,}114.7 + 0 = 22{,}348.8\ cfm$$

(364)

$$q_C = \left[1.08 \times Q_{infiltration} \times (T_E - T_I)\right] + \left[4{,}840 \times Q_{infiltration} \times (W_E - W_I)\right]$$
$$= [1.08 \times 22{,}348.8 \times (59.6 - 40)]$$
$$+ [4{,}840 \times 22{,}348.8 \times (0.00902 - 0.0048)] = 929{,}550.7\ Btu/hr$$

(365)

$$q_{insulation} = \left(\frac{1}{R_{old}} - \frac{1}{R_{new}}\right) \times L_O \times W_O \times (T_E - T_I) = \left(\frac{1}{5} - \frac{1}{0.8}\right) \times 13.5 \times 8.5 \times (59.6 - 40)$$
$$= -2{,}361.6\ Btu/hr$$

(366)

$$t_{door} = \left(\frac{1}{speed_{old}} - \frac{1}{speed_{new}}\right) \times \frac{L_O \times 12 \times Opens}{24 \times 60} = \left(\frac{1}{10} - \frac{1}{50}\right) \times \frac{13.5 \times 12 \times 100}{24 \times 60}$$
$$= 0.90\ min/hr$$

(367)

$$t_{open} = \frac{t_{door} \times AOH \times AOD}{60 \times 365} = \frac{0.90 \times 5{,}000 \times 260}{60 \times 365} = 53.4\ hours$$

(368)

$$t_{closed} = \frac{(60 - t_{door}) \times AOH \times AOD}{60 \times 365} = \frac{(60 - 0.90) \times 5{,}000 \times 260}{60 \times 365} = 3{,}508.2\ hours$$

(369)

$$kWh_{savings} = \frac{q \times t_{open} + q_{insulation} \times t_{closed}}{\varepsilon_C \times 3{,}412} = \frac{929{,}550.7 \times 53.4 + -2{,}361.6 \times 3{,}508.2}{\varepsilon_C \times 3{,}412}$$
$$= 4{,}850.7\ kWh$$

(370)

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760} = \frac{4{,}850.7}{8{,}760} = 0.554\ kW$$

(371)

3.7.14 High Efficiency Battery Chargers

Measure Description

Industrial electric vehicle fleets used for material handling, or forklifts, use battery charging systems to convert AC source power into DC power required to charge the vehicle batteries. Traditional charging systems include Ferro resonant (FR) and silicon-controlled rectifier (SCR) charging equipment. This measure is for a single high-frequency battery charger that converts AC to DC power more efficiently than traditional systems due to switch mode operation that reduces heat and power loss throughout the system.

Baseline and Efficiency Standards

The baseline conditions are a typical FR or SCR charging system operating in an industrial or warehouse setting to power forklifts. The efficient condition is a high efficiency battery charging system meeting the following performance requirements:

Table 422: Battery Charging System - Efficiency Requirements

Performance Factor	Requirement
Power Conversion Efficiency	≥ 89%
Maintenance Power	≤ 10W

Estimated Useful Life (EUL)

The EUL for High Efficiency Battery Chargers for Forklift applications is 15 years.[649]

Calculation of Deemed Savings

Deemed demand and annual savings are based on a study conducted for the Codes and Standards Enhancement (CASE) Initiative.[649]

$$kWh_{savings} = \frac{hours_{charge}\left(W_{charge_{pre}} - W_{charge_{post}}\right) + hours_{idle}\left(W_{idle_{pre}} - W_{idle_{post}}\right)}{1{,}000}$$

(372)

$$kW_{savings} = \frac{kWh_{savings}}{\left(hours_{charge} + hours_{idle}\right)} \times CF$$

(373)

Where:

$hours_{charge}$ = annual number of hours the charging system is actively charging. See Table 423.

W_{charge} = wattage draw of the charging system in active charging mode. See Table 423.

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[649] Battery Charger Title 20 CASE, Analysis of Standard Options for Battery Charger Systems. http://www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf. Accessed July 2016.

$hours_{idle}$ = annual number of hours the charging system is operating with no load or in maintenance mode on a fully charged battery See Table 423.

W_{idle} = wattage draw of the charging system is operating with no load or in maintenance mode on a fully charged battery. See Table 423.

CF = Coincidence Factor. See Table 423.

1,000 = Conversion factor

Table 423: Battery Charging System - Hours and Wattages[650]

Equipment	$hours_{charge}$	$hours_{idle}$	$W_{charge_{pre}}$	$W_{idle_{pre}}$	$W_{charge_{post}}$	$W_{idle_{post}}$	CF
Single Phase	3,942	4,818	2,000	50	1,767	10	0.19
Three Phase	8,234	526	5,785	34	5,111	10	1.0

Example **calculation for a single phase charger**

$$kWh_{savings} = \frac{3{,}942 hrs_{charge}\left(2{,}000 W_{charge_{pre}} - 1{,}767 W_{charge_{post}}\right) + 4{,}818 hrs_{idle}\left(50 W_{idle_{pre}} - 10 W_{idle_{post}}\right)}{1{,}000}$$

$$= 1{,}111\ kWh$$

$$kW_{savings} = \frac{1{,}111\ kWh}{\left(3{,}942\ hours_{charge} + 4{,}818\ hours_{idle}\right)} \times 0.19 = 0.02\ kW$$

Table 424: Battery Charging System - Deemed Savings Values per charger

Equipment	**kWh savings**	**kW savings**
Single Phase	1,111	0.02
Three Phase	5,562	0.63

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[650] Battery Charger Title 20 CASE, Analysis of Standard Options for Battery Charger Systems. Hours: Table 6, Wpre: Table 7, Wpost and CF: Table 10. http://www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf. Accessed July 2016.

3.8 Food Service Equipment

3.8.1 (Empty)

3.8.2 Commercial Ice Makers

Measure Description

This measure applies to ENERGY STAR® air-cooled commercial ice makers in retrofit and new construction applications. Commercial ice makers are classified as either of two equipment types: batch type (also known as cube-type) and continuous type (also known as nugget or flakers). Both of these equipment types are eligible for ENERGY STAR® certification based on their configuration as ice-making heads (IMHs), remote condensing units (RCUs) and self-contained units (SCUs). Also eligible are remote condensing units designed for connection to a remote condenser rack.

The industry standard for energy and potable water use and performance of commercial ice makers is the Department of Energy (DOE) Standard 10 CFR Part 431 Subpart H[651] and AHRI Standard 810. Key parameters reported for ice makers include the Equipment Type, Harvest Rate (lbs. of ice/24hrs) and Energy Consumption Rate (kWh/100lbs of ice). The AHRI Directory of Certified Equipment[652] lists these values by equipment manufacturer and model number.

Baseline & Efficiency Standard

The ENERGY STAR®[653] criteria for ice makers define efficiency requirements for both energy and potable water use. The baseline standard for batch ice makers are current federal minimum levels that went into effect January 1, 2010. DOE recently published “trial” baseline levels for continuous ice makers.[654] Baseline and efficiency standards should be reviewed on an annual basis to reflect the latest requirements.

Table 425: Federal Minimum Standards for Air-Cooled Batch Ice Makers (H=Harvest Rate)

Equipment Type	Ice Harvest Rate (H) Range (lbs. of ice/24 hrs)	Batch Ice Makers Energy Consumption Rate (kWh/100 lbs. ice)
Ice Making Heads	<450	10.26– 0.0086H
	≥450	6.89 – 0.0011H
Remote Condensing Units (w/out remote compressor)	<1,000	8.85 – 0.0038H
	≥1,000	5.10
Remote Condensing Units (w/ remote compressor)	<934	8.85 – 0.0038H
	≥934	5.3
Self-Contained Units	<175	18.0 – 0.0469H
	≥175	9.8

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[651] 10 CFR Part 431 Subpart H, Automatic Commercial Ice Makers. 77 FR 1591. January 11, 2012.

[652] http://www.ahridirectory.org/ahridirectory/pages/acim/defaultSearch.aspx

[653] ENERGY STAR® Commercial Ice Makers Version 2.0, effective on February 1, 2013.

[654] U.S. DOE Report on Automatic Commercial Ice Machines (ACIM) on baseline values, http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/acim_preliminary_tsd_ch5_engineering_2012_01_16.pdf

Table 426: DOE Trial Baseline Efficiency Levels for Air-Cooled Continuous Ice Makers (H=Harvest Rate)

Equipment Type	Ice Harvest Rate (H) Range (lbs. of ice/24 hrs)	DOE Trial Baseline for Continuous Ice Makers Energy Consumption Rate (kWh/100 lbs. ice)
Ice Making Heads	<1,000	10.3– 0.004H
	≥1,000	6.3
Remote Condensing Units (w/out remote compressor)	<1,000	9.5 – 0.004H
	≥1,000	5.5
Self-Contained Units	<175	18.0 – 0.0469H
	≥175	9.8

Table 427: ENERGY STAR® Requirements for Air-Cooled Batch Ice Makers (H = Harvest Rate)

Equipment Type	Ice Harvest Rate Range (lbs. of ice/24 hrs)	Batch Ice Makers Energy Consumption Rate (kWh/100 lbs. ice)	Potable Water Use (gal/100 lbs. ice)
Ice Making Heads	$200 \leq H \leq 1600$	$\leq 37.72 * H^{-0.298}$	≤ 20
Remote Condensing Units	$200 \leq H \leq 1600$	$\leq 22.95 * H^{-0.258} + 1.00$	≤ 20
	$1600 < H \leq 4000$	$\leq -0.00011 * H + 4.60$	
Self-Contained Units	$50 \leq H \leq 450$	$\leq 48.66 * H^{-0.326} + 0.08$	≤ 25

Table 428: ENERGY STAR® Requirements for Air-Cooled Continuous Ice Makers (H = Harvest Rate)

Equipment Type	Continuous Ice Makers Energy Consumption Rate (kWh/100 lbs. ice)	Potable Water Use(gal/100 lbs. ice)
Ice Making Heads	$\leq 9.18 * H^{-0.057}$	≤ 15
Remote Condensing Units	$\leq 6.00 * H^{-0.162} + 3.50$	≤ 15
Self-Contained Units	$\leq 59.45 * H^{-0.349} + 0.08$	≤ 15

Estimated Useful Life (EUL)

DEER 2011 database shows an estimated useful life (EUL) of 10 years for commercial ice makers.

Calculation of Deemed Savings

Annual electric savings can be calculated by determining the energy consumed for baseline ice makers compared against the energy consumed by the qualifying ENERGY STAR®[655] product using the harvest rate of the more efficient unit.

Peak demand savings can then be derived from the electric savings.

$$\Delta kWh = \frac{(kWh_{base,per100lb} - kWh_{ee,per100lb})}{100} \times DC \times H \times 365$$

(374)

$$\Delta kW = \left(\frac{\Delta kWh}{HRS}\right) \times CF$$

(375)

Where:

ΔkWh = Annual energy savings

$kWh_{base,per100lb}$ = Calculated based on the harvest rate and type of ice machine from the Federal Minimum Energy Consumption Rate relationships in Table 425: Federal Minimum Standards for Air-Cooled Batch Ice Makers

$kWh_{ee,per100lb}$ = Qualifying energy efficient model consumption found in the AHRI directory of certified products by model information.; use the equations in AHRI Table 3 and Table 4 to qualify products be deriving the maximum efficiency performance level[656]

100 = conversion factor to convert $\mathrm{kWh}_{\mathrm{base,per100lb}}$ and $\mathrm{kWh}_{\mathrm{ee,per100lb}}$ into maximum kWh consumption per pound of ice

DC = Duty Cycle of the ice maker representing the percentage of time the ice machine is making ice = 0.50 [657]

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[655] As of July 19,2013 the ENERGY STAR® calculator has not been updated to reflect new efficiency levels adopted in February 1, 2013. Deemed savings should be calculated as described here.

[656] AHRI Directory of Certified Automatic Commercial Ice Cube Machines (ACIM) can be found at http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

[657] TRM assumptions from Vermont, Pennsylvania and Ohio use 40%, Wisconsin uses 50% and Ameren Missouri uses 75% (similar to ENERGY STAR® Commercial Kitchen Equipment Savings Calculator). A field study in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). Conservative approach is to use 40%.

H = Harvest Rate [658] (lbs. of ice made per day)

365 = days per year

HRS = Annual operating hours = 365 × 24 = 8760 hours/year

CF = 1.0[659]

Example Savings Calculations

Savings calculations for varying Harvest Rates (H) can be seen below based on the ice maker equipment type. The examples below are assuming the energy efficient commercial ice maker as having an energy usage at the ENERGY STAR® level. Actual energy usage can be found on the AHRI directory of certified products.

Table 429: Savings Calculation for Different Qualifying Types of Energy Efficient Commercial Ice Makers

Performance	Batch Type			Continuous Type		
	SCU	IMH	RCU	SCU	IMH	RCU
Ice Harvest Rate (lbs. per day)	150	200	750	150	200	750
Baseline Energy Usage (kWh/100lbs)	10.97	8.54	6.00	10.97	9.50	6.50
ENERGY STAR® Qualifying Energy Usage (kWh/100lbs)	9.58	7.78	5.16	10.42	6.79	5.55
Baseline Daily Consumption (kWh)	6.58	6.83	18.00	6.58	7.60	19.50
EE Daily Consumption (kWh)	5.75	6.22	15.48	6.25	5.43	16.66
Baseline Annual Consumption (kWh/yr.)	2,401	2,494	6,570	2,401	2,774	7,118
EE Annual Consumption (kWh/yr.)	2,098	2,271	5,649	2,283	1,982	6,081
Baseline Demand (kW)	0.27	0.28	0.75	0.27	0.32	0.81
EE Demand (kW)	0.24	0.26	0.64	0.26	0.23	0.69
Annual Energy Savings (kWh/yr.)	303	223	921	118	792	1,037
Estimated Demand Savings (kW)	0.03	0.03	0.11	0.01	0.09	0.12

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[658] Harvest Rate for all Ice Machines tested in accordance to AHRI 810-2007can be found at http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[659] A New England study, *"Coincidence Factor Study for Residential and Commercial Industrial Lighting Measures", RLW Analytics*, Spring 2007 shows a CF of 0.775 for restaurants; California uses 0.9, Ameren Missouri and Wisconsin uses 1.0. Due to the applicability of this measure in other building types, 1.0 will be used.

3.8.3 Commercial Griddles

Measure Description

This measure applies to ENERGY STAR® or its equivalent natural gas and electric commercial griddles in retrofit and new construction applications. This appliance is designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface or a hot channeled cooking surface where plate temperature is thermostatically controlled.

Energy-efficient commercial electric griddles reduce energy consumption primarily through application of advanced controls and improved temperature uniformity. Energy efficient commercial gas griddles reduce energy consumption primarily through advanced burner design and controls.

Baseline & Efficiency Standard

Key parameters for defining griddle efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. There are currently no federal minimum standards for Commercial Griddles, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[660] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

ENERGY STAR® efficiency requirements apply to single and double sided griddles. The ENERGY STAR® criteria should be reviewed on an annual basis to reflect the latest requirements.

Table 430: ENERGY STAR® Criteria[661] for Electric and Gas Single and Double Sided Griddles

Performance Parameters	Electric Griddles	Gas Griddles
Heavy-Load Cooking Energy Efficiency	>= 70%	>= 38%
Idle Energy Rate	<= 320 watts per ft^2	<= 2,650 Btu/h per ft^2

Estimated Useful Life (EUL)

According to DEER 2008, commercial griddles are assigned an estimated useful life (EUL) of 12 years.[662]

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency griddle as compared with an ENERGY STAR® rated griddle.

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[660] The industry standard for energy use and cooking performance of griddles are ASTM F1275-03: Standard Test Method for the Performance of Griddles and ASTM F1605-01: Standard Test Method for the Performance of Double-Sided Griddles

[661] ENERGY STAR® Commercial Griddles Program Requirements Version 1.1, effective May 2009 for gas griddles and effective January 1, 2011 for electric.

[662] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

For electric savings,

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

(376)

$$kWh_{(base\ or\ eff)} = kWh_{cooking} + kWh_{idle} + kWh_{preheat}$$

(377)

$$kWh_{cooking} = \left(LB_{food} \times \frac{E_{food}}{CookEff}\right) \times Days$$

(378)

$$kWh_{idle} = IdleEnergy \times \left(DailyHrs - \frac{LB_{food}}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(379)

$$kWh_{preheat} = PreheatEnergy \times Days$$

(380)

For gas savings,

$$\Delta Btu = Btu_{base} - Btu_{eff}$$

(381)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

(382)

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat}$$

(383)

$$Btu_{cooking} = \left(LB_{food} \times \frac{E_{food}}{CookEff}\right) \times Days$$

(384)

$$Btu_{idle} = IdleEnergy \times \left(Daily\ Hrs - \frac{LB_{food}}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(385)

$$Btu_{preheat} = PreheatEnergy \times Days$$

(386)

Key parameters used to compute savings are defined in Table 431.

Table 431: Energy Consumption Related Parameters for Commercial Griddles[663]

Parameter	Description	Value	Source
Daily Hrs	Daily Operating Hours	12 hours	FSTC
PreheatTime	Time to Preheat (min)	15 min	FSTC
E_{food}	ASTM defined Energy to Food	0.139 kWh/lb, 475 Btu/lb	FSTC
Days	Number of days of operation	365 days	FSTC
CookEff	Cooking energy efficiency (%)	For electric, see Table 432 For gas, see Table 433	FSTC, ENERGY STAR®
IdleEnergy	Idle energy rate (kW), (Btu/h)		
Capacity	Production capacity (lbs./hr)		FSTC
PreheatEnergy	kWh/day, Btu/day		FSTC
LB_{food}	Food cooked per day (lb/day)		FSTC

General assumptions used for deriving deemed electric and gas savings are values are taken from the Food Service Technology Center (FSTC) work papers.[664] These deemed values assume that the griddles are 3 x 2 feet in size. Parameters in the table are per linear foot, with an assumed depth of 2 feet.

Table 432: Baseline and Efficient Assumptions for Electric Griddles

Parameter	Baseline Electric Griddles	Efficient Electric Griddles
Preheat Energy (kWh/ft.)	1.33	0.67
Idle Energy Rate (kW/ft.)	0.80	0.64
Cooking Energy Efficiency (%)	65%	70%
Production Capacity (lbs./h/ft.)	11.7	16.33
Lbs. of food cooked/day/ft.	33.33	33.33

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[663] Assumptions based on PG&E Commercial Griddles Work Paper developed by FSTC, May 22, 2012.

[664] FSTC food service equipment work papers submitted to CPUC for Energy Efficiency 2013-2014 Portfolio; document titled EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip

https://www.pge.com/regulation/EnergyEfficiency2013-2014-Portfolio/Testimony/PGE/2012/EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip.

Table 433: Baseline and Efficient Assumptions for Gas Griddles

Parameter	Baseline Gas Griddles	Efficient Gas Griddles
Preheat Energy (Btu/ft.)	7,000	5,000
Idle Rate (Btu/hr/ft.)	7,000	5,300
Cooking Efficiency (%)	32%	38%
Production Capacity (lbs./h/ft.)	8.33	16.33
Lbs. of food cooked/day/ft.	33.33	33.33

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

(387)

Where:

ΔkWh = Annual energy savings (kWh)

4380 = Operating Equivalent hours = 365 x 12 = 4380 hours

0.84[665] = Coincidence Factor (CF)

Deemed Savings Values

Deemed savings based on the assumptions above are tabulated below per griddle, per linear foot.

Table 434: Deemed Savings for Electric and Gas Commercial Griddles per Linear Foot

Measure Description	Deemed Savings per Griddle per linear foot		
	kW	kWh	Therms
Griddle, Electric, ENERGY STAR®	0.15	758	0
Griddle, Gas, ENERGY STAR®	0	0	46

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[665] Coincidence factors utilized in other jurisdictions for Commercial Griddles vary from 0.84 to 1.0. The KEMA report titled “Business Programs: Deemed Savings Parameter Development,” November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

3.8.4 Commercial Ovens

Measure Description

This section applies to the following types of Commercial Ovens;

- **Electric and Gas Convection Ovens:** A fully enclosed, insulated chamber that heats food by forcing hot dry air over the surface of the food product.
- **Gas Conveyor Ovens:** A heated chamber with a moving belt that carries food product into and through the chamber.
- **Gas Rack Ovens:** A fully enclosed, insulated chamber used to heat food on stationary racks.

High efficiency ovens exhibit better baking uniformity and higher production capacities while also including high-quality components and controls.

Estimated Useful Life (EUL)

According to the California Database of Energy Efficiency Resources (DEER 2008), all commercial ovens are assigned an estimated useful life (EUL) of 12 years.[666]

The following sections will describe how deemed savings may be derived for each type of commercial oven.

3.8.4.1 Convection Ovens

Baseline & Efficiency Standard

Efficient convection ovens are defined by ENERGY STAR® or its equivalent and apply to electric full-size and half-size convection ovens and gas full-size convection ovens. Full size ovens accept a minimum of five pans measuring 18 x 26 x 1-inch. Half size ovens accept a minimum of five sheet pans measuring 18 x 13 x 1-inch. The ENERGY STAR® criteria should be reviewed on an annual basis to reflect the latest requirements.

There are currently no federal minimum standards for Commercial Convection Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[667] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

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[666] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

[667] The industry standard for energy use and cooking performance of convection ovens is ASTM F-2861-10, Standard Test Method for Enhanced Performance of Combination Oven in Various Modes.

Table 435: ENERGY STAR® Criteria for Electric Convection Ovens [668]

Performance Parameters	Half Size Electric Ovens	Full Size Electric Ovens
Heavy-Load Cooking Energy Efficiency	≥ 71%	≥ 71%
Idle Energy Rate	≤ 1.0 kW	≤ 1.6 kW

Table 436: ENERGY STAR® Criteria for Gas Convection Ovens [669]

Performance Parameters	Full Size Gas Ovens
Heavy-Load Cooking Energy Efficiency	≥ 46%
Idle Energy Rate	<= 12,000 Btu/h

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency convection oven as compared with an ENERGY STAR® rated convection oven.

For electric savings,

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

(388)

$$kWh_{(base\ or\ eff)} = kWh_{cooking} + kWh_{idle} + kWh_{preheat}$$

(389)

$$kWh_{cooking} = \left(LB \times \frac{E_{food}}{CookEff}\right) \times Days$$

(390)

$$kWh_{idle} = IdleEnergy \times \left(DailyHrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(391)

$$kWh_{preheat} = PreheatEnergy \times Days$$

(392)

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[668] ENERGY STAR® Commercial Ovens Version 1.1, effective May 2009; Version 2.0 is currently under development to be released by 2013. New efficiency levels will be identified and scope will add Combination Ovens.

[669] Ibid.

For gas savings,,

$$\Delta Btu = Btu_{base} - Btu_{eff}$$

(393)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

(394)

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat}$$

(395)

$$Btu_{cooking} = \left(LB \times \frac{E_{food}}{CookEff}\right) \times Days$$

(396)

$$Btu_{idle} = IdleEnergy \times \left(Daily\ Hrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(397)

$$Btu_{preheat} = PreheatEnergy \times Days$$

(398)

General assumptions in Table 437 and Table 438 are from the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator – Convection Ovens which refers to the Food Service Technology Center (FSTC) work papers and research.[670]

Table 437: Baseline and Efficient Assumptions for Electric Convection Ovens

Parameter	Half-Size Electric Ovens		Fully Size Electric Ovens	
	Baseline Model	Efficient Model	Baseline Model	Efficient Model
Preheat Energy (kWh/day)	1.0	0.9	1.5	1.0
Idle Energy Rate (kW)	1.5	0.88	2.0	1.4
Cooking Energy Efficiency (%)	65%	72%	65%	73%
Production Capacity (lbs./hour)	45	53	70	82
Lbs. of food cooked/day	100	100	100	100
Efood (kWh/lb)	0.0732	0.0732	0.0732	0.0732

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[670] FSTC food service equipment work papers submitted to CPUC for Energy Efficiency 2013-2014 Portfolio; document titled EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip

Table 438: Baseline and Efficient Assumptions for Full-Size Gas Convection Ovens

Parameter	Full-Size Gas Ovens	
	Baseline Model	Efficient Model
Preheat Energy (Btu/day)	19,000	11,000
Idle Rate (Btu/h)	18,000	11,758
Cooking Efficiency (%)	30%	46%
Production Capacity (lbs./hour)	70	83
Lbs. of food Cooked/Day	100	100
Efood (Btu/lb)	250	250

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

(399)

Where:

ΔkWh = Annual energy savings (kWh)

$HOURS$ = Operating Equivalent hours = 365 x 12 = 4,380 hours [671]

CF = Coincidence Factor = 0.84 [672]

Deemed Savings Estimates for Convection Ovens

Deemed savings based on the assumptions above are tabulated below for electric and gas convection ovens.

Table 439: Deemed Savings Estimates for Electric and Gas Convection Ovens

Measure Description	Deemed Savings per Oven		
	kW	kWh	Therms
Half-Size Convection Oven, Electric, ENERGY STAR®	0.477	2,485	---
Full-Size Convection Oven, Electric, ENERGY STAR®	0.534	2,787	---
Full-Size Convection Oven, Gas, ENERGY STAR®	---	---	357

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[671] ENERGY STAR® Commercial Kitchen Equipment Savings Calculator – Convection Ovens assumes an operating time of 12 hours.

[672] KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

3.8.4.2 Commercial Conveyor Ovens

Baseline & Efficiency Standard

There are currently no federal minimum standards for Commercial Conveyor Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[673] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Baseline and efficient model information were drawn from a sample of equipment tested by the Food Service Technology Center.[674]

Table 440: Baseline and Efficient Criteria for Gas Conveyor Ovens

Performance Parameters	Gas Conveyor Oven Size >25” wide	
	Baseline Model	**Efficient Model Criteria**
Heavy-Load Cooking Energy Efficiency	20%	≥ 42%
Idle Energy Rate	70,000 Btu/h	<= 57,000 Btu/h

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency conveyor oven as compared with a high efficient conveyor oven.

For gas savings,

$$\Delta Btu = Btu_{base} - Btu_{eff} \tag{400}$$

$$\Delta Therms = \frac{\Delta Btu}{100{,}000} \tag{401}$$

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat} \tag{402}$$

$$Btu_{cooking} = \left(\frac{nPizzas \times E_{food}}{Cook\ Eff}\right) \times Days \tag{403}$$

---

[673] The industry standard for energy use and cooking performance of conveyor ovens is ASTM Standard Test Method for the Performance of Conveyor Ovens (F1817).

[674] Analysis conducted in June 2012, results presented in the PG&E Commercial Conveyor Ovens Work Paper submitted to CPUC titled EnergyEfficiency2013-2014-Portfolio_Test_PGE_20120702_242194.zip

$$Btu_{idle} = Idle\ Energy \times \left(Daily\ Hrs - \frac{nPizzas}{Capacity} - \frac{nP \times Preheat\ Time}{60}\right) \times Days$$

(404)

$$Btu_{preheat} = nP \times Preheat\ Energy \times Days$$

(405)

Where:

E_{food} = ASTM defined Energy to Food = 190 Btu/pizza

$Cook\ Eff$ = Heavy Load Cooking Efficiency

$Days$ = Operating Day per Year = 365 days/yr

$nPizzas$ = Pizzas cooked/day = assume 250

$Capacity$ = Number of pizzas/hour

$Idle\ Energy$ = Idle Energy Rate (Btu/h)

$Daily\ Hrs$= Daily operating hours, deemed at 12 hours

$Preheat\ Time$ = Time to preheat (min) = 15 min

$Preheat\ Energy$ = Energy to preheat conveyor oven

nP = Number of Preheats = assume 1 based on FSTC research

Table 441: Baseline and Efficient Assumptions[675] for Gas Conveyor Ovens at >25" Wide

Parameter	>25" wide	
	Baseline	Efficient
Preheat Energy (Btu/day)	35,000	18,000
Idle Energy Rate (Btu/h)	70,000	57,000
Cooking Energy Efficiency (%)	20%	42%
Production Capacity (pizzas/hr)	150	220
Number of Pizzas cooked/day	250	250

Deemed Savings Values for Conveyor Ovens

Deemed savings based on the assumptions above are tabulated below for conveyor ovens at > 25" wide.

Table 442: Deemed Savings for Conveyor Ovens

Measure Description	Deemed Gas Savings per Oven (Therms)
Conveyor Oven >25" wide, Gas, high efficiency	884

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[675] Assumptions based on PG&E Commercial Rack Ovens Work Paper developed by FSTC in June 5, 2012 and the FSTC Life Cycle Cost Calculator.

3.8.4.3 Rack Ovens

Baseline & Efficiency Standard

There are currently no federal minimum standards for Commercial Rack Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[676] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results. The baseline and high efficiency parameters for single rack and double rack ovens are defined below.

Table 443: Baseline and Efficient Criteria[677] for Gas Single Rack Ovens.

Performance Parameters	Baseline Model	Efficient Model Criteria
Heavy-Load Cooking Energy Efficiency	30%	≥ 48%
Idle Energy Rate	43,000 Btu/h	<= 25,000 Btu/h

Table 444: Baseline and Efficient Criteria[678] for Gas Double Rack Ovens.

Performance Parameters	Baseline Model	Efficient Model Criteria
Heavy-Load Cooking Energy Efficiency	30%	≥ 50%
Idle Energy Rate	65,000 Btu/h	<= 35,000 Btu/h

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency rack oven as compared with a high efficiency rack oven.

For gas savings,

$$\Delta Btu = Btu_{base} - Btu_{eff}$$

(406)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

(407)

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[676] The industry standard for energy use and cooking performance of rack ovens is ASTM Standard Test Method for the Performance of Commercial Rack Ovens (F2093).

[677] 677 Efficient criteria from ENERGY STAR® Commercial Ovens Specification Version 2.2, October 2015. Baseline parameters from ENERGY STAR® Commercial Kitchen Equipment Calculator, 03-15-2016.

[678] Assumptions based on PG&E Commercial Rack Ovens Work Paper developed by FSTC, June 5, 2012 and sample of equipment tested by the Food Service Technology Center.

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat}$$

(408)

$$Btu_{cooking} = \left(LB \times \frac{E_{food}}{CookEff}\right) \times Days$$

(409)

$$Btu_{idle} = IdleEnergy \times \left(Daily\ Hrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(410)

$$Btu_{preheat} = PreheatEnergy \times Days$$

(411)

Where:

E_{food} = ASTM defined Energy to Food = 235 Btu/lb

$Cook\ Eff$ = Heavy Load Cooking Efficiency

$Days$ = Operating Day per Year = 365 days/yr.

LB = lbs. of food cooked a day = assume 1,200(double rack), 600 (single rack).

$Capacity$ = lbs. per hour

$IdleEnergy$ = Idle energy rate (Btu/h)

$DailyHrs$ = Daily operating hours, deemed at 12 hours

nap = Number of Preheats = assume 1 based on FSTC research

$Preheat\ Time$ = Time to preheat (min) = 20 min

$PreheatEnergy$ = Energy to preheat rack oven

Table 445: Baseline and Efficient Assumptions[679] for Gas Single and Double Rack Ovens

Parameter	Single Rack		Double Rack	
	Baseline	**Efficient**	**Baseline**	**Efficient**
Preheat Energy (Btu/day)	50,000	44,000	100,000	85,000
Idle Energy Rate (Btu/h)	43,000	29,000	65,000	35,000
Cooking Energy Efficiency (%)	30%	50%	30%	50%
Production Capacity (lbs./hr)	130	140	250	280
Lbs. of food cooked/day	600	600	1,200	1,200

Deemed Savings Estimates for Rack Ovens

Deemed savings based on the assumptions above are tabulated below for single rack and double rack ovens.

Table 446: Deemed Savings for Gas Single and Double Rack Ovens

Measure Description	Deemed Savings per Oven (Therms)
Single Rack Oven, Gas, high efficiency	1,034
Double Rack Oven, Gas, high efficiency	2,113

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[679] Assumptions based on PG&E Commercial Rack Ovens Work Paper developed by FSTC, June 5, 2012 as well as FSTC Life Cycle Cost Calculator.

3.8.5 Combination Ovens

Baseline & Efficiency Standard

There are currently no federal minimum standards for Commercial Combination Ovens, however, the American Society of Testing and Materials (ASTM) publishes Test Methods[680] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

As of January 1, 2014, efficient combination ovens are defined by ENERGY STAR® and apply to both electric and gas ovens. Combination ovens combines the function of hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating, to perform steaming, baking, roasting, rethermalizing, and proofing of various food products.

Table 447: High Efficiency Requirements for Electric and Gas Combination Ovens by Pan Capacity (P)

Mode	Idle Rate	Cooking Efficiency (%)
Gas, where P ≥ 6		
Steam Mode	≤ 200P + 6,511 Btu/h	≥ 41%
Convection Mode	≤ 150P + 5,425 Btu/h	≥ 56%
Electric, where P is ≥ 5 and ≤ 20		
Steam Mode	≤ 0.133P + 0.64 kW	≥ 55%
Convection Mode	≤ 0.08P + 0.4989 kW	≥ 76%

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency combination oven as compared with a high efficiency combination oven.

For electric savings,

$$\Delta kWh = kWh_{total,base} - kWh_{total,eff}$$

(412)

$$kWh_{(total,base\ or\ total,eff)} = kWh_{oven} + kWh_{steam} + kWh_{preheat}$$

(413)

$$kWh_{(oven\ or\ steam)} = kWh_{cooking} + kWh_{idle}$$

(414)

$$kWh_{cooking\ (oven\ or\ steam)} = \left(LB_{oven\ or\ steam} \times \frac{E_{food}}{CookEff}\right) \times Days$$

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[680] The industry standard for energy use and cooking performance of combination ovens is ASTM Standard Test Method for Enhanced Performance of Combination Ovens in Various Modes (F2861).

$Where\ LB_{oven} =$ LB × $(1$-% $Steam)$ and $LB_{steam} =$ LB × % $Steam$

(415)

$$kWh_{idle(oven)} = (1 - \%Steam) \times IdleEnergy \times \left(DailyHrs - \frac{LB_{oven}}{Capacity} - \frac{nP \times PreheatTime}{60}\right) \times Days$$

(416)

$$kWh_{idle(steam)} = (\%Steam) \times IdleEnergy \times \left(DailyHrs - \frac{LB_{steam}}{Capacity} - \frac{np \times PreheatTime}{60}\right) \times Days$$

(417)

$$kWh_{preheat} = nP \times PreheatEnergy \times Days$$

(418)

For gas savings,

$$\Delta Btu = Btu_{total,base} - Btu_{total,eff}$$

(419)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

(420)

$$Btu_{(total,base\ or\ total,eff)} = Btu_{oven} + Btu_{steam} + Btu_{preheat}$$

(421)

$$Btu_{oven\ or\ steam} = Btu_{cooking} + Btu_{idle}$$

(422)

$$Btu_{cooking\ (oven\ or\ steam)} = \left(LB_{oven\ or\ steam} \times \frac{E_{food}}{CookEff}\right) \times Days$$

Where LB_{oven} = LB × (1 – % Steam) and LB_{steam} = LB × % Steam

(423)

$$Btu_{idle(oven)} = (1 - \%Steam) \times IdleEnergy \times \left(Daily\ Hrs - \frac{LB}{Capacity} - \frac{nP \times PreheatTime}{60}\right) \times Days$$

(424)

$$Btu_{preheat} = nP \times PreheatEnergy \times Days$$

(425)

Key parameters used to compute savings are listed in Table 448, Table 449, and Table 450.

Table 448: Energy Consumption Related Parameters for Commercial Combination Ovens

Parameter	Description	Value	Source/Approach
Daily Hrs	Daily Operating Hours	12 hours	ENERGY STAR® Commercial Kitchen Equipment Calculator
PreheatTime	Time to Preheat (min)	15 min	FSTC Life Cycle & Energy Cost Calculator
nap	Number of Preheats per Day	1	FSTC Life Cycle & Energy Cost Calculator
$E_{food,oven}$	ASTM defined Energy to Food for Convection Ovens	0.0732 kWh/lb, 250 Btu/lb	ASTM
$E_{food,steam}$	ASTM defined Energy to Food for Steam Cookers	0.0308 kWh/lb, 105 Btu/lb	ASTM
Days	Number of days of operation	365 days	ENERGY STAR® Commercial Kitchen Equipment Calculator
%Steam	Percent of time in Steam Mode	50%	ENERGY STAR® Commercial Kitchen Equipment Calculator
CookEff	Cooking energy efficiency (%)	For Electric, see Table 449 For Gas, see Table 450	Baseline: Average from ENERGY STAR® and FSTC Calculators[681]
IdleEnergy	Idle energy rate (kW), (Btu/h)		
Capacity	Production capacity (lbs./hr)		Average from ENERGY STAR® Qualifying Products Listing
PreheatEnergy	kWh/day, Btu/day		FSTC Life Cycle & Energy Cost Calculator ENERGY STAR® Products Listing
$LB_{oven,steam}$	Food cooked per day (lb/day) in steam mode or oven mode		ENERGY STAR® Commercial Kitchen Equipment Calculator

General assumptions used for deriving deemed electric and gas savings are defined in the following tables. These values were taken from the ENERGY STAR® Food Service Appliance Calculator as well as the Food Service Technology Center (FSTC) Life Cycle and Energy Cost Calculator.

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[681] Baseline cooking efficiencies and idle energy rates were averaged between the ENERGY STAR® Food Service Appliance Calculator and the FSTC food service life cycle cost calculator.

Table 449: Baseline and Efficient Assumptions for Electric Combination Ovens

Parameter	**5 ≤ P ≤ 10**		**10 < P ≤ 14**		**14 < P ≤ 20**	
	Baseline	**Efficient**	**Baseline**	**Efficient**	**Baseline**	**Efficient**
Preheat Energy (kWh/day)	3.0	1.0	3.0	1.26	3.75	1.56
Convection Idle Energy Rate (kW)	2.16	calculated	2.16	calculated	3.02	calculated
Steam Idle Energy Rate (kW)	7.63	calculated	7.63	calculated	10.61	calculated
Convection Cooking Energy Efficiency (%)	69%	76%	69%	76%	69%	76%
Steam Cooking Energy Efficiency (%)	45%	55%	45%	55%	45%	55%
Convection Production Capacity (lbs./hour)	79	85	79	143	166	198
Steam Production Capacity (lbs./hour)	126	122	126	185	295	308
Lbs. of food cooked/day	200	200	200	200	250	250

Table 450: Baseline and Efficient Assumptions for Gas Combination Ovens

Parameter	**5 ≤ P ≤ 10**		**10 < P ≤ 14**		**15 < P ≤ 22**	
	Baseline	**Efficient**	**Baseline**	**Efficient**	**Baseline**	**Efficient**
Preheat Energy (Btu/day)	18,000	8,525	22,000	7,043	32,000	14,856
Convection Idle Energy Rate (Btu/h)	11,874	calculated	11,874	calculated	13,912	calculated
Steam Idle Energy Rate (Btu/h)	31,828	calculated	31,828	calculated	42,281	calculated
Convection Cooking Energy Efficiency (%)	44%	56%	44%	56%	44%	56%
Steam Cooking Energy Efficiency (%)	30%	41%	30%	41%	30%	41%
Convection Production Capacity (lbs./hr)	125	100	125	137	176	197
Steam Production Capacity (lbs./hr)	195	120	195	207	211	229
Lbs. of food cooked/day	200	200	200	200	250	250

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF \tag{426}$$

Where:

ΔkWh = Annual energy savings (kWh)

$Hours =$ Operating Equivalent hours = 365 x 12 = 4,380[682] hours

$CF =$ Coincidence Factor = 0.84 (default)[683]

Deemed Savings Estimates for Combination Ovens

Deemed savings based on the assumptions above are tabulated below for electric and gas combination ovens based on number of pans. Savings from the steamer component of a more efficient combination oven is also provided for the replacement of a steamer with a combination oven.

Table 451: Deemed Savings[684] per Oven for ENERGY STAR® Electric and Gas Combination Ovens

Measure Description	**Savings from Replacement of a baseline Combination Oven**			**Steamer Savings from Replacement of a Steam Cooker[685]**		
	kW	**kWh**	**Therms**	**kW**	**kWh**	**Therms**
Combination Oven, Electric, high efficiency, 5 ≤ P ≤ 10	3.13	16,323	---	4.64	24,196	---
Combination Oven, Electric, high efficiency, 14 pans	2.44	12,472	---	N/A		
Combination Oven, Electric, high efficiency, 20 pans	3.69	19,220	---			
Combination Oven, Gas, high efficiency, 5 ≤ P ≤ 10	---	---	755	1,591		
Combination Oven, Gas, high efficiency, 10 < P ≤ 14	---	---	768	N/A		
Combination Oven, Gas, high efficiency, 15 < P ≤ 22	---	---	1005			

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[682] ENERGY STAR® Commercial Kitchen Equipment Savings Calculator – Rack Ovens assumes an operating time of 12 hours.

[683] KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

[684] Baseline values differed significantly between the FSTC Life Cycle Cost Calculator and ENERGY STAR® Food Service Appliance Calculator. Deemed savings are based on an average of baselines reported by both calculators.

[685] Baseline steam cooker performance applied average consumption values between a conventional unit and a more efficient unit.

3.8.6 Commercial Fryers

Measure Description

This measure applies to ENERGY STAR**®** or its equivalent natural gas and electric commercial open-deep fat fryers in retrofit and new construction applications. Commercial fryers consist of a reservoir of cooking oil that allows food to be fully submerged without touching the bottom of the vessel. For a commercial gas fryer, the cooking oil is heated by atmospheric or infrared gas burners underneath the fry pot (or vat) or in tubes that pass through the fry pot. Electric fryers use a heating element immersed in the cooking oil.

High efficiency standard and large vat fryers offer shorter cook times and higher production rates through the use of advanced burner and heat exchanger design. Standby losses are reduced in more efficient models through the use of fry pot insulation.

Baseline & Efficiency Standard

Key parameters for defining fryer efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. ENERGY STAR® requirements apply to a standard fryer and a large vat fryer. A standard fryer measures 14 to 18 inches wide with a vat capacity from 25 to 60 pounds. A large vat fryer measures 18 inches to 24 inches wide with a vat capacity greater than 50 pounds. The ENERGY STAR® criteria should be reviewed on an annual basis to reflect the latest requirements.

There are currently no federal minimum standards for Commercial Fryers, however, ASTM publishes Test Methods[686] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Table 452: ENERGY STAR® Criteria[687] and FSTC Baseline for Open Deep-Fat Electric Fryers

Performance Parameters	**ENERGY STAR® Electric Fryer Criteria**	
	Standard Fryers	**Large Vat Fryers**
Heavy-Load Cooking Energy Efficiency	≥83%	≥ 80%
Idle Energy Rate	≤ 800 kW	≤ 1.1 kW

Table 453: ENERGY STAR® Criteria and FSTC Baseline for Open Deep-Fat Gas Fryers

Performance Parameters	**ENERGY STAR® Gas Fryer Criteria**	
	Standard Fryers	**Large Vat Fryers**
Heavy-Load Cooking Energy Efficiency	≥ 50%	≥ 50%
Idle Energy Rate	≤ 9,000 Btu/hr	≤ 12,000 Btu/hr

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[686] The industry standards for energy use and cooking performance of fryers are ASTM Standard Test Method for the Performance of Open Deep Fat Fryers (F1361) and ASTM Standard Test Method for the Performance of Large Vat Fryers (FF2144).

[687] ENERGY STAR® Version 2.0, effective April 22, 2011.

Estimated Useful Life (EUL)

According to DEER 2008, commercial fryers are assigned an estimated useful life (EUL) of 12 years.[688]

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency fryer as compared with an ENERGY STAR® rated fryer.

For electric savings,

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

(427)

$$kWh_{(base\ or\ eff)} = kWh_{cooking} + kWh_{idle} + kWh_{preheat}$$

(428)

$$kWh_{cooking} = \left(LB \times \frac{E_{food}}{CookEff}\right) \times Days$$

(429)

$$kWh_{idle} = IdleEnergy \times \left(DailyHrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(430)

$$kWh_{preheat} = PreheatEnergy \times Days$$

(431)

For gas savings,

$$\Delta Btu = Btu_{base} - Btu_{eff}$$

(432)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

(433)

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat}$$

(434)

$$Btu_{cooking} = \left(LB \times \frac{E_{food}}{CookEff}\right) \times Days$$

(435)

$$Btu_{idle} = IdleEnergy \times \left(Daily\ Hrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

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[688] Database for Energy Efficient Resources, 2008, http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls

(436)

$$Btu_{preheat} = PreheatEnergy \times Days$$

(437)

Key parameters used to compute savings are defined in Table 454.

Table 454: Energy Consumption Related Parameters for Commercial Fryers[689]

Parameter	Description	Value	Source
Daily Hrs	Daily Operating Hours	12 hours	FSTC
PreheatTime	Time for Fryer to Preheat (min)	15 min	FSTC
E_{food}	ASTM defined Energy to Food	0.167 kWh/lb, 570 Btu/lb	FSTC
Days	Number of days of operation	365 days	FSTC
CookEff	Cooking energy efficiency (%)	For electric, see Table 455 For gas, see Table 456	FSTC, ENERGY STAR®
IdleEnergy	Idle energy rate (kW), (Btu/h)		
Capacity	Production capacity (lbs./hr)		FSTC
PreheatEnergy	kWh/day, Btu/day		FSTC
LB	Food cooked per day (lb/day)		FSTC

General assumptions used for deriving deemed electric and gas savings are defined in the following tables. These values are taken from the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator as well as the Food Service Technology Center (FSTC) work papers and research.

Table 455: Baseline and Efficient Assumptions for Electric Standard and Large Vat Fryers

Parameter	Baseline Electric Fryers		Efficient Electric Fryers	
	Standard	Large Vat	Standard	Large Vat
Preheat Energy (kWh/day)	2.3	2.5	1.7	2.1
Idle Energy Rate (kW)	1.05	1.35	0.8	1.1
Cooking Energy Efficiency (%)	75%	70%	83%	80%
Production Capacity (lbs./hour)	65	100	70	110
Lbs. of food cooked/day	150	150	150	150

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[689] Assumptions based on PG&E Commercial Fryers Work Paper developed by FSTC, June 13, 2012

Table 456: Baseline and Efficient Assumptions for Gas Standard and Large Vat Fryers

Parameter	**Baseline Gas Fryers**		**Efficient Gas Fryers**	
	Standard	**Large Vat**	**Standard**	**Large Vat**
Preheat Energy (Btu/day)	16,000	21,000	15,500	16,500
Idle Rate (Btu/hr)	14,000	16,000	9,000	12,000
Cooking Efficiency (%)	35%	35%	50%	50%
Production Capacity (lbs./hour)	60	100	65	110
Lbs. of food Cooked/Day	150	150	150	150

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

(438)

Where:

$\Delta kWh =$ Annual energy savings (kWh)

$HOURS$ = Operating equivalent hours = 365 x 12 = 4,380

CF = Coincidence factor = 0.84 [690]

Deemed Savings Values

Deemed savings using the assumptions above are tabulated below. These values are per installed unit based on the type of fryer.

Table 457: Deemed Savings per Fryer Vat

Measure Description	**Deemed Savings per Fryer Vat**		
	kW	**kWh**	**Therms**
Fryer, Electric, ENERGY STAR®	0.39	2055	0
Fryer, Gas, ENERGY STAR®	0	0	432
Fryer, Large Vat, Electric, ENERGY STAR®	0.51	2659	0
Fryer, Large Vat, Gas, ENERGY STAR®	0	0	428

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[690] Coincidence factors utilized in other jurisdictions for Commercial Fryers vary from 0.84 to 1.0. The KEMA report titled “Business Programs: Deemed Savings Parameter Development,” November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

3.8.7 Commercial Steam Cookers

Measure Description

This measure applies to ENERGY STAR® or its equivalent gas and electric steam cookers in retrofit and new construction applications. Commercial steam cookers, also known as "compartment steamers," vary in configuration and size based on the number of pans. High efficiency steam cookers offer shorter cook times, higher production rates and reduced heat loss due to better insulation and more efficient steam delivery system.

Baseline & Efficiency Standard

Key parameters for defining steam cookers efficiency are Heavy Load Cooking Energy Efficiency and Idle Energy Rate. ENERGY STAR® requirements apply to steam cookers based on the pan capacity. These criteria should be reviewed on an annual basis to reflect the latest ENERGY STAR® requirements.

There are currently no federal minimum standards for Commercial Steam Cookers, however, ASTM publishes Test Methods[691] that allow uniform procedures to be applied to each commercial cooking appliance for a fair comparison of performance results.

Table 458: ENERGY STAR® Criteria for Electric Steam Cookers [692]

Pan Capacity	Cooking Efficiency	Idle Rate (watts)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Table 459: ENERGY STAR® Criteria for Gas Steam Cookers [693]

Pan Capacity	Cooking Efficiency	Idle Rate (Btu/h)
5-pan	38%	10,400
6-pan and larger	38%	12,500

Estimated Useful Life (EUL)

According to DEER 2008, steam cookers are assigned an estimated useful life (EUL) of 12 years.

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[691] The industry standard for steam cookers energy use and cooking performance is ASTM Standard F1484-99, Test Method for the Performance of Steam Cookers/

[692] ENERGY STAR® Commercial Steam Cookers Version 1.2, effective August 1, 2003.

[693] ENERGY STAR® provides criteria for 3-pan, 4-pan but availability of products in this range is limited or unavailable.

Calculation of Deemed Savings

Energy savings for steam cookers is derived by determining the total energy consumed by standard steam cooker as compared with an ENERGY STAR® rated steam cooker. Total energy for a steam cooker includes the energy used during cooking, the energy used when the equipment is idling, the energy spent when set in a constant steam mode and the energy required during pre-heat.

$$\Delta Energy = Energy_{base,total} - Energy_{eff,total}$$

(439)

$$Energy_{(base,total\ or\ eff,total)} = Energy_{cooking} + Energy_{idle} + Energy_{steam} + Energy_{preheat}$$

(440)

where,

$$Energy_{cooking} = \frac{LB_{\ food} \times E_{food}}{Cook\ Eff} \times Days$$

(441)

$$Energy_{idle} = (1 - \%Steam) \times IdleEnergy \times \left(DailyHrs - \frac{LB_{\ food}}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(442)

$$Energy_{steam} = (\%Steam) \times \frac{Capacity \times E_{food}}{Cook\ Eff} \times \left(DailyHrs - \frac{LB_{\ food}}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(443)

$$Energy_{preheat} = PreheatEnergy \times Days$$

(444)

General assumptions used for deriving deemed electric and gas savings are defined in the following tables. These values are taken from the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator as well as the Food Service Technology Center (FSTC) work papers and research.

Table 460: Energy Consumption Related Parameters for Commercial Steam Cookers

Parameter	Description	Value	Source
Daily Hrs	Daily Operating Hours	12 hours	FSTC
PreheatTime	Steam Cooker Preheat time (min)	15 min	FSTC
E_{food}	ASTM defined Energy to Food	0.0308 kWh/lb, 105 Btu/lb	FSTC
Days	Number of days of operation	365 days	FSTC
CookEff	Cooking energy efficiency (%)	For electric, see Table 455 For gas, see Table 456	FSTC, ENERGY STAR®
IdleEnergy	Idle energy rate (kW), (Btu/h)		
%Steam	Constant Steam Energy Use		FSTC
Capacity	Production capacity (lbs./hr)		ENERGY STAR®
PreheatEnergy	kWh/day, Btu/day		ENERGY STAR®
LB_{food}	Food cooked per day (lb/day)		ENERGY STAR®

Table 461: Deemed Savings Assumptions for Electric Steam Cookers

Parameter	Baseline Model	Efficient Electric Model
Cooking Efficiency (%)	26%	50%
Preheat Energy (kWh)	1.5	1.5
Constant Steam Mode Time (%)	0.9	0.1
Lbs. of food Cooked/Day	100	100
Production Capacity (lbs./hr/pan)	23.33	16.67
Idle Energy Rate (kW/pan)	0.33	0.13

Table 462: Deemed Savings Assumptions for Gas Steam Cookers

Parameter	Baseline Model	Efficient Gas Model
Cooking Efficiency (%)	15%	38%
Preheat Energy (Btu)	20,000	9,000
Constant Steam Mode Time (%)	0.9	0.1
Lbs. of food Cooked/Day	100	100
Production Capacity (lbs./h/pan)	23.3	20.83
Idle Energy Rate (Btu/h/pan)	2,500	2,083

Peak Demand Savings can be derived by dividing the annual energy savings by the operating Equivalent hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HOURS}\right) \times CF$$

(445)

Where:

ΔkWh = Annual energy savings (kWh)

4380 = Operating Equivalent hours = 365 x 12 = 4380 hours

0.84[694] = Coincidence Factor (CF)

Deemed Savings Values

Deemed savings are per installed unit based on the number of pans per steam cooker.

Table 463: Deemed Savings for Steam Cookers

Measure Description	Deemed Savings		
	kW	kWh	Therms
Steam Cooker, Electric, 3 pan - ENERGY STAR®	5.4	28,214	0
Steam Cooker, Electric, 4 pan - ENERGY STAR®	7.3	38,081	0
Steam Cooker, Electric, 5 pan - ENERGY STAR®	9.2	47,948	0
Steam Cooker, Electric, 6 pan - ENERGY STAR®	11.1	57,815	0
Steam Cooker, Gas, 5 pan - ENERGY STAR®	0	0	2,680
Steam Cooker, Gas, 6 pan - ENERGY STAR®	0	0	3,215

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[694] Coincidence factors utilized in other jurisdictions for Commercial Steam Cookers vary from 0.84 to 1.0. The KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

3.8.8 Commercial Underfired Broilers

Measure Description

This measure applies to underfired broilers, also referred to as charbroilers. Underfired broilers generate heat upwards at high temperatures to a series of grates or ribs. These products have the highest input rate and production capacity amongst broilers.

Estimated Useful Life (EUL)

According to the Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from the FSTC Broiler Technology Assessment, commercial broilers are assigned an estimated useful life (EUL) of 12 years.[695]

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency gas broiler as compared with a higher efficiency gas broiler.

$$\Delta Therms = \frac{\Delta Btu_{cooking} + \Delta Btu_{preheat}}{100{,}000}$$

(446)

$$\Delta Btu_{cooking} = (CookingEnergyRate_{base} - CookingEnergyRate_{ee}) \times Duty \times Hours$$

(447)

$$\Delta Btu_{preheat} = (Preheat_{base} - Preheat_{ee}) \times \frac{Preheat\ Time}{60}$$

(448)

Key parameters used to compute savings are defined next.

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[695] See the Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator.

Table 464: Deemed Assumptions for Commercial Underfired Broilers[696]

Parameter	Baseline Model	Efficient Gas Model
Cooking Energy Rate (Btu/h) per foot	32,000	24,000
Preheat Energy (Btu) per foot	16,000	13,500
Preheat Time (min)	15	15
Hours per Day	12	12
Days per Year	312	312
Duty[697]	80%	80%

Using the parameter assumptionsin Table 464 deemed savings are calculated below based on the size of the broiler in feet.

Table 465: Deemed Savings for Commercial Underfired Broilers

Measure Description	Therms
Underfired Broiler, Gas, 2 foot	483
Underfired Broiler, Gas, 3 foot	725
Underfired Broiler, Gas, 4 foot	966
Underfired Broiler, Gas, 5 foot	1208
Underfired Broiler, Gas, 6 foot	1449

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[696] Parameters from FSTC Broiler Technology Assessment, Table 4.3 and from FSTC Calculator for Underfired Broilers.

3.8.9 Commercial Conveyor Broilers

Measure Description

This measure applies to conveyor broilers, also known as “chain” broilers. This type of broiler contains one to four belts on which food is placed either on the belt or in pans that travel on the belt. Food is cooked simultaneously by burners located above and below the belts. Conveyor gas broilers are used in high-volume facilities.

Estimated Useful Life (EUL)

According to the Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from the FSTC Broiler Technology Assessment, commercial broilers are assigned an estimated useful life (EUL) of 12 years.[698]

Calculation of Deemed Savings

Annual savings can be calculated by determining the energy consumed by a standard efficiency conveyor broiler as compared with a higher efficiency conveyor broiler.

$$\boldsymbol{\Delta Btu = Btu_{base} - Btu_{eff}}$$

(449)

$$Btu_{(base\ or\ eff)} = Btu_{cooking} + Btu_{idle} + Btu_{preheat}$$

(450)

$$Btu_{cooking} = \left(\frac{LB_{food} \times E_{food}}{Capacity}\right) \times CookEff \times Days$$

(451)

$$Btu_{idle} = IdleEnergy \times \left(DailyHrs - \frac{LB}{Capacity} - \frac{PreheatTime}{60}\right) \times Days$$

(452)

$$Btu_{preheat} = PreheatEnergy \times Days$$

(453)

$$\Delta Therms = \frac{\Delta Btu}{100{,}000}$$

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[698] See the Food Service Technology Center Gas Conveyor Broiler Life-Cycle Cost Calculator.

Table 466: Savings Parameters for Commercial Conveyor Broilers[699]

Parameter	Description	Baseline Model	Efficient Model
DailyHrs	Daily Hrs (hours)	18	18
PreheatTime	Preheat Time (min)	15	15
Days	Number of days of operation	364	364
Efood, gas	Energy to Food (btu/lb)	392	392
Idle Energy (Btu/h)	IdleEnergy (Btu/h)	80000	48000
LB	Pounds of food a day	250	250
PreheatEnergy (Btu)	Preheat Energy	14130	14210
CookEff	Cooking energy efficiency (%)	25%	35%
Capacity (lbs/h)	Production Capacity (lbs/h)	41.7	41.7

Table 467: Deemed Savings for Commercial Conveyor Broilers

Measure	Therm Savings
Conveyor Broiler	1781

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[699] Assumptions based on Food Service Technology Center Gas Conveyor Broiler Life Cycle Cost Calculator.

3.8.10 ENERGY STAR® Commercial Dishwashers

Measure Description

This measure defines electric and gas savings from ENERGY STAR® commercial dishwashers in retrofit and new construction applications. Commercial dishwashers, also known as "warewashers," fall into two categories of machine type: stationary rack and conveyor. Key parameters used to characterize the efficient performance of commercial dishwashers are Idle Energy Rate and Water Consumption Rate. Energy savings from commercial dishwashers is primarily attributed to reducing the amount of water used which reduces the energy consumed to heat that water.

Baseline & Efficiency Standard

High efficiency commercial dishwashers, as defined by ENERGY STAR®, include stationary rack and conveyor machines that are configured as follows:

Stationary Rack Machines – A dishwashing machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles.

- Under Counter – A stationary rack machine with an overall height of 38 inches or less, designed to be installed under food preparation workspaces. Under counter dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Stationary Single Tank Door – A stationary rack machine designed to accept a standard 20 inch x 20 inch dish rack, which requires the raising of a door to place the rack into the wash/rinse chamber. Closing of the door typically initiates the wash cycle. Single tank door type models can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Pot, Pan, and Utensil – A stationary rack, door type machine designed to clean and sanitize pots, pans, and kitchen utensils.

Conveyor Machines – A dishwashing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine.

- Single Tank Conveyor – A conveyor machine that includes a tank for wash water followed by a sanitizing rinse (pumped or fresh water). This type of machine does not have a pumped rinse tank. This type of machine may include a pre-washing section ahead of the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the power rinse and sanitizing rinse sections. Single tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
- Multiple Tank Conveyor – A conveyor type machine that includes one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a sanitizing rinse. This type of machine may include a pre-washing section before the washing section and an auxiliary rinse section, for purposes of reusing the sanitizing rinse water, between the power rinse and sanitizing rinse sections. Multiple tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.

Each of these machines are further classified by their rinse water washing strategies; high temperature, sanitized by heat with boost heating (~180°) and low temperature, sanitized by chemicals (~120°-140°).

There are currently no federal minimum standards for Commercial Dishwashers, however, the ASTM and the National Sanitation Foundation (NSF) publishes Test Methods[700] that allow uniform procedures to be applied to each commercial dishwasher for a fair comparison of performance results.

Table 468: ENERGY STAR®[701] Requirements for Commercial Dishwashers[702]

Machine Type	**High Temp Efficiency Requirements**		**Low Temp Efficiency Requirements**	
	Tank Heater Idle Energy Rate (kW)	**Water Consumption**	**Tank Heater Idle Energy Rate (kW)**	**Water Consumption**
Under Counter	≤ 0.50	≤ 0.86 GPR	≤ 0.50	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.70	≤ 0.89 GPR	≤ 0.60	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 1.20	≤ 0.58 GPSF	≤ 1.00	≤ 0.58 GPSF
Single Tank Conveyor	≤ 1.50	≤ 0.70 GPR	≤ 1.50	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 2.25	≤ 0.54 GPR	≤ 2.00	≤ 0.54 GPR

$GPR =$ Gallons per Rack

$GPSF =$ Gallons per Square Foot of Rack

$GPH =$ Gallons per Hour

Estimated Useful Life[703] (EUL)

The estimated useful life (EUL) of commercial dishwashers vary based on the machine type. Under Counters have an EUL of 10 years, Door-Types have an EUL of 15 years and Conveyor Types have an EUL of 20 years.

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[700] The industry standards for energy use is ASTM Standard F1920, Standard Test Method for Energy Performance of Rack Conveyor, Hot Water Sanitizing, Commercial Dishwashing Machines, ASTM Standard F1696, Standard Test Method for Energy Performance of Single-Rack Hot Water Sanitizing, Door-Type Commercial Dishwashing Machines and NSF/ANSI 3-2007 Standard, Commercial Warewashing Equipment.

[701] ENERGY STAR® Commercial Dishwashers Version 2.0 effective as of February 1, 2013. http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers.

[702] ENERGY STAR® Commercial Dishwashers Version 2.0 includes 3 new dishwasher types: 1) Pot, Pan, and Utensil, 2) Single Tank Flight Type, and 3) Multiple Tank Flight Type. These new dishwasher types will be incorporated into the measure once they are incorporated into the ENERGY STAR® Commercial Dishwasher Savings Calculator.

[703] EUL values from CEE Program Design Guidance-Commercial Dishwashers, updated 5/11/2009.

Calculation of Deemed Savings[704]

Annual savings were calculated by determining the energy consumed for baseline commercial dishwashers compared against ENERGY STAR® performance requirements. The annual energy consumption for commercial dishwashers was determined by the summation of the annual energy used for water heating, the booster heater and when the machine is in idle mode.

$$E_{total} = E_{DHW} + E_{boost} + E_{idle} \tag{454}$$

These are defined as follows for both gas and electric calculations:

$$E_{DHW} = \frac{(RPD \times GPR \times Days \times d \times c_p \times \Delta T_{DHW})}{EF_{DHW} \times Conversion\ Factor} \tag{455}$$

$$E_{BOOST} = \frac{(RPD\ x\ GPR\ x\ Days\ x\ d\ x\ c_p\ x\ \Delta T_{BOOST})}{EF_{BOOST}\ x\ Conversion\ Factor}$$

(*only* applicable in High Temperature Machines)

(456)

$$E_{idle} = kW_{\text{idle}} \times \left(HRS - \frac{(RPD \times MPR)}{60}\right) \times \text{Days} \tag{457}$$

Where:

RPD = Average number of racks washed per day, varies by machine

GPR = Average gallons per rack used by dishwasher, varies by machine

$Days$ = Operating Day per Year = 365 days/yr.

d = Density of water, constant value 8.34 lb/gal

c_p = Specific heat of water, 1 Btu/lb-°F

ΔT_{DHW} = Temperature rise at primary water heater, 70°F (default)

ΔT_{BOOST} = Temperature rise at booster heater, 40°F (default)

EF_{DHW} = Efficiency of building water heater, 80% for gas, 98% for electric (default)

EF_{BOOST} = Efficiency of booster water heater, 80% for gas, 98% for electric (default)

$Conversion\ Factor$ = 100,000 Btu/therm or 3,413 Btu/kWh.

kW_{idle} = Energy consumed while idle, varies by machine

HRS = Hours per day dishwasher operates, 18 hours (default)

MPR = Time to wash one rack of dishes, minutes per rack, varies by machines

60 = Minutes per hour

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[704] Assumptions from the ENERGY STAR® Commercial Dishwashers Savings Calculator (May 2013 update).

To determine electric and gas savings for the different types of commercial dishwashers, Table 469 and Table 470 list the assumptions made for the machine dependent parameters; Idle Power, Racks per Day, Minutes per Rack and Gallons per Rack. Table 469 lists the parameters for machines that employ Low Temperature cleaning and Table 470 lists parameters for machines that employ High Temperature cleaning.

Table 469: Default Assumptions for Low Temperature, Electric and Gas Water Heaters

Performance	**Under Counter**		**Single Tank Door**		**Single Tank Conveyor**		**Multi Tank Conveyor**	
	Base	**Change**	**Base**	**Change**	**Base**	**Change**	**Base**	**Change**
Idle Power	0.5	0.5	0.6	0.6	1.6	1.5	2.0	2.0
Racks/Day	75	75	280	280	400	400	600	600
Min/Rack	2.0	2.0	1.5	1.5	0.3	0.3	0.3	0.3
Gal/Rack	1.73	1.19	2.1	1.18	1.31	0.79	1.04	0.54

Table 470: Default Assumptions for High Temperature, Electric and Gas Water Heaters[4]

Performance	**Under Counter**		**Single Tank Door**		**Pot, Pan, and Utensil**		**Single Tank Conveyor**		**Multi Tank Conveyor**	
	Base	**Change**	**Base**	**Change**	**Base**	**Change**	**Base**	**Change**	**Base**	**Change**
Idle Power	0.76	0.5	0.87	0.7	1.2	1.2	1.93	1.5	2.59	2.25
Racks/Day	75	75	280	280	280	280	400	400	600	600
Min/Rack	2.0	2.0	1.0	1.0	3.0	3.0	0.3	0.3	0.2	0.2
Gal/Rack	1.09	0.86	1.29	0.89	0.70	0.58	0.87	0.70	0.97	0.54

Peak Demand Savings can be derived by dividing the annual energy savings by the operating hours and multiplying by the Coincidence Factor.

$$\Delta kW = \left(\frac{\Delta kWh}{HRS}\right) \times CF$$

(458)

Where:

ΔkWh = Annual energy savings (kWh)

HRS = Operating hours = 365 x 18 = 6,570 hours (default)

CF = Coincidence Factor = 0.84 (default)[705]

Deemed Savings Values

If specific equipment data is not available for use with the measure savings calculations described

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[705] The KEMA report titled "Business Programs: Deemed Savings Parameter Development," November 2009 conducted for Wisconsin Focus on Energy lists Coincidence Factors by building type and identifies food service at 0.84.

above, deemed electric and gas savings from ENERGY STAR® commercial dishwashers can be seen in Table 471. Equipment savings are defined based on the following information:

- Dishwasher Type (Under Counter, Stationary Single Tank Door, Pots, Pans, and Utensils, Single Tank Conveyor, or Multiple Tank Conveyor)
- Water Temperature (Low Temperature or High Temperature)
- Building Water Heater Fuel (Electric or Gas)
- Booster Water Heater Fuel (Electric or Gas) *Only applicable in High Temperature Units*
- Default Assumptions from ENERGY STAR® Commercial Dishwasher Savings Calculator (May 2013 update)

Table 471: Deemed Savings for Commercial Dishwashers

Water Temperature	Water Heater Fuel/Booster Heater Fuel	Measure Description	kW	kWh	Therms
High Temperature	Electric/ Electric	Under Counter	0.4	3,198	--
		Stationary Single Tank Door	1.5	12,040	--
		Pots, Pans, and Utensils	0.4	3,364	--
		Single Tank Conveyor	1.2	9,319	--
		Multiple Tank Conveyor	3.6	27,815	--
	Gas/ Electric	Under Counter	0.3	2,099	256
		Stationary Single Tank Door	0.6	4,905	469
		Pots, Pans, and Utensils	0.2	1,223	
		Single Tank Conveyor	0.6	4,987	524
		Multiple Tank Conveyor	1.5	11,378	1,023
	Gas/ Gas	Under Counter	0.2	1,471	72
		Stationary Single Tank Door	0.1	827	469
		Pots, Pans, and Utensils	--	--	141
		Single Tank Conveyor	0.3	2,511	285
		Multiple Tank Conveyor	0.3	1,986	1,080
Low Temperature	Electric/ No Booster	Under Counter	0.3	2,580	--
		Stationary Single Tank Door	2.1	16,411	--
		Single Tank Conveyor	1.8	13,835	--
		Multiple Tank Conveyor	2.4	19,112	--
	Gas/ No Booster	Under Counter	--	--	108
		Stationary Single Tank Door	--	--	686
		Single Tank Conveyor	--	--	554
		Multiple Tank Conveyor	--	--	799

3.8.11 Low-Flow Pre-Rinse Spray Valves

Measure Description

This measure consists of installing low-flow pre-rinse spray valves which reduce hot water usage and save energy associated with heating the water. The low-flow pre-rinse spray valves have the same cleaning effect as the existing standard spray valves even though they use less water.

Baseline & Efficiency Standard

The savings values for low-flow pre-rinse spray valves are applicable for the retrofit of existing operational pre-rinse spray valves with a flow rate of 2.25 gallons per minute or higher. Facilities that use gas or electric water heaters are both eligible for this measure.

The baseline pre-rinse spray valves are assumed to have a flow rate of 2.25 gallons per minute.[706] The maximum flow rate of qualifying low-flow pre-rinse spray valves is 1.28 gallons per minute.[707]

Estimated Useful Life (EUL)

The effective useful life (EUL) for this measure is 5 years.[708]

Calculation of Deemed Savings

Annual gas savings and peak day gas savings can be calculated by using the following equations:

$$\Delta Therms = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times \frac{Days}{Year}}{100{,}000 BTU/Therm}$$

(459)

$$\Delta Peak\ Therms = \frac{\Delta Therms}{\frac{Days}{Year}}$$

(460)

Annual kWh electric and peak kW savings can be calculated using the following equations:

$$\Delta kWh = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times \frac{Days}{Year}}{3412 BTU/kWh}$$

(461)

$$\Delta kW = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times P}{3412 BTU/kWh}$$

(462)

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[706] Impact and Process Evaluation Final Report for California Urban Water Conservation Council, 2004-5. Pre-Rinse Spray Valve Installation Program (Phase 2), SWB Consulting, 2007.

[707] FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-Rinse Spray Valves.

[708] FEMP Purchasing Specification for Energy-Efficiency Products, Pre-Rinse Spray Valves: http://www1.eere.energy.gov/femp/pdfs/pseep_spray_valves.pdf

Table 472: Variables for the Deemed Savings Algorithm

Parameter	Description	Value
F_B	Average baseline flow rate of sprayer (GPM)	2.25[1]
F_P	Average post measure flow rate of sprayer (GPM)	1.28[1,2]
$Days/Year$	Annual operating days for the applications: see Table 473 for building type definitions: 1. Fast food restaurant 2. Casual dining restaurant 3. Institutional 4. Dormitory 5. K-12 school	365[709] 365[3] 365[3] 274[710] 200[3]
T_{supply}	Average supply (cold) water temperature (°F) from Table 348	Zone 9: 65.6 Zone 8: 66.1 Zone 7: 67.8 Zone 6: 70.1
T_H	Average mixed hot water (after spray valve) temperature (°F)	120[711]
U_B	Baseline water usage duration for the following applications: 1. Fast food restaurant (see Table 474– small service) 2. Casual dining restaurant (see Table 474 – medium service) 3. Institutional (see Table 474 – large service) 4. Dormitory (see Table 474 – large service) 5. K-12 school (see Table 474 – medium service)	45 min/day/unit[712] 105 min/day/unit[6] 210 min/day/unit[6] 210 min/day/unit[6] 105 min/day/unit[713]
ρ	Density of water 8.33 BTU/Gallon	8.33
C_P	Heat capacity of water, 1 BTU/I°F	1

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[709] Osman S &. Koomey, J. G. , . Lawrence Berkeley National Laboratory 1995. *Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting*. December.

[710] For dormitories with few occupants in the summer: 365 x (9/12) = 274.

[711] According to ASTM F2324 03 Cleanability Test the optimal operating conditions are at 120°F.

[712] CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Valves.

[713] School mealtime duration is assumed to be half of that of institutions, assuming that institutions (e.g. prisons, university dining halls, hospitals, nursing homes) serve three meals per day at 70 minutes each, and schools serve breakfast to half of the students and lunch to all, yielding 105 minutes per day.

Parameter	Description	Value
E_t	Thermal efficiency of water heater	Default value 0.98 for electric and 0.80 for gas
P	Hourly peak demand as a fraction of daily water consumption for the following applications: 1. Fast food restaurant (Fast Food) 2. Casual dining restaurant (Sit down rest.) 3. Institutional (Nursing Home) 4. Dormitory (Sit down rest.) 5. K-12 School (High school)	0.05[714] 0.04[8] 0.03[8] 0.04[8] 0.05[8]

Table 473: Building Type Definitions

Building Type	Operating Days per Year	Representative PRSV Usage Examples
1. Fast food restaurant	365	Establishments engaged in providing food services where patrons order and pay before eating. These facilities typically use disposable serving ware. PRSV are used for rinsing cooking ware, utensils, trays, etc. Examples: Fast food restaurant, supermarket food preparation and food service area, drive-ins, grills, luncheonettes, sandwich, and snack shops.
2. Casual dining restaurant	365	Establishments primarily engaged in providing food services to customers who order and are served while seated (i.e. waiter/waitress service). These facilities typically use chinaware and use the PRSV to rinse dishes, cooking ware, utensils, trays, etc. Example: Full meal restaurant.
3. Institutional	365	Establishments located in institutional facilities (e.g. nursing homes, hospitals, prisons, military) where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, tray, etc. Examples: Nursing home, hospital, prison cafeteria, and military barrack mess hall.

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[714] *ASHRAE Handbook 2011. HVAC Applications*. Chapter 50 –Service Water Heating. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE) 2011. ASHRAE, Inc., Atlanta, GA. The hourly flow profiles given in Figure 24 on page 50.19 were reviewed and analyzed. The hourly peak demand as a percent of the daily flow was estimated using the total daily flow, the hourly flow, and the peak demand period window in Arkansas.

Building Type	**Operating Days per Year**	**Representative PRSV Usage Examples**
4. Dormitory	274	Establishments located in higher education facilities where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, trays, etc. Example: University dining halls.
5. K-12 School	200	Establishments located in K-12 schools where food is prepared in large volumes and patrons order food before eating, such as in dining halls and cafeterias. These facilities typically use disposable serving ware and serving trays. PRSVs are used for rinsing cooking ware, utensils, trays, etc. Example: K-12 school cafeterias

Table 474: Daily Operating Hours

Food Service Operation	**Min (Min/Day)**	**Max (Min/Day)**	**Average Min/Day)**
Small Service (e.g., quick-service restaurants)	30	60	45
Medium Service (e.g., casual dining restaurants)	90	120	105
Large Service (e.g., institutional such as cafeterias in universities, prisons, and nursing homes)	180	240	210

The following are example calculations for a fast food restaurant in Fayetteville using the previous equations.

$$\Delta Therms = \frac{8.33\ x\ 45\ \frac{min}{day}\ x\ [2.25 - 1.28]GPM\ x\ (120 - 65.6°\mathrm{F})x\ \left(\frac{1}{0.8}\right)\ x\ \frac{365day}{year}}{100{,}000\frac{BTU}{Therm}}$$

$$= 90\ Therms/yr$$

(463)

$$\Delta\ Peak\ Therms = \frac{8.33\ x\ 45\ \frac{min}{day}\ x\ [2.25 - 1.28]GPM\ x\ (120 - 65.6°\mathrm{F})x\ \left(\frac{1}{0.8}\right)}{100{,}000\frac{BTU}{Therm}}$$

$$= 0.25\ Therms$$

(464)

$$\Delta kWh = \frac{8.33\ x\ 45\frac{min}{day}\ x\ [2.25 - 1.28]GPM\ x\ (120 - 65.6°\mathrm{F})x\ \left(\frac{1}{0.98}\right)x\ \frac{365\ days}{year}}{3412\frac{BTU}{kWh}}$$

$$= 2159\ kWh$$

(465)

$$\Delta kW\ = \frac{0.05\ x\ 8.33\ x\ 45\frac{min}{day}\ x\ (2.25 - 1.28)GPM\ x\ (120 - 65.6°\mathrm{F})x\ (\frac{1}{0.98})}{3412\frac{BTU}{kWh}}$$

$$0.30\ kW$$

(466)

4. GENERAL REFERENCE INFORMATION

4.1 Acronyms & Abbreviations

AC	Air-Conditioning
ACH	Air Changes per Hour
ACCA	Air-Conditioning Contractors of America
ACEEE	American Council for an Energy Efficient Economy
AFUE	Annual Fuel Utilization Efficiency
AHAM	Association of Home Appliance Manufacturers
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ANSI	American National Standards Institute
ARI	(see AHRI)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
BTUh	British Thermal Units per Hour
C&I	Commercial and Industrial
CALMAC	California Measurement Advisory Committee
CEUS	Commercial End Use Survey of 2006
CBECS	Commercial Building Energy Consumption Survey
CCT	Correlated Color Temperature
CEE	Consortium for Energy Efficiency
CF	Coincidence Factor
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CNRC	Canada National Research Council
CO	Carbon Monoxide
COP	Coefficient of Performance
CR	Converted Residence
DEER	Database for Energy Efficient Resources

DHW	Domestic Hot Water
DLC	DesignLights™ Consortium
DOE	Department of Energy
DOE2	Department of Energy (building simulation model version 2)
DSE	Distribution System Efficiency
DSM	Demand-Side Management
DX	Direct Expansion
ECM	Electrically Commutated Motor
EER	Energy Efficiency Ratio
EF	Efficiency Factor
EFLH	Equivalent Full Load Hours
EPAct	Energy Policy Act
EISA	Energy Independence and Security Act of 2007
EUL	Estimated Useful Life
F	Fahrenheit
FESC	Florida Solar Energy Center
GAMA	Gas Appliance Manufacturer Association
GPM	Gallons per Minute
GSFL	General Service Fluorescent Lamp
GSIL	General Service Incandescent Lamp
HDD	Heating Degree Day
HE	High-Efficiency
HERS	Home Energy Rating System
HIM	High Impact Measure
hp	Horsepower
HP	Heat Pump
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilating, and Air-Conditioning
IECC	International Energy Conservation Code
IES	(see IESNA)
IESNA	Illuminating Engineering Society of North America

IMEF	Integrated Modified Energy Factor
IMH	Ice-making Heads
IPLV	Integrated Part-Load Value
ISTMT	In-Situ Temperature Measurement Test
IWF	Integrated Water Factor
KBTUH	Thousand British Thermal Units per Hour
kW	Kilowatt
kWh	Kilowatt hour
LED	Light Emitting Diode
LPD	Lighting Power Density
LPW	Lumens Per Watt
Low-E	Low Emissivity
LRC	Lighting Research Center
MBH	Thousand British Thermal Units per Hour (KBTUH)
MBTU	Thousand British Thermal Units
MF	Multifamily
MHEA	Manufactured Housing Energy Audit
MMBTU	Million British Thermal Units
MW	Megawatt
MWh	Megawatt hour
NATE	North American Technician Excellence
NBI	New Buildings Institute
NEAT	National Energy Audit Tool
NEEP	Northeast Energy Efficiency Partnerships
NPCC	Northwest Power and Conservation Council
NVLAP	National Voluntary Laboratory Accreditation Program
NYSERDA	New York State Energy Research Development Authority
OSHA	Occupational Safety and Health Administration
PAF	Power Adjustment Factor
PIR	Passive Infrared
PSI	Pounds per Square Inch

PTAC	Packaged Terminal Air-Conditioners
PTHP	Packaged Terminal Heat Pump
R-Value	Resistance Value-measures insulating value
RECS	Residential Energy Consumption Survey
RIMA	Reflective Insulation Manufacturers Association International
ROB	Replace on Burnout
SC	Small Commercial
SEER	Seasonal Energy Efficiency Ratio
sf	Square feet
SF	Single-Family
SHGC	Solar Heat Gain Coefficient
SL	Standby Loss
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SRI	Solar Reflective Index
SP	Shaded Pole
SSE	Steady State Efficiency
SSL	Solid-State Lighting (e.g., LED lighting)
T-12	Fluorescent lamp tube, 1.5” in diameter
T-5	Fluorescent lamp tube, 5/8” in diameter
T-8	Fluorescent lamp tube, 1” in diameter
TMY/TMY2/TMY3	Typical Meteorological Year
Ton	Refrigeration ton, or 12,000 BTU of cooling
TRM	Technical Reference Manual
TXV	Thermal Expansion Valves
U-Factor	U-Value (measures heat loss—inverse of R-Value)
UES	Unit Energy Savings
W	Watt
w.g.	Water gauge (as in, inches water gauge)
WHJ	Water Heater Jacket

4.2 Coincidence Factors for HVAC

Coincidence Factor (CF) is defined as the ratio of a building's HVAC system's *average* demand (measured in kW) during the 3-hour peak period to the rating of the building's HVAC system (also measured in kW).

Coincidence factors were calculated for each type of commercial building and for residences. The calculation of peak electrical demand savings throughout the TRM uses CF values in the following formula:

Peak demand savings (kW) = Reduction in the building's maximum demand (kW) x CF.

The CF of a building depends on what time of day it demands the most energy. If the building's maximum demand happens to occur during the 3-hour peak period, the CF is equal to 1.0. Otherwise, the CF will be less than 1.0.

Peak period is defined as the time interval starting at 3 pm and ending at 6 pm of the hottest weekday of the year (designated the peak day). Frontier analyzed TMY3 data to select the peak period for Arkansas.

Frontier then simulated the electrical energy use pattern for each type of commercial building to determine the building's HVAC system's maximum kW demand on the peak day, and the HVAC system's kW demand during the 3-hour peak period. CF was then computed for each building type as the ratio of these two kW demand values.

In order to conduct these electric use pattern simulations, Frontier needed to make certain assumptions about the common practice for sizing HVAC systems for different types of commercial buildings. The following source was used for this purpose: New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, Oct. 15, 2010.

Coincidence Factors for different types of commercial buildings in Arkansas are shown in Table 475.

For residential coincidence factors, Frontier used the Air Conditioning Contractors of America (ACCA) Manual S, which recommends that residential HVAC systems be sized at 115% of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours 3 to 6 pm, this sizing guideline leads to a coincidence factor for residential HVAC of 1.0/1.15 = 0.87.

Table 475: Commercial Coincidence Factors by Building Type[715]

Building Type	Coincidence Factor
Assembly	0.82
College	0.84
Fast Food	0.78
Full Menu	0.85
Grocery	0.90
Health Clinic	0.85
Large Office	0.84
Lodging	0.77
Religious Worship	0.82
Retail	0.88
School	0.71
Small Office	0.84

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[715] Values for Assembly and Religious Worship building types developed using an adjustment factor derived through a comparison of average CFs for College/University and Assembly/Religious Worship building types from the Texas state Technical Reference Manual. College/University was selected as a reference building type due to average alignment with Assembly/Religious worship building types in other TRMs, inclusion of a summer session, and increased evening usage.

4.3 Equivalent Full Load Hours

To estimate equivalent full-load hours for heating and cooling, Frontier relied on calibrated DOE-2.2 simulation models, a method akin to that in the New York State Technical Reference Manual.[716] Models were created using eQUEST software for representative buildings with a variety of functions: small and large offices, retail, grocery stores, schools, colleges, healthcare facilities, full menu and fast food restaurants, and lodging. These models had their internal gains (such as lighting, cooking, and office equipment) calibrated to the real world using the results of the California Commercial End Use Survey of 2006 (CEUS). The daily profiles of end use consumption, as well as the intensity (usage per square foot) were matched to survey results for each building type. Building occupancy, another large component of internal gains, was not tracked directly by the CEUS. Instead, Frontier employed the hourly usage of various end uses to proxy building occupancy, for example by using office equipment to indicate occupancy of an office building.

Full-load hours were determined with these models by dividing the total heating and cooling loads on the building over the course of the year, as taken from DOE2.2 report SS-D, by the rated capacity of equipment. Rated capacity was determined using the sum of space peak loads from the DOE2.2 SS-A reports assuming a 15% safety factor.

Table 476 shows the capacity used for each building, as well as their conditioned square footage. Using this method, full-load hours are based on the total load delivered divided by the capacity of the system, yielding the equivalent run time of equipment at full load.

Buildings were assumed to let their fans operate continuously, and to have space heating and cooling systems available to meet loads as needed at all times. Thermostat set points were 70º for heating and 76º for cooling. Building models can be found online at
http://www.frontierassoc.com/resources/.

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[716] http://www.dps.ny.gov/TechManualNYRevised10-15-10.pdf

Table 476: Equipment Sizing

Building Type	Conditioned Floor Area (square feet)	Cooling Equipment Capacity (kBTU/h)	Heating Equipment Capacity (kBTU/h)
Assembly [717]	12,695	354	262
College/University	12,695	354	262
Fast Food Restaurant	2,500	118	89
Full Menu Restaurant	5,000	293	72
Grocery Store	9,000	372	299
Health Clinic	1,139	55	38
Lodging	32,375	1,170	572
Large Office (>30k SqFt)	125,000	3,192	1,942
Small Office (<=30k SqFt)	15,000	481	241
Religious Worship [718]	12,695	354	262
Retail	7,500	209	201
School	12,695	318	293

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[717] Equivalent to value specified for College/University

[718] Equivalent to value specified for School/University

Table 477. Equivalent Full-Load Hours for Cooling ($EFLH_C$) By Weather Zone[719]

Building Type	Zone 6	Zone 7	Zone 8	Zone 9
Assembly	2,017	1,723	1,632	1,287
College/University	1,698	1,450	1,374	1,083
Fast Food Restaurant	1,393	1,199	1,170	968
Full Menu Restaurant	1,819	1,661	1,640	1,512
Grocery Store	1,594	1,361	1,300	1,030
Health Clinic	1,627	1,379	1,368	1,144
Lodging	1,434	1,258	1,274	1,144
Large Office (>30k SqFt)	2,387	2,112	1,957	1,588
Small Office (<=30k SqFt)	1,696	1,486	1,448	1,207
Religious Worship	1,799	1,537	1,456	1,148
Retail	1,560	1,291	1,214	965
School	1,494	1,233	1,183	932

Table 478. Equivalent Full-Load Hours for Heating ($EFLH_H$) By Weather Zone[720]

Building Type	Zone 6	Zone 7	Zone 8	Zone 9
Assembly	615	854	915	1,032
College/University	674	936	1,002	1,130
Fast Food Restaurant	287	439	472	549
Full Menu Restaurant	178	321	362	438
Grocery Store	692	941	1,001	1,129
Health Clinic	641	878	915	1,045
Lodging	391	589	637	722
Large Office (>30k SqFt)	816	1,020	1,060	1,157
Small Office (<=30k SqFt)	351	534	564	644
Religious Worship	575	798	854	963
Retail	781	1,043	1,133	1,287
School	777	1,030	1,094	1,236

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[719] Values for Assembly and Religious Worship building types developed using an adjustment factor derived through a comparison of average EFLHs for College/University and Assembly/Religious Worship building types from the Connecticut, New York, Pennsylvania, and Texas state Technical Reference Manuals. College/University was selected as a reference building type due to average alignment with Assembly/Religious worship building types in other TRMs, inclusion of a summer session, and increased evening usage.

[720] Ibid.

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SUPPORTING APPENDICES

TRM Version 7.0 Volume 3: Supporting Appendices

Applicable for Program Year 2018

Submitted to:

Arkansas Public Service Commission

Prepared by:

The Independent Evaluation Monitor

on behalf of the

Parties Working Collaboratively

August 31, 2017

Table of Contents

Appendix A: Prototype Building Characteristics

Various building energy usage computer models have been used in development of deemed savings included in the TRM according to several factors:

- Building Type and Use. Prototype buildings support deemed savings development for measures to be implemented in the following building types: residential, converted residence (CR), commercial, and small commercial (SC).
- Model Vintage. Original prototypes date back to deemed savings developed in 2007/08 for use in the QuickStart programs. Prototype inputs have been updated for more recent models.
- Measure being modeled. Specific changes to a prototype are introduced to represent the specific measure being implemented in a given building.

In this Appendix, "top level" tables – those tables with the letter A followed only by a number in their table name (e.g. Table A1) provide the general characteristics of a given model prototype. "Supplemental tables" – (e.g. Table A1.a) – provide the specific changes introduced to a given prototype for the modeling of specific measures.

The following inputs describe the prototype home used to develop deemed savings for the Hydronic Heating measure. Using the values, EnergyGauge USA was used with TMY3 weather data to estimate energy savings for a series of models using the DOE-2 simulation engine.

Table A1: Hydronic Heating – Prototype Home Characteristics

Shell Characteristic	Value	Source
Conditioned Area	2,000	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Foundation	Slab-on-grade, with R-4 to R-5 insulation	IECC 2003 prescriptive code
Ceiling Insulation	R-30	IECC 2003 prescriptive code
Wall Insulation	R-13	IECC 2003 prescriptive code
Window Area	15% of floor area	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	0.24 to 0.32 ACH dependent on climate zone	Average air changes per hour of air infiltration for new construction homes used during calibration of model
Window U-value	0.50	IECC 2003 prescriptive code
Thermostat Settings	68° winter; 78° summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	15% overall loss	Default value set by EnergyGauge during calibration of model
Air Conditioning	13.0 SEER	Federal Standard baseline

Shell Characteristic	Value	Source
Gas Heating Baseline	78% AFUE	Federal Standard baseline
Hydronic Heating Change	90% AFUE	Efficiency Measure
Water Heating Baseline	0.59 EF	Federal Standard baseline for 40-gallon gas storage water heater
Water Heating Change	0.82 or 0.89 EF	Efficiency measure

The following inputs describe the prototype home used to develop deemed savings for the Duct Insulation and Roof Deck Insulation measures. Unique modifications for the Duct Insulation measure are provided in supplemental Table A2. EnergyGauge USA was used to estimate energy savings for these measures.

Table A2: Multiple Measures – Prototype Home Characteristics

Shell Characteristic	Value	Source
Conditioned Area	1,850	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Foundation	Slab-on-grade, no edge insulation	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Ceiling Insulation	R-19	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Wall Insulation	R-11	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Window Area	10% of floor area	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	0.40 to 0.53 ACH dependent on climate zone	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.87	Default U-value used assuming metal framed, double-pane clear glass windows
Thermostat Settings	68° winter; 78° summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	15% overall loss	Default value set by EnergyGauge during calibration of model
Air Conditioning	10.0 SEER	Federal Standard in effect from 1990-2006
Gas Heating	78% AFUE	Annual Fuel Utilization Efficiency – base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems

Shell Characteristic	Value	Source
Electric Heat Pump	HSPF = 7.2	Average HSPF based on shipment-weighted average efficiency
Duct Insulation Baseline	No existing insulation	Existing condition applicable for this measure
Duct Insulation Change Case	R-8 insulation	Efficiency measure

The following table applies to the Attic Knee Wall Insulation, Ceiling Insulation, Wall Insulation, Floor Insulation, Roof Deck Insulation, Air Infiltration, Radiant Barriers, ENERGY STAR® Windows, and Window Film measures. Unique modifications for each specific measure are listed in supplemental Tables A3.a through A3.h. BEopt™ – a residential building modeling platform developed by NREL – was used to estimate energy savings for these measures using the U.S. DOE EnergyPlus simulation engine.

Table A3: Residential Envelope Measures – Prototype Home Characteristics

Shell Characteristic	Value	Source(s)
Site/Layout		
Conditioned Floor Area	1,764 ft^2	Average square footage of conditioned (heated) space between one story home and all SFD homes in 2009 RECS microdata for AR/LA/OK.[1]
Orientation	Square building with faces on each cardinal direction	LBNL: Nationally Representative Housing Sample[2]
Number of Stories	Single story with unfinished attic	Preponderance of SFD homes in 2009 RECS microdata are single story
Building Envelope		
Foundation	Slab-on-ground, no edge insulation	Preponderance of SFD homes in 2009 RECS microdata (62%) have slab foundation Also a conservative assumption for base energy usage.
Slab Insulation	None – no perimeter, under-slab, or above-slab insulation	Not part of standard practice, also no requirement for slab insulation in residential code for relevant weather regions except the NW corner of state in IECC Climate Zone 4.
Ceiling Insulation	R-12	Table 25 of BA Home Simulation Protocols suggests R-9 is appropriate for homes closed rafter roofs built with 2 x 6 beams, R-15 for 2 x 10. Suspect 2 x 6 is more likely, but some share of

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[1] 2009 RECS, Available at: http://www.eia.gov/consumption/residential/data/2009/

[2] Simulating a Nationally Representative Housing Sample Using EnergyPlus, Available at: http://www.osti.gov/scitech/servlets/purl/1012239

Shell Characteristic	**Value**	**Source(s)**
		homes will have had ceiling insulation replaced/added. Select R-12 based on the above information and engineering judgment.[3]
Wall Insulation	R-11	BAHSP, p. 35 – value for homes built 1980-1989
Air Leakage	0.9 ACH	Median ACH for older, low income housing[4]
Fenestration		
Window Area	15% of wall area	American Housing Survey 2007 and 2008 was used to inform the value for likely participants.
Window U-value	0.81	2009 ASHRAE Fundamentals, Ch. 15 Table 4. Value for double-pane, metal frame, fixed, clear glass window.
Window SHGC	0.64	2009 ASHRAE Fundamentals, Ch. 15 Table 10. Value for double-pane, metal frame, fixed, clear glass window.
HVAC		
Efficiency Rating, Air Conditioner	10 SEER	Federal Standard in effect from 1990-2006. Representative of low-efficiency program participant homes.
Efficiency Rating, Space Heating (Gas Furnace)	78% AFUE	Annual Fuel Utilization Efficiency – base gas furnace efficiency
Efficiency Rating, Space Heating (Electric Resistance Heat)	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Efficiency Rating, Space Heating (Heat Pump)	HSPF = 7.25	Average of Federal Standards: 1992 – 1/2006: 6.8 HSPF 1/2006 – 1/2015: 7.7 HSPF
Thermostat Settings	Heating: 71°F Cooling: 76° F	BAHSP, p. 49
Duct Losses	20%	Lower tier of air leakage for typical homes as cited by ENERGY STAR®[5]
Duct Insulation	R-4 insulation	
Domestic Hot Water		
Energy Factor, Electric Storage	0.90	BAHSP (p. 42) EWH with 50-gal tank, 3-inch insulation.
Energy Factor, Gas Storage	0.59	BAHSP (p. 42), midpoint between options 2 and 3

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[3] Building America Home Simulation Protocols (BAHSP); Available at: http://www.nrel.gov/docs/fy11osti/49246.pdf.

[4] Referenced information is from 2009 ASHRAE Fundamentals, Section 16.17 Residential Ventilation.

[5] ENERGY STAR®, Duct Sealing: http://www.energystar.gov/?c=home_improvement.hm_improvement_ducts

Shell Characteristic	**Value**	**Source(s)**
Lighting		
Share of Lighting by Type	Lamps are 66% incandescent, 21% CFL, 13% T-8 linear fluorescent	BAHSP (p. 16)

The following inputs apply to the Attic Knee Wall Insulation measure, in addition to (or substituting for) values shown in Table A3.a.

Table A3.a: Attic Knee Wall Insulation – Prototype Home Characteristics

Shell Characteristic	**Value**	**Source**
Ceiling Construction	2-foot-wide vaulted ceiling around the perimeter of the conditioned floor area	This modeling approach reduces simulation distortions introduced by a large vaulted ceiling area, while still exposing the attic knee walls to the conditioned living space.
Base Knee Wall Insulation	No existing insulation	Encountered insulation level drives eligibility for this measure
Improved Knee Wall Insulation	(1) Insulate to R-19, or (2) Insulate to R-30	Efficiency Measure

The following inputs apply to the Ceiling Insulation measure, in addition to (or substituting for) values shown in Table A3.b.

Table A3.b: Ceiling Insulation – Prototype Home Characteristics

Shell Characteristic	**Value**	**Source**
Base Ceiling Insulation	Five ranges of encountered ceiling insulation: R-0 to R-1 R-2 to R-4 R-5 to R-8 R-9 to R-14 R-15 to R-22	Insulation level as encountered by the EESP drives eligibility for this measure
Improved Ceiling Insulation	Insulate to R-38 & R-49	Efficiency measure – retrofit insulation level

The following inputs apply to the Wall Insulation measure, in addition to (or substituting for) values shown in Table A3.c.

Table A3.c: Wall Insulation – Prototype Home Characteristics

Shell Characteristic	Value	Source
Base Wall Insulation	R-0	Insulation level as encountered by the EESP drives eligibility for this measure
Improved Wall Insulation	R-13 & R-23	3.5” of fiberglass batt at R-3.7/in provides R-13 Full thickness of 4” cavity with open cell foam provides R-13 Full thickness of 4” cavity with closed cell foam provides R-23

The following inputs apply to the Floor Insulation measure, in addition to (or substituting for) values shown in Table A3.d.

Table A3.d: Floor Insulation – Prototype Home Characteristics

Shell Characteristic	Value	Source
Foundation	Pier and beam with vented crawlspace	Floor Insulation not a relevant measure for homes with slab foundation
Base Floor Insulation	R-0	Insulation level as encountered by the EESP drives eligibility for this measure
Change Floor Insulation	R-19	This brings existing homes in compliance with IECC 2009.
Crawlspace Insulation	R-13	This brings existing homes in compliance with IECC 2009.

The following inputs apply to the Roof Deck Insulation measure, in addition to (or substituting for) values shown in Table A3.e.

Table A3.e: Roof Deck Insulation – Prototype Home Characteristics

Shell Characteristic	Value	Source
Base Roof Deck Insulation	No existing roof deck insulation and five ranges of encountered ceiling insulation: R-0 to R-1 R-2 to R-4 R-5 to R-8 R-9 to R-14 R-15 to R-22	Existing condition applicable for this measure
Change Roof Deck Insulation	R-19 & R-38	Efficiency measure

The following inputs apply to the Air Infiltration measure, in addition to (or substituting for) values shown in Table A3.f.

Table A3.f: Air Infiltration – Prototype Home Characteristics

Shell Characteristic	Value	Source
Base Air Leakage	0.9 ACH	Median infiltration value of older low-income housing sample:2009 ASHRAE Fundamentals, 16.17
Change Air Leakage	0.35 ACH	Minimum allowable air exchanges assuming a 1,764 ft^2 and 3-bedroom prototype home: ASHRAE 62.2 P - 2010

The following inputs apply to the Radiant Barriers measure, in addition to (or substituting for) values shown in Table A3.g.

Table A3.g: Radiant Barriers – Prototype Home Characteristics

Shell Characteristic	Value	Source
Ceiling Insulation Case 1	⩽ R-19	Assumed existing insulation level
Ceiling Insulation Case 2	> R-19	Assumed existing insulation level
Base roof deck	No radiant barrier	Existing condition applicable for this measure
Change roof deck	Double-Sided, Foil: Installed radiant barrier meeting ENERGY STAR® standards	Efficiency measure

The following inputs apply to the ENERGY STAR® Windows measure, in addition to (or substituting for) values shown in Table A3.h.

Table A3.h: ENERGY STAR® Windows – Prototype Home Characteristics

Shell Characteristic	Value	Source
Baseline Window U-factors and SHGCs	Single-pane: 1.12 U-factor/0.79 SHGC Double-pane: 0.81 U-factor/0.64 SHGC	U-values and SHGCs assuming metal framed, single and double-pane clear glass windows 2009 ASHRAE Fundamentals, Ch.15 Tables 4 and 10
Change Case Window U-factors and SHGCs	Zone 9: 0.32 U-factor/ 0.40 SHGC Zones 8, 7, and 6: 0.35 U-factor/0.30 SHGC	ENERGY STAR® Criteria

The following inputs apply to the Window Film measure, in addition to (or substituting for) values shown in Table A3.i.

Table A3.i: Window Film – Prototype Home Characteristics

Shell Characteristic	Value	Source
Baseline Window Characteristics – double-pane model	0.81 U-value/ 0.64 SHGC	U-value assuming metal framed, double-pane clear glass windows 2009 ASHRAE Fundamentals, Ch.15 Tables 4 and 10
Baseline Window Characteristics – single-pane model	1.12 U-value/ 0.79 SHGC	U-value assuming metal framed, single-pane clear glass windows 2009 ASHRAE Fundamentals, Ch.15 Tables 4 and 10
Change Case Window Characteristics – double-pane model	0.81 U-value/ 0.49 SHGC	Efficiency Measure – values based on 3M product performance and technical data
Change Case Window Characteristics – single-pane model	1.12 U-value/ 0.40 SHGC	Efficiency Measure – values based on 3M product performance and technical data

The following inputs apply to the Small Commercial Duct Efficiency, Duct Insulation, Cool Roofs, and Window Awnings measures. EQuest was used to estimate energy savings for these measures.

Table A4: Duct Efficiency Improvements, Duct Insulation (SC), Cool Roofs, & Window Awnings (SC) – Prototype Building Characteristics

Building Characteristic	Building Type		
	Small Office	Stand-Alone Retail	Strip Mall
General			
Ground Area (Sq. Ft.)	7,500	15,000	7,500
# of Stories	2	1	1
Floor Area (Sq. Ft.)	15,000	15,000	7,500
Roof			
Construction	Metal Frame, > 24 in. o.c.	Metal Frame, > 24 in. o.c.	Metal Frame, > 24 in. o.c.
Ext. Finish	Roof, Built up	Roof, Built up	Roof, Built up
Ext. Color	Med (abs = 0.6)	Med (abs = 0.6)	Med (abs = 0.6)
Ext. Insulation	Varied	Varied	Varied
Add'l Insulation	No batt or radiant barrier	No batt or radiant barrier	No batt or radiant barrier
Walls			
Construction	Metal Frame, 2x6, 24 in. o.c.	Metal Frame, 2x6, 16 in. o.c.	Metal Frame, 2x4, 16 in. o.c.
Ext. Finish	Wood/Plywood	CMU	Stucco/Gunite
Ext. Color	Med (abs = 0.6)	Med (abs = 0.6)	Med (abs = 0.6)
Ext. Insulation	3/4 in. fiber bd sheathing (R-2)	3/4 in. fiber bd sheathing (R-2)	1/2 in. fiber bd sheathing (R-1.3)
Add'l Insulation	R-19 batt	R-11 batt	R-11 batt

Building Characteristic	**Building Type**		
	Small Office	**Stand-Alone Retail**	**Strip Mall**
Ceiling			
Construction	Acoustic Tile	Acoustic Tile	Acoustic Tile
Insulation	varied	varied	varied
Windows			
Glass Category	Double Clr/Tint 1/4", 1/2" air	Double Clr/Tint 1/4", 1/2" air	Double Clr/Tint 1/4", 1/2" air
Window Area	70% of all walls	70% of North wall; all others 0%	70% of East wall; all others 0%
Lighting			
Lighting Density (W/Sq. Ft.)	1.330	2.030	2.030
HVAC			
Cooling Source	DX Coils	DX Coils	DX Coils
System Type	Packaged Single Zone	Packaged Single Zone	Packaged Single Zone
Typ. Unit Size	11.25 – 20 tons	5.4 – 7.5 tons	< 5.4 tons
EER (Base)	8.50 EER	8.90 EER	9.70 SEER
Heating Source	Furnace	Furnace	Furnace
Typ. Unit Size	> 225 kBTUh	< 225 kBTUh	< 225 kBTUh
Efficiency (AFUE)	0.806	0.780	0.780
Fans			
Min. Design Flow (cfm/ft^2)	0.50	0.50	0.50
Cycle Fans at Night?	Cycle Fans (no OA at night)	Cycle Fans (no OA at night)	Cycle Fans (no OA at night)
DHW			
Fuel	Natural Gas	Natural Gas	Natural Gas
Type	Storage	Storage	Storage
Tank Insulation R-Value	12.00	12.00	12.00
Tank Capacity (gal)	39	21	11

The following inputs apply to the Converted Residence Duct Insulation measure. EnergyGauge USA was used to estimate energy savings for these measures.

Table A5: Duct Insulation (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Conditioned Area	1,850 ft^2	American Housing Survey 2007
Foundation	Slab-on-grade, no edge insulation	American Housing Survey 2007
Ceiling Insulation	R-19	Assumed existing insulation level
Wall Insulation	R-11	Assumed existing insulation level
Window Area	10% of floor area	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	0.40 to 0.53 ACH dependent on climate zone	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.87	Default U-value used assuming metal framed, double-pane clear glass windows
Thermostat Settings	68° winter; 78° summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	15% overall loss	Default value set by EnergyGauge during calibration of model
Duct Insulation Baseline	No existing insulation	Existing condition applicable for this measure
Duct Insulation Change Case	R-8 insulation	Efficiency measure
Air Conditioning	10.0 SEER	Federal Standard in effect from 1990-2006
Gas Heating	0.78 AFUE	Annual Fuel Utilization Efficiency – base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Electric Heat Pump	HSPF = 7.2	Average HSPF based on shipment-weighted average efficiency

The following table applies to all Converted Residence Ceiling Insulation, Air Infiltration, Roof Deck Insulation, Wall Insulation, and Window Film measures. Unique modifications for each specific measure are listed in supplemental tables A6.a through A6.e. EnergyGauge USA was used to estimate energy savings for these measures.

Table A6: Multiple Converted Residence Measures – Prototype Building Characteristics

Shell Characteristic	Value	Source
Conditioned Area	1,850 ft^2	American Housing Survey 2007
Foundation	Slab-on-grade, no edge insulation	American Housing Survey 2007
Ceiling Insulation	R-19	Assumed existing insulation level
Wall Insulation	R-11	Assumed existing insulation level
Window Area	13.7% of floor area (~15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	0.7 ACH	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	1.27	Default U-value used assuming metal framed, single-pane clear glass windows
Thermostat Settings	71.25° winter; 77.5° summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	15% overall loss	Default value set by EnergyGauge during calibration of model
Air Conditioning	10.0 SEER	Federal Standard in effect from 1990-2006
Gas Heating	0.78 AFUE	Annual Fuel Utilization Efficiency – base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Electric Heat Pump	HSPF = 7.7	Current Federal Standard

The following inputs apply for the CR Ceiling Insulation measure, in addition to (or substituting for) values shown in Table A6.a.

Table A6.a: Ceiling Insulation (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Base Ceiling Insulation	R-0 to R-22	Existing insulation level
Change Ceiling Insulation	R-38	Efficiency measure – retrofit insulation level as required by DOE

The following inputs apply for the CR Air Infiltration measure, in addition to (or substituting for) values shown in Table A6.b.

Table A6.b: Air Infiltration (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Pre-Air Infiltration	0.7 ACH	Average air changes per hour of air infiltration for existing homes used during calibration of model
Post-Air Infiltration	12.46 ACH_{50}	Efficiency Measure

The following inputs apply for the CR Roof Deck Insulation measure, in addition to (or substituting for) values shown in Table A6.c.

Table A6.c: Roof Deck Insulation (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Base Roof Deck Insulation	No existing insulation	Existing condition applicable for this measure
Change Roof Deck Insulation	R-19	Efficiency measure

The following inputs apply for the CR Wall Insulation measure, in addition to (or substituting for) values shown in Table A6.d.

Table A6.d: Wall Insulation (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Base Wall Insulation	R-0	Existing insulation level
Change Wall Insulation	R-13	Assumes 3.5” of cellulose @ R-3.7 per inch

The following inputs apply for the CR Window Film measure, in addition to (or substituting for) values shown in Table A6.e.

Table A6.e: Window Film (CR) – Prototype Building Characteristics

Shell Characteristic	Value	Source
Window Area	10% of floor area	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	0.53 ACH	Average air changes per hour of air infiltration for existing homes used during calibration of model
Baseline Window Characteristics – double-pane model	0.87 U-value/ 0.66 SHGC	Default U-value used assuming metal framed, double-pane clear glass windows
Baseline Window Characteristics – single-pane model	1.27 U-value/ 0.75 SHGC	Default U-value used assuming metal framed, single-pane clear glass windows
Change Case Window Characteristics – double-pane model	0.87 U-value/ 0.49 SHGC	Efficiency Measure – values based on 3M product performance and technical data
Change Case Window Characteristics – single-pane model	1.27 U-value/ 0.40 SHGC	Efficiency Measure – values based on 3M product performance and technical data
Thermostat Settings	68° winter;78° summer	Average thermostat settings used during calibration of model

The following inputs apply to the Small Commercial Roof Deck Insulation measure. EQuest was used to estimate energy savings for this measure.

Table A7: Roof Deck Insulation (SC) – Prototype Building Characteristics [6]

Building Characteristic	Building Type	
	Stand-Alone Retail	Small Office
General		
Ground Area (Sq. Ft.)	15,000	7,500
# of Stories	1	2
Floor Area (Sq. Ft.)	15,000	15,000
Roof		
Construction	Metal Frame, > 24 in. o.c.	Metal Frame, > 24 in. o.c.
Ext. Finish	Roof, Built up	Roof, Built up
Ext. Color	Med (abs = 0.6)	Med (abs = 0.6)
Ext. Insulation	R-6, R-14	R-6, R-14
Add'l Insulation	no batt or radiant barrier	no batt or radiant barrier
Walls		
Construction	Metal Frame, 2x6, 16 in. o.c.	Metal Frame, 2x6, 24 in. o.c.

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[6] The assumptions in this table were not used for the Equivalent Full Load Hour estimates. For those assumptions and work papers, please see http://www.frontierassoc.com/links.html.

Building Characteristic	**Building Type**					
	Stand-Alone Retail			**Small Office**		
Ext. Finish	CMU			Wood/Plywood		
Ext. Color	Med (abs = 0.6)			Med (abs = 0.6)		
Ext. Insulation	3/4 in. fiber bd sheathing (R-2)			3/4 in. fiber bd sheathing (R-2)		
Add'l Insulation	R-11 batt			R-19 batt		
Ceiling						
Construction	Acoustic Tile			Acoustic Tile		
Insulation	R-13			R-13		
Windows						
Glass Category	Double Clr/Tint 1/4", 1/2" air			Double Clr/Tint 1/4", 1/2" air		
Window Area	70% of North wall; all others 0%			70% of all walls		
Lighting						
Lighting Density (W/Sq. Ft.)	2.030			1.330		
HVAC						
Cooling Source	DX Coils			DX Coils		
Heating Source	Air-source Heat Pump	Furnace	Elec. Res.	Air-source Heat Pump	Furnace	Elec. Res.
Typ. Unit Size	auto-size	auto-size	auto-size	auto-size	auto-size	auto-size
System Type	Split System Single Zone HP	Packaged Single Zone	Packaged Single Zone	Split System Single Zone HP	Packaged Single Zone	Packaged Single Zone
Typ. Unit Size	5.4 – 7.5 tons			5.4 – 7.5 tons		
EER (Base)	8.90 EER			8.90 EER		
Efficiency (AFUE)	COP = 3.00	0.780	not spec'd	COP = 3.00	0.780	not spec'd
OA Economizer	none			none		
Fans						
Min. Design Flow (cfm/ft^2)	0.50			0.50		
Cycle Fans at Night?	Cycle Fans (no OA at night)			Cycle Fans (no OA at night)		
DHW						
Fuel	Natural Gas			Natural Gas		
Type	Storage			Storage		
Tank Insulation R-Value	12.00			12.00		
Tank Capacity (gal)	21			21		

The following inputs apply to the Commercial Occupancy-Based PTAC/PTHP Controls measure. BEopt™ was used to estimate energy savings for this measure.

Table A8: Occupancy-Based PTAC/PTHP Controls – Prototype Building Characteristics

Building Characteristic	Value	Source(s)
Site/Layout		
Conditioned Floor Area	420 ft^2	Average square footage from DOE Commercial Prototype Building Model.[7]
Orientation	Average of all cardinal orientations	NA
Number of Stories	Single story	NA
Building Envelope		
Foundation	NA	NA
Slab Insulation	Superinsulated R-1000 (simulating adiabatic floor)	Simulating non-bottom floor guest room with conditioned space below
Ceiling Insulation	Superinsulated R-1000 (simulating adiabatic ceiling)	Simulating non-top floor guest room with conditioned space above
Wall Insulation	R-11 (exterior wall); other 3 walls are modeled as adiabatic	BAHSP, p. 35 – value for homes built 1980-1989
Air Leakage	0.7 ACH	BAHSP cites ASHRAE, which provides two estimates based on samples from separate studies: one of new, energy-efficient homes (median ACH = 0.5) and one of older, low-income housing (median ACH = 0.9). Typical participant will be between these two extremes.[8]
Fenestration		
Window Area	24 ft^2 window on single wall	CASE, Guest Room Occupancy Controls: 2013 California Building Energy Efficiency Standards
Window U-value	0.49	NFRC rating for standard double-pane, clear, non-metal frame, air fill
Window SHGC	0.56	NFRC rating for standard double-pane, clear, non-metal frame, air fill
HVAC		
Efficiency Rating, Air Conditioner	10.7 EER	DOE Commercial Prototype Building Model.
Efficiency Rating, Space Heating (Gas Furnace)	NA	NA

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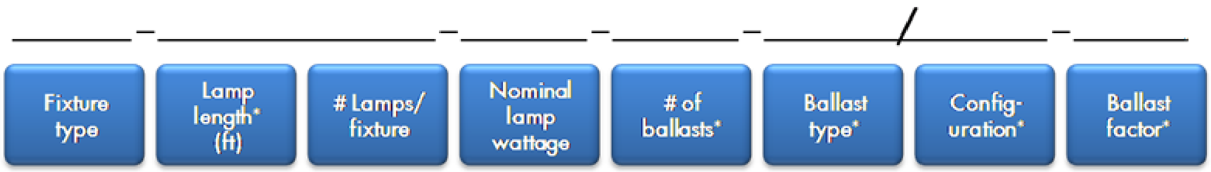
[7] Available at: http://www.energycodes.gov/development/commercial/90.1_models

[8] Referenced information is from 2009 ASHRAE Fundamentals, Section 16.17 Residential Ventilation.

Building Characteristic	**Value**	**Source(s)**
Efficiency Rating, Space Heating (Electric Resistance Heat)	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Efficiency Rating, Space Heating (Heat Pump)	9.0 HSPF	IECC 2009 Min Efficiency (2.6 COP) for PTHP Replacements
Thermostat Settings	Heating/Cooling: 70°F (base) 5°F and 10°F setback change cases weighted based on typical occupancy schedule	DOE Commercial Prototype Building Model.
Duct Losses	NA	NA
Duct Insulation	NA	NA
Domestic Hot Water		
Energy Factor, Electric Storage	NA	NA
Energy Factor, Gas Storage	0.59	BAHSP (p. 42), midpoint between options 2 and 3
Lighting		
Share of Lighting by Type	lamps are 66% incandescent, 21% CFL, 13% T-8 linear fluorescent	BAHSP (p. 16)

Appendix B: Lighting Fixture Legend

Fixture Code Format



* If applicable

Fixture Code Explanations

Fixture Type

Code	Category	Lamp
CFGU	Compact fluorescent	GU24 base
CFIM	Compact fluorescent	Integrated ballast - medium base
CFP	Compact fluorescent	Pin-based lamp - 2 or 4 pin
ECF	Exit	Compact fluorescent
EF	Exit	Fluorescent
EI	Exit	Incandescent
ELED	Exit	LED
FC	Fluorescent circline	T9
FUT8	Fluorescent U tube	T8
FUT12	Fluorescent U tube	T12
CMH	HID	Ceramic metal halide
HPS	HID	High pressure sodium
MV	HID	Mercury vapor
MH	HID	Metal halide
PSMH	HID	Pulse-start metal halide
H	Incandescent	Halogen
HLV	Incandescent	Halogen low voltage
INC	Incandescent	Medium base
INDSB	Induction	Self-ballasted induction lamp
FT5	Linear fluorescent	T5
FT8	Linear fluorescent	T8
FT10	Linear fluorescent	T10
FT12	Linear fluorescent	T12
FT12HO	Linear fluorescent	T12 HO
FT12VHO	Linear fluorescent	T12 VHO
FT17	Linear fluorescent	T17

Ballast Type [1,2]

Code	Description
SM	std mag ballast
EM	efficient mag ballast
SEI	std IS elect. ballast
SER	std RS/PRS elect. ballast
EEI	efficient IS elect. ballast
EER	efficient RS/PRS elect. ballast
CWA	constant wattage autotransformer-magnetic ballast
SCWA	super CWA ballast
LR	linear reactor- magnetic ballast
RL	regulated lag- magnetic ballast
L	HID electronic low frequency ballast

Configuration

Code	Description
D1	1 lamp delamped
D2	2 lamps delamped
D3	3 lamps delamped
D4	4 lamps delamped
T2	tandem - 2 fixtures/ballast
T3	tandem - 3 fixtures/ballast
T4	tandem - 4 fixtures/ballast
HDW	hard-wired

Ballast Factor

Code	Description	BF Range
VR	very reduced light output (BF ≤ 0.80)	(BF ≤ 0.80)
R	reduced light output (0.80 < BF ≤ 0.85)	(0.80 < BF ≤ 0.85)
N	normal light output (0.85 < BF ≤ 0.95)	(0.85 < BF ≤ 0.95)
H	high light output (0.95 < BF ≤ 1.10)	(0.95 < BF ≤ 1.10)
VH	very high light output (BF > 1.10)	(BF > 1.10)

Notes

[1] Efficient magnetic ballasts are defined as EPAct compliant

[2] Efficient electronic ballasts are those defined as Premium ballasts by CEE (www.cee1.org/com/com-lt/lamps-ballasts.xls)

Sample Fixture Codes

FT5-42-54-1SER-H	CFGU-1-23-1SEI-H	FT8-41-25-1EEI/T2-N
Linear fluorescent, (2) 4' 54w T5 w/1 standard rapid/programmed-rapid start electronic ballast (0.95 < BF < 1.10)	Compact fluorescent, (1) 23w GU24 base w/1 standard instant start electronic ballast (0.95 < BF < 1.10)	Linear fluorescent, (1) 4' 25w T8 w/1 efficient instant start electronic ballast (0.85 < BF < 0.95), tandem wired - 2 fixtures/ballast

Figure B1: Lighting Fixture Code Format and Explanations

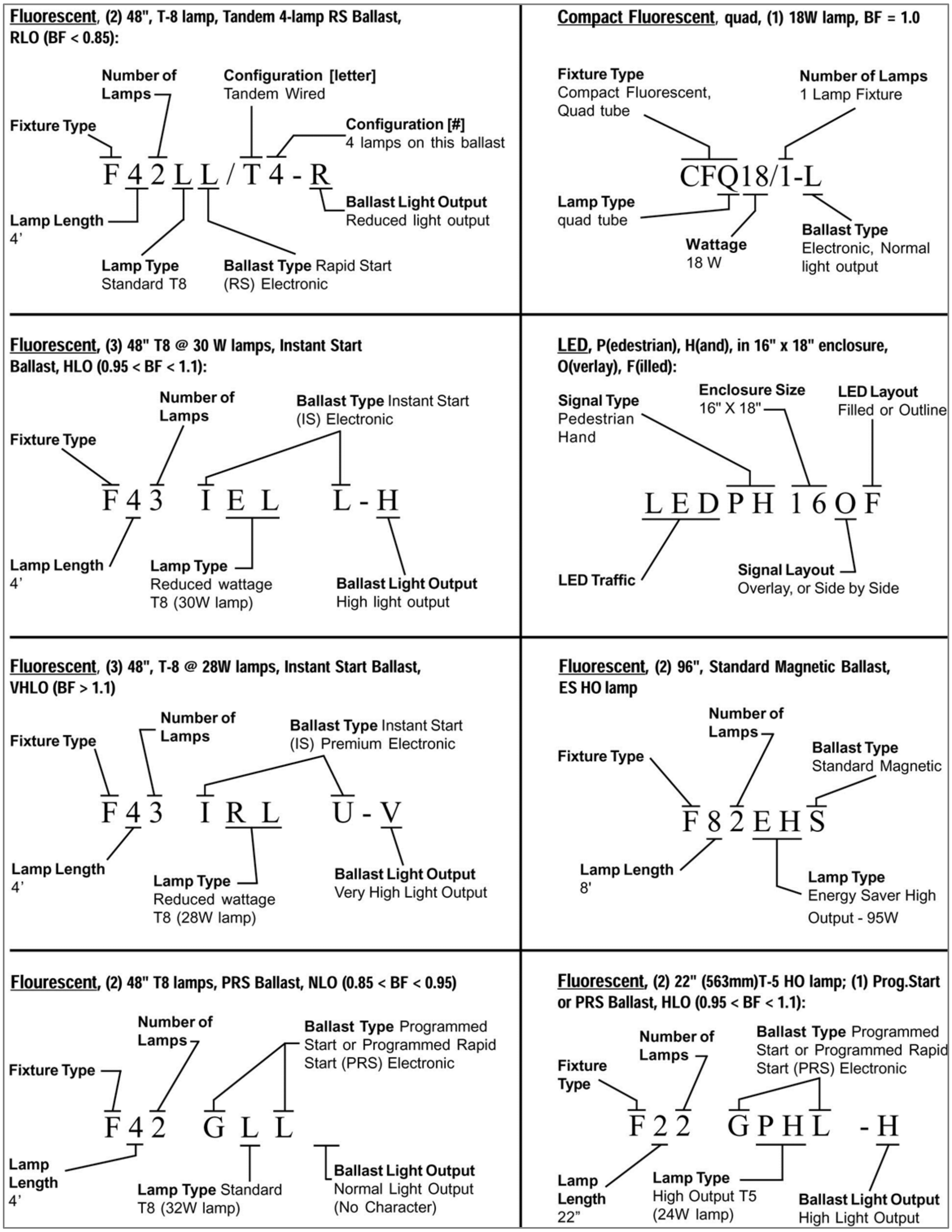


Figure B2: Lighting Fixture Code Examples

Table B1: Fixture Code Legend

Legend	
Fixture Type	**Description**
CF	Compact Fluorescent
CFC	Compact Fluorescent, Cold Cathode
CFD	Compact Fluorescent, Double-D Shape
CFG	Compact Fluorescent, GU24 LVS Socket
CFM	Compact Fluorescent, Multi Tube
CFT	Compact Fluorescent, Twin Tube (including “Biaxial fixtures)
CFQ	Compact Fluorescent, Quad Tube
ECF	Exit Sign, Compact Fluorescent
EF	Exit Sign, Linear Fluorescent (T1, T5)
EI	Exit Sign, Incandescent
ELED	Exit Sign, Light Emitting Diode
EP	Exit Sign, Photoluminescent
F	Fluorescent, Linear
FC	Fluorescent, Circline
FEI	Fluorescent, Electrodeless Induction
FU	Fluorescent, U-Tube
H	Halogen Incandescent
HLV	Halogen Low Voltage
HPS	High Pressure Sodium
I	Incandescent
LED	Light Emitting Diode
LEDT	LED Traffic Signal
MH	Metal Halide
MV	Mercury Vapor
NEON	NEON

Table B2: Lamp Type Legend for Fluorescent and LED Fixtures

Lamp Type	Description
For fluorescent fixtures:	
A	T12, F25T12 type—25 watt, 4 ft.
B	T5, bi-axial twin lube for compact fluorescent
E	T12, bi-pin, EPAct energy efficient
EH	T12, EPAct, high output (800 mA)
EI	T12, EPAct, 4 ft. or 8 ft., single pin instant start
EL	T8, reduced wattage 4 ft., 30 watt
ER	T8, 8 ft. reduced wattage linear (57, 55, 54, & 51 watt)
EV	T12, EPAct, very high output (1500 mA)
L	T8, bi-pin for instant start or rapid start
NL	T8, reduced wattage 4 ft., 25 watt
P	T5, linear, 2-5 ft. lengths
PH	T5, linear high output lamp
PR	T5, reduced wattage linear high output (51 & 49 watt)
RL	T8, reduced wattage 4 ft., 28 watt
S	T12, bi-pin, standard wattage
SI	T12, standard, single pin, instant start
SH	T12, standard, high output
SV	T12, standard, very high output
T	T10 lamp
For LED traffic signals and other LEDs:	
12GA	12” green arrow
12GB	12” green ball
12RA	12” red arrow
12RB	12” red ball
12YA	12” yellow arrow
12YB	12” yellow bulb
8GB	8” green ball
8RB	8” red ball
8YB	8” yellow ball
F	Filled fixture
O	Overlay or outline fixture
OO	Overlay and outline fixture
PCOUNT	Pedestrian count down timer
PH	Pedestrian hand signal

Lamp Type	Description
PP	Pedestrian personal signal
S	Side-by-side fixture

Table B3: Ballast Type Legend for Fluorescent and Metal Halide Fixtures

Ballast Type	Description
For fluorescent fixtures:	
IxL	Electronic, Instant Start (IS) (x = lamp code)
xL	Electronic, Rapid Start (RS) (x = lamp code)
GxL	Electronic, Programmed Start or Program Rapid Start (PRS) (x = lamp code)
S	Standard Magnetic
E	EPAct Energy Efficient Magnetic
U	Premium Ballast
For Metal Halide Fixtures:	
CWA	Constant Wattage Autotransformer – Magnetic
RL	Regulated Lag – Magnetic
LR	Linear Reactor – Magnetic
L	Electronic Low Frequency (w/ Pulse Start or Ceramic Lamps)

Table B4: Ballast Light Output Legend

2	Description
VR	Very Reduced light output, or VRLO (BF < 0.70)
R	Reduced light output, or RLO (0.70 < BF < 0.85
"_"	No character – Normal light output or, NLO (0.85 < BF < 0.95)
H	High light output, or HLO (0.95 < BF < 1.1)
V	Very High light output, or VHLO (BF > 1.1)

Appendix C: Heating and Cooling Degree Days (65 °F Base)

Table C1: Heating and Cooling Degree Days (65°F Base)

Station Name	State	Heating Base (°F)	Cooling Base (°F)
Alicia	AR	3768	1937
Alum Fork	AR	3631	1569
Arkadelphia 2 N	AR	2672	2044
Arkansas Post	AR	2839	2087
Batesville Live	AR	3297	1918
Batesville L&D	AR	3970	1631
Beedeville 4 Ne	AR	3520	1829
Benton	AR	3278	1748
Bentonville 4 S	AR	4483	1269
Blakely Mountain	AR	3575	1548
Blue Mountain D	AR	3416	1909
Blytheville	AR	3544	1979
Booneville 3 Ss	AR	3171	1960
Brinkley	AR	3456	1827
Cabot 4 Sw	AR	3470	1699
Calico Rock 2 W	AR	4336	1251
Calion Lock & D	AR	2853	1999
Camden 1	AR	2872	1973
Clarendon	AR	3491	1854
Clarksville	AR	3804	1648
Conway	AR	3320	1961
Corning	AR	3958	1711
Crossett 2 Sse	AR	3030	1788
Dardanelle	AR	3221	1882
Deer	AR	5001	912
Dequeen	AR	3198	1860
Dermott 3 Ne	AR	2886	2105
Des Arc	AR	3266	2027
Dumas	AR	2697	2159
El Dorado Goodwin Field[9]	AR	2946	2622
Eudora	AR	2574	2291
Eureka Springs	AR	3851	1520

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[9] Updated to TMY3 weather station El Dorado Goodwin Field.

Station Name	State	Heating Base (°F)	Cooling Base (°F)
Evening Shade 1	AR	4095	1535
Fayetteville Drake Field[10]	AR	3864	1885
Fordyce	AR	3374	1618
Fort Smith Regional AP[11]	AR	3919	2129
Gilbert	AR	3670	1578
Gravette	AR	3923	1515
Greenbrier	AR	3857	1587
Greers Ferry Da	AR	3808	1616
Harrison Boone Hro	AR	4063	1443
Hector 2 Ssw	AR	3599	1591
Helena	AR	3120	2098
Hope 3 Ne	AR	3093	1834
Hot Springs 1 N	AR	3133	1993
Huntsville 1 Ss	AR	3944	1381
Jonesboro 4 N	AR	3737	1858
Keiser	AR	3655	1829
Keo	AR	2932	2010
Lead Hill	AR	4372	1439
Leola	AR	2959	1893
Little Rock Adams Field[12]	AR	3344	2184
Magnolia	AR	2876	1859
Malvern	AR	2989	1846
Mammoth Spring	AR	4319	1331
Marianna 2 S	AR	3409	1867
Marshall	AR	3897	1533
Mena	AR	3649	1463
Monticello 3 Sw	AR	2937	1960
Morrilton	AR	3614	1701
Mount Ida 3 Se	AR	3854	1417
Mountainburg 2	AR	3347	1683
Mountain Home 1	AR	4249	1413
Mountain View	AR	3848	1571
Murfreesboro 5	AR	3455	1648

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[10] Updated to TMY3 weather station Fayetteville Drake Field.

[11] Updated to TMY3 weather station Fort Smith Regional AP.

[12] Updated to TMY3 weather station Little Rock Adams Field.

Station Name	State	Heating Base (°F)	Cooling Base (°F)
Nashville	AR	3087	1879
Newport	AR	3490	1967
Nimrod Dam	AR	3594	1712
North Little Ro	AR	2980	2196
Okay	AR	2543	2180
Ozark	AR	3679	1739
Paragould 1 S	AR	3872	1725
Pine Bluff	AR	2935	2099
Pocahontas 1	AR	4037	1641
Portland	AR	2847	2079
Prescott	AR	2976	1947
Rogers AWOS[13]	AR	4402	1757
Rohwer 2 Nne	AR	2979	2023
Saint Charles	AR	3123	1984
Searcy	AR	3655	1726
Sheridan	AR	3282	1813
Siloam Springs	AR	4283	1373
Sparkman	AR	3127	1908
Stamps	AR	2694	2031
Stuttgart 9 Ese	AR	3103	2073
Subiaco	AR	3366	1763
Texarkana Webb	AR	2421	2280
Waldron	AR	3272	1751
Warren 2 Wsw	AR	3032	1877
West Memphis	AR	3417	1903
Wynne	AR	3715	1722

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[13] Updated to TMY3 weather station Rogers AWOS.

Appendix D: Abbreviated Steam Tables

Table D1: Abbreviated Steam Tables

Saturated Steam Tables – h= BTU/lb F				
Steam psig	**Saturated Temperature**	**Heat of the Liquid h_f**	**Latent Heat h_{fg}**	**Heat of the Saturated Vapor h_g**
0	212	180	970	1,150
1	215	183	969	1,152
5	227	196	961	1,156
10	240	209	950	1,161
15	250	218	946	1,164
20	259	228	938	1,168
25	267	236	935	1,170
30	274	243	928	1,173
35	281	250	925	1,175
40	287	256	919	1,176
50	298	267	911	1,180
60	308	278	905	1,183
70	316	287	898	1,185
75	320	290	896	1,186
80	324	295	892	1,187
90	331	302	887	1,189
100	338	309	882	1,190
110	344	316	876	1,192
125	353	325	869	1,195
130	356	328	867	1,196
140	361	333	862	1,196
150	366	339	858	1,197
160	371	344	854	1,198
170	375	348	850	1,198
175	377	351	848	1,199
180	380	353	846	1,199
190	384	358	842	1,200
200	388	362	838	1,201
225	397	372	830	1,202
250	406	381	821	1,203
275	414	391	813	1,204
300	421	398	806	1,204
325	429	407	798	1,205
350	436	414	791	1,205
375	442	421	784	1,205
400	448	428	778	1,205

Source: Information extracted from http://www.boilerroom.com website

Appendix E: Standard Wattage Table

Table E1: Standard Wattage Table

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED001-SCRW	Integrated-ballast LED Lamps	(1) 1W screw-in lamp/base, any bulb shape	NA	NA	1	Electronic
LED002-SCRW	Integrated-ballast LED Lamps	(1) 2W screw-in lamp/base, any bulb shape	NA	NA	2	Electronic
LED003-SCRW	Integrated-ballast LED Lamps	(1) 3W screw-in lamp/base, any bulb shape	NA	NA	3	Electronic
LED004-SCRW	Integrated-ballast LED Lamps	(1) 4W screw-in lamp/base, any bulb shape	NA	NA	4	Electronic
LED005-SCRW	Integrated-ballast LED Lamps	(1) 5W screw-in lamp/base, any bulb shape	NA	NA	5	Electronic
LED006-SCRW	Integrated-ballast LED Lamps	(1) 6W screw-in lamp/base, any bulb shape	NA	NA	6	Electronic
LED007-SCRW	Integrated-ballast LED Lamps	(1) 7W screw-in lamp/base, any bulb shape	NA	NA	7	Electronic
LED008-SCRW	Integrated-ballast LED Lamps	(1) 8W screw-in lamp/base, any bulb shape	NA	NA	8	Electronic
LED009-SCRW	Integrated-ballast LED Lamps	(1) 9W screw-in lamp/base, any bulb shape	NA	NA	9	Electronic
LED010-SCRW	Integrated-ballast LED Lamps	(1) 10W screw-in lamp/base, any bulb shape	NA	NA	10	Electronic
LED011-SCRW	Integrated-ballast LED Lamps	(1) 11W screw-in lamp/base, any bulb shape	NA	NA	11	Electronic
LED012-SCRW	Integrated-ballast LED Lamps	(1) 12W screw-in lamp/base, any bulb shape	NA	NA	12	Electronic
LED013-SCRW	Integrated-ballast LED Lamps	(1) 13W screw-in lamp/base, any bulb shape	NA	NA	13	Electronic
LED014-SCRW	Integrated-ballast LED Lamps	(1) 14W screw-in lamp/base, any bulb shape	NA	NA	14	Electronic
LED015-SCRW	Integrated-ballast LED Lamps	(1) 15W screw-in lamp/base, any bulb shape	NA	NA	15	Electronic
LED016-SCRW	Integrated-ballast LED Lamps	(1) 16W screw-in lamp/base, any bulb shape	NA	NA	16	Electronic
LED017-SCRW	Integrated-ballast LED Lamps	(1) 17W screw-in lamp/base, any bulb shape	NA	NA	17	Electronic
LED018-SCRW	Integrated-ballast LED Lamps	(1) 18W screw-in lamp/base, any bulb shape	NA	NA	18	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED019-SCRW	Integrated-ballast LED Lamps	(1) 19W screw-in lamp/base, any bulb shape	NA	NA	19	Electronic
LED020-SCRW	Integrated-ballast LED Lamps	(1) 20W screw-in lamp/base, any bulb shape	NA	NA	20	Electronic
LED021-SCRW	Integrated-ballast LED Lamps	(1) 21W screw-in lamp/base, any bulb shape	NA	NA	21	Electronic
LED022-SCRW	Integrated-ballast LED Lamps	(1) 22W screw-in lamp/base, any bulb shape	NA	NA	22	Electronic
LED023-SCRW	Integrated-ballast LED Lamps	(1) 23W screw-in lamp/base, any bulb shape	NA	NA	23	Electronic
LED024-SCRW	Integrated-ballast LED Lamps	(1) 24W screw-in lamp/base, any bulb shape	NA	NA	24	Electronic
LED025-SCRW	Integrated-ballast LED Lamps	(1) 25W screw-in lamp/base, any bulb shape	NA	NA	25	Electronic
LED026-SCRW	Integrated-ballast LED Lamps	(1) 26W screw-in lamp/base, any bulb shape	NA	NA	26	Electronic
LED027-SCRW	Integrated-ballast LED Lamps	(1) 27W screw-in lamp/base, any bulb shape	NA	NA	27	Electronic
LED028-SCRW	Integrated-ballast LED Lamps	(1) 28W screw-in lamp/base, any bulb shape	NA	NA	28	Electronic
LED029-SCRW	Integrated-ballast LED Lamps	(1) 29W screw-in lamp/base, any bulb shape	NA	NA	29	Electronic
LED030-SCRW	Integrated-ballast LED Lamps	(1) 30W screw-in lamp/base, any bulb shape	NA	NA	30	Electronic
LED031-SCRW	Integrated-ballast LED Lamps	(1) 31W screw-in lamp/base, any bulb shape	NA	NA	31	Electronic
LED032-SCRW	Integrated-ballast LED Lamps	(1) 32W screw-in lamp/base, any bulb shape	NA	NA	32	Electronic
LED033-SCRW	Integrated-ballast LED Lamps	(1) 33W screw-in lamp/base, any bulb shape	NA	NA	33	Electronic
LED034-SCRW	Integrated-ballast LED Lamps	(1) 34W screw-in lamp/base, any bulb shape	NA	NA	34	Electronic
LED035-SCRW	Integrated-ballast LED Lamps	(1) 35W screw-in lamp/base, any bulb shape	NA	NA	35	Electronic
LED036-SCRW	Integrated-ballast LED Lamps	(1) 36W screw-in lamp/base, any bulb shape	NA	NA	36	Electronic
LED037-SCRW	Integrated-ballast LED Lamps	(1) 37W screw-in lamp/base, any bulb shape	NA	NA	37	Electronic
LED038-SCRW	Integrated-ballast LED Lamps	(1) 38W screw-in lamp/base, any bulb shape	NA	NA	38	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED039-SCRW	Integrated-ballast LED Lamps	(1) 39W screw-in lamp/base, any bulb shape	NA	NA	39	Electronic
LED040-SCRW	Integrated-ballast LED Lamps	(1) 40W screw-in lamp/base, any bulb shape	NA	NA	40	Electronic
LED041-SCRW	Integrated-ballast LED Lamps	(1) 41W screw-in lamp/base, any bulb shape	NA	NA	41	Electronic
LED042-SCRW	Integrated-ballast LED Lamps	(1) 42W screw-in lamp/base, any bulb shape	NA	NA	42	Electronic
LED043-SCRW	Integrated-ballast LED Lamps	(1) 43W screw-in lamp/base, any bulb shape	NA	NA	43	Electronic
LED044-SCRW	Integrated-ballast LED Lamps	(1) 44W screw-in lamp/base, any bulb shape	NA	NA	44	Electronic
LED045-SCRW	Integrated-ballast LED Lamps	(1) 45W screw-in lamp/base, any bulb shape	NA	NA	45	Electronic
LED046-SCRW	Integrated-ballast LED Lamps	(1) 46W screw-in lamp/base, any bulb shape	NA	NA	46	Electronic
LED047-SCRW	Integrated-ballast LED Lamps	(1) 47W screw-in lamp/base, any bulb shape	NA	NA	47	Electronic
LED048-SCRW	Integrated-ballast LED Lamps	(1) 48W screw-in lamp/base, any bulb shape	NA	NA	48	Electronic
LED049-SCRW	Integrated-ballast LED Lamps	(1) 49W screw-in lamp/base, any bulb shape	NA	NA	49	Electronic
LED050-SCRW	Integrated-ballast LED Lamps	(1) 50W screw-in lamp/base, any bulb shape	NA	NA	50	Electronic
LED001-FIXT	Light Emitting Diode (LED)	(1) 1W fixture, any bulb shape, any application	NA	NA	1	Electronic
LED002-FIXT	Light Emitting Diode (LED)	(1) 2W fixture, any bulb shape, any application	NA	NA	2	Electronic
LED003-FIXT	Light Emitting Diode (LED)	(1) 3W fixture, any bulb shape, any application	NA	NA	3	Electronic
LED004-FIXT	Light Emitting Diode (LED)	(1) 4W fixture, any bulb shape, any application	NA	NA	4	Electronic
LED005-FIXT	Light Emitting Diode (LED)	(1) 5W fixture, any bulb shape, any application	NA	NA	5	Electronic
LED006-FIXT	Light Emitting Diode (LED)	(1) 6W fixture, any bulb shape, any application	NA	NA	6	Electronic
LED007-FIXT	Light Emitting Diode (LED)	(1) 7W fixture, any bulb shape, any application	NA	NA	7	Electronic
LED008-FIXT	Light Emitting Diode (LED)	(1) 8W fixture, any bulb shape, any application	NA	NA	8	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED009-FIXT	Light Emitting Diode (LED)	(1) 9W fixture, any bulb shape, any application	NA	NA	9	Electronic
LED010-FIXT	Light Emitting Diode (LED)	(1) 10W fixture, any bulb shape, any application	NA	NA	10	Electronic
LED011-FIXT	Light Emitting Diode (LED)	(1) 11W fixture, any bulb shape, any application	NA	NA	11	Electronic
LED012-FIXT	Light Emitting Diode (LED)	(1) 12W fixture, any bulb shape, any application	NA	NA	12	Electronic
LED013-FIXT	Light Emitting Diode (LED)	(1) 13W fixture, any bulb shape, any application	NA	NA	13	Electronic
LED014-FIXT	Light Emitting Diode (LED)	(1) 14W fixture, any bulb shape, any application	NA	NA	14	Electronic
LED015-FIXT	Light Emitting Diode (LED)	(1) 15W fixture, any bulb shape, any application	NA	NA	15	Electronic
LED016-FIXT	Light Emitting Diode (LED)	(1) 16W fixture, any bulb shape, any application	NA	NA	16	Electronic
LED017-FIXT	Light Emitting Diode (LED)	(1) 17W fixture, any bulb shape, any application	NA	NA	17	Electronic
LED018-FIXT	Light Emitting Diode (LED)	(1) 18W fixture, any bulb shape, any application	NA	NA	18	Electronic
LED019-FIXT	Light Emitting Diode (LED)	(1) 19W fixture, any bulb shape, any application	NA	NA	19	Electronic
LED020-FIXT	Light Emitting Diode (LED)	(1) 20W fixture, any bulb shape, any application	NA	NA	20	Electronic
LED021-FIXT	Light Emitting Diode (LED)	(1) 21W fixture, any bulb shape, any application	NA	NA	21	Electronic
LED022-FIXT	Light Emitting Diode (LED)	(1) 22W fixture, any bulb shape, any application	NA	NA	22	Electronic
LED023-FIXT	Light Emitting Diode (LED)	(1) 23W fixture, any bulb shape, any application	NA	NA	23	Electronic
LED024-FIXT	Light Emitting Diode (LED)	(1) 24W fixture, any bulb shape, any application	NA	NA	24	Electronic
LED025-FIXT	Light Emitting Diode (LED)	(1) 25W fixture, any bulb shape, any application	NA	NA	25	Electronic
LED026-FIXT	Light Emitting Diode (LED)	(1) 26W fixture, any bulb shape, any application	NA	NA	26	Electronic
LED027-FIXT	Light Emitting Diode (LED)	(1) 27W fixture, any bulb shape, any application	NA	NA	27	Electronic
LED028-FIXT	Light Emitting Diode (LED)	(1) 28W fixture, any bulb shape, any application	NA	NA	28	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED029-FIXT	Light Emitting Diode (LED)	(1) 29W fixture, any bulb shape, any application	NA	NA	29	Electronic
LED030-FIXT	Light Emitting Diode (LED)	(1) 30W fixture, any bulb shape, any application	NA	NA	30	Electronic
LED031-FIXT	Light Emitting Diode (LED)	(1) 31W fixture, any bulb shape, any application	NA	NA	31	Electronic
LED032-FIXT	Light Emitting Diode (LED)	(1) 32W fixture, any bulb shape, any application	NA	NA	32	Electronic
LED033-FIXT	Light Emitting Diode (LED)	(1) 33W fixture, any bulb shape, any application	NA	NA	33	Electronic
LED034-FIXT	Light Emitting Diode (LED)	(1) 34W fixture, any bulb shape, any application	NA	NA	34	Electronic
LED035-FIXT	Light Emitting Diode (LED)	(1) 35W fixture, any bulb shape, any application	NA	NA	35	Electronic
LED036-FIXT	Light Emitting Diode (LED)	(1) 36W fixture, any bulb shape, any application	NA	NA	36	Electronic
LED037-FIXT	Light Emitting Diode (LED)	(1) 37W fixture, any bulb shape, any application	NA	NA	37	Electronic
LED038-FIXT	Light Emitting Diode (LED)	(1) 38W fixture, any bulb shape, any application	NA	NA	38	Electronic
LED039-FIXT	Light Emitting Diode (LED)	(1) 39W fixture, any bulb shape, any application	NA	NA	39	Electronic
LED040-FIXT	Light Emitting Diode (LED)	(1) 40W fixture, any bulb shape, any application	NA	NA	40	Electronic
LED041-FIXT	Light Emitting Diode (LED)	(1) 41W fixture, any bulb shape, any application	NA	NA	41	Electronic
LED042-FIXT	Light Emitting Diode (LED)	(1) 42W fixture, any bulb shape, any application	NA	NA	42	Electronic
LED043-FIXT	Light Emitting Diode (LED)	(1) 43W fixture, any bulb shape, any application	NA	NA	43	Electronic
LED044-FIXT	Light Emitting Diode (LED)	(1) 44W fixture, any bulb shape, any application	NA	NA	44	Electronic
LED045-FIXT	Light Emitting Diode (LED)	(1) 45W fixture, any bulb shape, any application	NA	NA	45	Electronic
LED046-FIXT	Light Emitting Diode (LED)	(1) 46W fixture, any bulb shape, any application	NA	NA	46	Electronic
LED047-FIXT	Light Emitting Diode (LED)	(1) 47W fixture, any bulb shape, any application	NA	NA	47	Electronic
LED048-FIXT	Light Emitting Diode (LED)	(1) 48W fixture, any bulb shape, any application	NA	NA	48	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED049-FIXT	Light Emitting Diode (LED)	(1) 49W fixture, any bulb shape, any application	NA	NA	49	Electronic
LED050-FIXT	Light Emitting Diode (LED)	(1) 50W fixture, any bulb shape, any application	NA	NA	50	Electronic
LED051-FIXT	Light Emitting Diode (LED)	(1) 51W fixture, any bulb shape, any application	NA	NA	51	Electronic
LED052-FIXT	Light Emitting Diode (LED)	(1) 52W fixture, any bulb shape, any application	NA	NA	52	Electronic
LED053-FIXT	Light Emitting Diode (LED)	(1) 53W fixture, any bulb shape, any application	NA	NA	53	Electronic
LED054-FIXT	Light Emitting Diode (LED)	(1) 54W fixture, any bulb shape, any application	NA	NA	54	Electronic
LED055-FIXT	Light Emitting Diode (LED)	(1) 55W fixture, any bulb shape, any application	NA	NA	55	Electronic
LED056-FIXT	Light Emitting Diode (LED)	(1) 56W fixture, any bulb shape, any application	NA	NA	56	Electronic
LED057-FIXT	Light Emitting Diode (LED)	(1) 57W fixture, any bulb shape, any application	NA	NA	57	Electronic
LED058-FIXT	Light Emitting Diode (LED)	(1) 58W fixture, any bulb shape, any application	NA	NA	58	Electronic
LED059-FIXT	Light Emitting Diode (LED)	(1) 59W fixture, any bulb shape, any application	NA	NA	59	Electronic
LED060-FIXT	Light Emitting Diode (LED)	(1) 60W fixture, any bulb shape, any application	NA	NA	60	Electronic
LED061-FIXT	Light Emitting Diode (LED)	(1) 61W fixture, any bulb shape, any application	NA	NA	61	Electronic
LED062-FIXT	Light Emitting Diode (LED)	(1) 62W fixture, any bulb shape, any application	NA	NA	62	Electronic
LED063-FIXT	Light Emitting Diode (LED)	(1) 63W fixture, any bulb shape, any application	NA	NA	63	Electronic
LED064-FIXT	Light Emitting Diode (LED)	(1) 64W fixture, any bulb shape, any application	NA	NA	64	Electronic
LED065-FIXT	Light Emitting Diode (LED)	(1) 65W fixture, any bulb shape, any application	NA	NA	65	Electronic
LED066-FIXT	Light Emitting Diode (LED)	(1) 66W fixture, any bulb shape, any application	NA	NA	66	Electronic
LED067-FIXT	Light Emitting Diode (LED)	(1) 67W fixture, any bulb shape, any application	NA	NA	67	Electronic
LED068-FIXT	Light Emitting Diode (LED)	(1) 68W fixture, any bulb shape, any application	NA	NA	68	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED069-FIXT	Light Emitting Diode (LED)	(1) 69W fixture, any bulb shape, any application	NA	NA	69	Electronic
LED070-FIXT	Light Emitting Diode (LED)	(1) 70W fixture, any bulb shape, any application	NA	NA	70	Electronic
LED071-FIXT	Light Emitting Diode (LED)	(1) 71W fixture, any bulb shape, any application	NA	NA	71	Electronic
LED072-FIXT	Light Emitting Diode (LED)	(1) 72W fixture, any bulb shape, any application	NA	NA	72	Electronic
LED073-FIXT	Light Emitting Diode (LED)	(1) 73W fixture, any bulb shape, any application	NA	NA	73	Electronic
LED074-FIXT	Light Emitting Diode (LED)	(1) 74W fixture, any bulb shape, any application	NA	NA	74	Electronic
LED075-FIXT	Light Emitting Diode (LED)	(1) 75W fixture, any bulb shape, any application	NA	NA	75	Electronic
LED076-FIXT	Light Emitting Diode (LED)	(1) 76W fixture, any bulb shape, any application	NA	NA	76	Electronic
LED077-FIXT	Light Emitting Diode (LED)	(1) 77W fixture, any bulb shape, any application	NA	NA	77	Electronic
LED078-FIXT	Light Emitting Diode (LED)	(1) 78W fixture, any bulb shape, any application	NA	NA	78	Electronic
LED079-FIXT	Light Emitting Diode (LED)	(1) 79W fixture, any bulb shape, any application	NA	NA	79	Electronic
LED080-FIXT	Light Emitting Diode (LED)	(1) 80W fixture, any bulb shape, any application	NA	NA	80	Electronic
LED081-FIXT	Light Emitting Diode (LED)	(1) 81W fixture, any bulb shape, any application	NA	NA	81	Electronic
LED082-FIXT	Light Emitting Diode (LED)	(1) 82W fixture, any bulb shape, any application	NA	NA	82	Electronic
LED083-FIXT	Light Emitting Diode (LED)	(1) 83W fixture, any bulb shape, any application	NA	NA	83	Electronic
LED084-FIXT	Light Emitting Diode (LED)	(1) 84W fixture, any bulb shape, any application	NA	NA	84	Electronic
LED085-FIXT	Light Emitting Diode (LED)	(1) 85W fixture, any bulb shape, any application	NA	NA	85	Electronic
LED086-FIXT	Light Emitting Diode (LED)	(1) 86W fixture, any bulb shape, any application	NA	NA	86	Electronic
LED087-FIXT	Light Emitting Diode (LED)	(1) 87W fixture, any bulb shape, any application	NA	NA	87	Electronic
LED088-FIXT	Light Emitting Diode (LED)	(1) 88W fixture, any bulb shape, any application	NA	NA	88	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED089-FIXT	Light Emitting Diode (LED)	(1) 89W fixture, any bulb shape, any application	NA	NA	89	Electronic
LED090-FIXT	Light Emitting Diode (LED)	(1) 90W fixture, any bulb shape, any application	NA	NA	90	Electronic
LED091-FIXT	Light Emitting Diode (LED)	(1) 91W fixture, any bulb shape, any application	NA	NA	91	Electronic
LED092-FIXT	Light Emitting Diode (LED)	(1) 92W fixture, any bulb shape, any application	NA	NA	92	Electronic
LED093-FIXT	Light Emitting Diode (LED)	(1) 93W fixture, any bulb shape, any application	NA	NA	93	Electronic
LED094-FIXT	Light Emitting Diode (LED)	(1) 94W fixture, any bulb shape, any application	NA	NA	94	Electronic
LED095-FIXT	Light Emitting Diode (LED)	(1) 95W fixture, any bulb shape, any application	NA	NA	95	Electronic
LED096-FIXT	Light Emitting Diode (LED)	(1) 96W fixture, any bulb shape, any application	NA	NA	96	Electronic
LED097-FIXT	Light Emitting Diode (LED)	(1) 97W fixture, any bulb shape, any application	NA	NA	97	Electronic
LED098-FIXT	Light Emitting Diode (LED)	(1) 98W fixture, any bulb shape, any application	NA	NA	98	Electronic
LED099-FIXT	Light Emitting Diode (LED)	(1) 99W fixture, any bulb shape, any application	NA	NA	99	Electronic
LED100-FIXT	Light Emitting Diode (LED)	(1) 100W fixture, any bulb shape, any application	NA	NA	100	Electronic
LED101-FIXT	Light Emitting Diode (LED)	(1) 101W fixture, any bulb shape, any application	NA	NA	101	Electronic
LED102-FIXT	Light Emitting Diode (LED)	(1) 102W fixture, any bulb shape, any application	NA	NA	102	Electronic
LED103-FIXT	Light Emitting Diode (LED)	(1) 103W fixture, any bulb shape, any application	NA	NA	103	Electronic
LED104-FIXT	Light Emitting Diode (LED)	(1) 104W fixture, any bulb shape, any application	NA	NA	104	Electronic
LED105-FIXT	Light Emitting Diode (LED)	(1) 105W fixture, any bulb shape, any application	NA	NA	105	Electronic
LED106-FIXT	Light Emitting Diode (LED)	(1) 106W fixture, any bulb shape, any application	NA	NA	106	Electronic
LED107-FIXT	Light Emitting Diode (LED)	(1) 107W fixture, any bulb shape, any application	NA	NA	107	Electronic
LED108-FIXT	Light Emitting Diode (LED)	(1) 108W fixture, any bulb shape, any application	NA	NA	108	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED109-FIXT	Light Emitting Diode (LED)	(1) 109W fixture, any bulb shape, any application	NA	NA	109	Electronic
LED110-FIXT	Light Emitting Diode (LED)	(1) 110W fixture, any bulb shape, any application	NA	NA	110	Electronic
LED111-FIXT	Light Emitting Diode (LED)	(1) 111W fixture, any bulb shape, any application	NA	NA	111	Electronic
LED112-FIXT	Light Emitting Diode (LED)	(1) 112W fixture, any bulb shape, any application	NA	NA	112	Electronic
LED113-FIXT	Light Emitting Diode (LED)	(1) 113W fixture, any bulb shape, any application	NA	NA	113	Electronic
LED114-FIXT	Light Emitting Diode (LED)	(1) 114W fixture, any bulb shape, any application	NA	NA	114	Electronic
LED115-FIXT	Light Emitting Diode (LED)	(1) 115W fixture, any bulb shape, any application	NA	NA	115	Electronic
LED116-FIXT	Light Emitting Diode (LED)	(1) 116W fixture, any bulb shape, any application	NA	NA	116	Electronic
LED117-FIXT	Light Emitting Diode (LED)	(1) 117W fixture, any bulb shape, any application	NA	NA	117	Electronic
LED118-FIXT	Light Emitting Diode (LED)	(1) 118W fixture, any bulb shape, any application	NA	NA	118	Electronic
LED119-FIXT	Light Emitting Diode (LED)	(1) 119W fixture, any bulb shape, any application	NA	NA	119	Electronic
LED120-FIXT	Light Emitting Diode (LED)	(1) 120W fixture, any bulb shape, any application	NA	NA	120	Electronic
LED121-FIXT	Light Emitting Diode (LED)	(1) 121W fixture, any bulb shape, any application	NA	NA	121	Electronic
LED122-FIXT	Light Emitting Diode (LED)	(1) 122W fixture, any bulb shape, any application	NA	NA	122	Electronic
LED123-FIXT	Light Emitting Diode (LED)	(1) 123W fixture, any bulb shape, any application	NA	NA	123	Electronic
LED124-FIXT	Light Emitting Diode (LED)	(1) 124W fixture, any bulb shape, any application	NA	NA	124	Electronic
LED125-FIXT	Light Emitting Diode (LED)	(1) 125W fixture, any bulb shape, any application	NA	NA	125	Electronic
LED126-FIXT	Light Emitting Diode (LED)	(1) 126W fixture, any bulb shape, any application	NA	NA	126	Electronic
LED127-FIXT	Light Emitting Diode (LED)	(1) 127W fixture, any bulb shape, any application	NA	NA	127	Electronic
LED128-FIXT	Light Emitting Diode (LED)	(1) 128W fixture, any bulb shape, any application	NA	NA	128	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED129-FIXT	Light Emitting Diode (LED)	(1) 129W fixture, any bulb shape, any application	NA	NA	129	Electronic
LED130-FIXT	Light Emitting Diode (LED)	(1) 130W fixture, any bulb shape, any application	NA	NA	130	Electronic
LED131-FIXT	Light Emitting Diode (LED)	(1) 131W fixture, any bulb shape, any application	NA	NA	131	Electronic
LED132-FIXT	Light Emitting Diode (LED)	(1) 132W fixture, any bulb shape, any application	NA	NA	132	Electronic
LED133-FIXT	Light Emitting Diode (LED)	(1) 133W fixture, any bulb shape, any application	NA	NA	133	Electronic
LED134-FIXT	Light Emitting Diode (LED)	(1) 134W fixture, any bulb shape, any application	NA	NA	134	Electronic
LED135-FIXT	Light Emitting Diode (LED)	(1) 135W fixture, any bulb shape, any application	NA	NA	135	Electronic
LED136-FIXT	Light Emitting Diode (LED)	(1) 136W fixture, any bulb shape, any application	NA	NA	136	Electronic
LED137-FIXT	Light Emitting Diode (LED)	(1) 137W fixture, any bulb shape, any application	NA	NA	137	Electronic
LED138-FIXT	Light Emitting Diode (LED)	(1) 138W fixture, any bulb shape, any application	NA	NA	138	Electronic
LED139-FIXT	Light Emitting Diode (LED)	(1) 139W fixture, any bulb shape, any application	NA	NA	139	Electronic
LED140-FIXT	Light Emitting Diode (LED)	(1) 140W fixture, any bulb shape, any application	NA	NA	140	Electronic
LED141-FIXT	Light Emitting Diode (LED)	(1) 141W fixture, any bulb shape, any application	NA	NA	141	Electronic
LED142-FIXT	Light Emitting Diode (LED)	(1) 142W fixture, any bulb shape, any application	NA	NA	142	Electronic
LED143-FIXT	Light Emitting Diode (LED)	(1) 143W fixture, any bulb shape, any application	NA	NA	143	Electronic
LED144-FIXT	Light Emitting Diode (LED)	(1) 144W fixture, any bulb shape, any application	NA	NA	144	Electronic
LED145-FIXT	Light Emitting Diode (LED)	(1) 145W fixture, any bulb shape, any application	NA	NA	145	Electronic
LED146-FIXT	Light Emitting Diode (LED)	(1) 146W fixture, any bulb shape, any application	NA	NA	146	Electronic
LED147-FIXT	Light Emitting Diode (LED)	(1) 147W fixture, any bulb shape, any application	NA	NA	147	Electronic
LED148-FIXT	Light Emitting Diode (LED)	(1) 148W fixture, any bulb shape, any application	NA	NA	148	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED149-FIXT	Light Emitting Diode (LED)	(1) 149W fixture, any bulb shape, any application	NA	NA	149	Electronic
LED150-FIXT	Light Emitting Diode (LED)	(1) 150W fixture, any bulb shape, any application	NA	NA	150	Electronic
LED151-FIXT	Light Emitting Diode (LED)	(1) 151W fixture, any bulb shape, any application	NA	NA	151	Electronic
LED152-FIXT	Light Emitting Diode (LED)	(1) 152W fixture, any bulb shape, any application	NA	NA	152	Electronic
LED153-FIXT	Light Emitting Diode (LED)	(1) 153W fixture, any bulb shape, any application	NA	NA	153	Electronic
LED154-FIXT	Light Emitting Diode (LED)	(1) 154W fixture, any bulb shape, any application	NA	NA	154	Electronic
LED155-FIXT	Light Emitting Diode (LED)	(1) 155W fixture, any bulb shape, any application	NA	NA	155	Electronic
LED156-FIXT	Light Emitting Diode (LED)	(1) 156W fixture, any bulb shape, any application	NA	NA	156	Electronic
LED157-FIXT	Light Emitting Diode (LED)	(1) 157W fixture, any bulb shape, any application	NA	NA	157	Electronic
LED158-FIXT	Light Emitting Diode (LED)	(1) 158W fixture, any bulb shape, any application	NA	NA	158	Electronic
LED159-FIXT	Light Emitting Diode (LED)	(1) 159W fixture, any bulb shape, any application	NA	NA	159	Electronic
LED160-FIXT	Light Emitting Diode (LED)	(1) 160W fixture, any bulb shape, any application	NA	NA	160	Electronic
LED161-FIXT	Light Emitting Diode (LED)	(1) 161W fixture, any bulb shape, any application	NA	NA	161	Electronic
LED162-FIXT	Light Emitting Diode (LED)	(1) 162W fixture, any bulb shape, any application	NA	NA	162	Electronic
LED163-FIXT	Light Emitting Diode (LED)	(1) 163W fixture, any bulb shape, any application	NA	NA	163	Electronic
LED164-FIXT	Light Emitting Diode (LED)	(1) 164W fixture, any bulb shape, any application	NA	NA	164	Electronic
LED165-FIXT	Light Emitting Diode (LED)	(1) 165W fixture, any bulb shape, any application	NA	NA	165	Electronic
LED166-FIXT	Light Emitting Diode (LED)	(1) 166W fixture, any bulb shape, any application	NA	NA	166	Electronic
LED167-FIXT	Light Emitting Diode (LED)	(1) 167W fixture, any bulb shape, any application	NA	NA	167	Electronic
LED168-FIXT	Light Emitting Diode (LED)	(1) 168W fixture, any bulb shape, any application	NA	NA	168	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED169-FIXT	Light Emitting Diode (LED)	(1) 169W fixture, any bulb shape, any application	NA	NA	169	Electronic
LED170-FIXT	Light Emitting Diode (LED)	(1) 170W fixture, any bulb shape, any application	NA	NA	170	Electronic
LED171-FIXT	Light Emitting Diode (LED)	(1) 171W fixture, any bulb shape, any application	NA	NA	171	Electronic
LED172-FIXT	Light Emitting Diode (LED)	(1) 172W fixture, any bulb shape, any application	NA	NA	172	Electronic
LED173-FIXT	Light Emitting Diode (LED)	(1) 173W fixture, any bulb shape, any application	NA	NA	173	Electronic
LED174-FIXT	Light Emitting Diode (LED)	(1) 174W fixture, any bulb shape, any application	NA	NA	174	Electronic
LED175-FIXT	Light Emitting Diode (LED)	(1) 175W fixture, any bulb shape, any application	NA	NA	175	Electronic
LED176-FIXT	Light Emitting Diode (LED)	(1) 176W fixture, any bulb shape, any application	NA	NA	176	Electronic
LED177-FIXT	Light Emitting Diode (LED)	(1) 177W fixture, any bulb shape, any application	NA	NA	177	Electronic
LED178-FIXT	Light Emitting Diode (LED)	(1) 178W fixture, any bulb shape, any application	NA	NA	178	Electronic
LED179-FIXT	Light Emitting Diode (LED)	(1) 179W fixture, any bulb shape, any application	NA	NA	179	Electronic
LED180-FIXT	Light Emitting Diode (LED)	(1) 180W fixture, any bulb shape, any application	NA	NA	180	Electronic
LED181-FIXT	Light Emitting Diode (LED)	(1) 181W fixture, any bulb shape, any application	NA	NA	181	Electronic
LED182-FIXT	Light Emitting Diode (LED)	(1) 182W fixture, any bulb shape, any application	NA	NA	182	Electronic
LED183-FIXT	Light Emitting Diode (LED)	(1) 183W fixture, any bulb shape, any application	NA	NA	183	Electronic
LED184-FIXT	Light Emitting Diode (LED)	(1) 184W fixture, any bulb shape, any application	NA	NA	184	Electronic
LED185-FIXT	Light Emitting Diode (LED)	(1) 185W fixture, any bulb shape, any application	NA	NA	185	Electronic
LED186-FIXT	Light Emitting Diode (LED)	(1) 186W fixture, any bulb shape, any application	NA	NA	186	Electronic
LED187-FIXT	Light Emitting Diode (LED)	(1) 187W fixture, any bulb shape, any application	NA	NA	187	Electronic
LED188-FIXT	Light Emitting Diode (LED)	(1) 188W fixture, any bulb shape, any application	NA	NA	188	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED189-FIXT	Light Emitting Diode (LED)	(1) 189W fixture, any bulb shape, any application	NA	NA	189	Electronic
LED190-FIXT	Light Emitting Diode (LED)	(1) 190W fixture, any bulb shape, any application	NA	NA	190	Electronic
LED191-FIXT	Light Emitting Diode (LED)	(1) 191W fixture, any bulb shape, any application	NA	NA	191	Electronic
LED192-FIXT	Light Emitting Diode (LED)	(1) 192W fixture, any bulb shape, any application	NA	NA	192	Electronic
LED193-FIXT	Light Emitting Diode (LED)	(1) 193W fixture, any bulb shape, any application	NA	NA	193	Electronic
LED194-FIXT	Light Emitting Diode (LED)	(1) 194W fixture, any bulb shape, any application	NA	NA	194	Electronic
LED195-FIXT	Light Emitting Diode (LED)	(1) 195W fixture, any bulb shape, any application	NA	NA	195	Electronic
LED196-FIXT	Light Emitting Diode (LED)	(1) 196W fixture, any bulb shape, any application	NA	NA	196	Electronic
LED197-FIXT	Light Emitting Diode (LED)	(1) 197W fixture, any bulb shape, any application	NA	NA	197	Electronic
LED198-FIXT	Light Emitting Diode (LED)	(1) 198W fixture, any bulb shape, any application	NA	NA	198	Electronic
LED199-FIXT	Light Emitting Diode (LED)	(1) 199W fixture, any bulb shape, any application	NA	NA	199	Electronic
LED200-FIXT	Light Emitting Diode (LED)	(1) 200W fixture, any bulb shape, any application	NA	NA	200	Electronic
LED201-FIXT	Light Emitting Diode (LED)	(1) 201W fixture, any bulb shape, any application	NA	NA	201	Electronic
LED202-FIXT	Light Emitting Diode (LED)	(1) 202W fixture, any bulb shape, any application	NA	NA	202	Electronic
LED203-FIXT	Light Emitting Diode (LED)	(1) 203W fixture, any bulb shape, any application	NA	NA	203	Electronic
LED204-FIXT	Light Emitting Diode (LED)	(1) 204W fixture, any bulb shape, any application	NA	NA	204	Electronic
LED205-FIXT	Light Emitting Diode (LED)	(1) 205W fixture, any bulb shape, any application	NA	NA	205	Electronic
LED206-FIXT	Light Emitting Diode (LED)	(1) 206W fixture, any bulb shape, any application	NA	NA	206	Electronic
LED207-FIXT	Light Emitting Diode (LED)	(1) 207W fixture, any bulb shape, any application	NA	NA	207	Electronic
LED208-FIXT	Light Emitting Diode (LED)	(1) 208W fixture, any bulb shape, any application	NA	NA	208	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED209-FIXT	Light Emitting Diode (LED)	(1) 209W fixture, any bulb shape, any application	NA	NA	209	Electronic
LED210-FIXT	Light Emitting Diode (LED)	(1) 210W fixture, any bulb shape, any application	NA	NA	210	Electronic
LED211-FIXT	Light Emitting Diode (LED)	(1) 211W fixture, any bulb shape, any application	NA	NA	211	Electronic
LED212-FIXT	Light Emitting Diode (LED)	(1) 212W fixture, any bulb shape, any application	NA	NA	212	Electronic
LED213-FIXT	Light Emitting Diode (LED)	(1) 213W fixture, any bulb shape, any application	NA	NA	213	Electronic
LED214-FIXT	Light Emitting Diode (LED)	(1) 214W fixture, any bulb shape, any application	NA	NA	214	Electronic
LED215-FIXT	Light Emitting Diode (LED)	(1) 215W fixture, any bulb shape, any application	NA	NA	215	Electronic
LED216-FIXT	Light Emitting Diode (LED)	(1) 216W fixture, any bulb shape, any application	NA	NA	216	Electronic
LED217-FIXT	Light Emitting Diode (LED)	(1) 217W fixture, any bulb shape, any application	NA	NA	217	Electronic
LED218-FIXT	Light Emitting Diode (LED)	(1) 218W fixture, any bulb shape, any application	NA	NA	218	Electronic
LED219-FIXT	Light Emitting Diode (LED)	(1) 219W fixture, any bulb shape, any application	NA	NA	219	Electronic
LED220-FIXT	Light Emitting Diode (LED)	(1) 220W fixture, any bulb shape, any application	NA	NA	220	Electronic
LED221-FIXT	Light Emitting Diode (LED)	(1) 221W fixture, any bulb shape, any application	NA	NA	221	Electronic
LED222-FIXT	Light Emitting Diode (LED)	(1) 222W fixture, any bulb shape, any application	NA	NA	222	Electronic
LED223-FIXT	Light Emitting Diode (LED)	(1) 223W fixture, any bulb shape, any application	NA	NA	223	Electronic
LED224-FIXT	Light Emitting Diode (LED)	(1) 224W fixture, any bulb shape, any application	NA	NA	224	Electronic
LED225-FIXT	Light Emitting Diode (LED)	(1) 225W fixture, any bulb shape, any application	NA	NA	225	Electronic
LED226-FIXT	Light Emitting Diode (LED)	(1) 226W fixture, any bulb shape, any application	NA	NA	226	Electronic
LED227-FIXT	Light Emitting Diode (LED)	(1) 227W fixture, any bulb shape, any application	NA	NA	227	Electronic
LED228-FIXT	Light Emitting Diode (LED)	(1) 228W fixture, any bulb shape, any application	NA	NA	228	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED229-FIXT	Light Emitting Diode (LED)	(1) 229W fixture, any bulb shape, any application	NA	NA	229	Electronic
LED230-FIXT	Light Emitting Diode (LED)	(1) 230W fixture, any bulb shape, any application	NA	NA	230	Electronic
LED231-FIXT	Light Emitting Diode (LED)	(1) 231W fixture, any bulb shape, any application	NA	NA	231	Electronic
LED232-FIXT	Light Emitting Diode (LED)	(1) 232W fixture, any bulb shape, any application	NA	NA	232	Electronic
LED233-FIXT	Light Emitting Diode (LED)	(1) 233W fixture, any bulb shape, any application	NA	NA	233	Electronic
LED234-FIXT	Light Emitting Diode (LED)	(1) 234W fixture, any bulb shape, any application	NA	NA	234	Electronic
LED235-FIXT	Light Emitting Diode (LED)	(1) 235W fixture, any bulb shape, any application	NA	NA	235	Electronic
LED236-FIXT	Light Emitting Diode (LED)	(1) 236W fixture, any bulb shape, any application	NA	NA	236	Electronic
LED237-FIXT	Light Emitting Diode (LED)	(1) 237W fixture, any bulb shape, any application	NA	NA	237	Electronic
LED238-FIXT	Light Emitting Diode (LED)	(1) 238W fixture, any bulb shape, any application	NA	NA	238	Electronic
LED239-FIXT	Light Emitting Diode (LED)	(1) 239W fixture, any bulb shape, any application	NA	NA	239	Electronic
LED240-FIXT	Light Emitting Diode (LED)	(1) 240W fixture, any bulb shape, any application	NA	NA	240	Electronic
LED241-FIXT	Light Emitting Diode (LED)	(1) 241W fixture, any bulb shape, any application	NA	NA	241	Electronic
LED242-FIXT	Light Emitting Diode (LED)	(1) 242W fixture, any bulb shape, any application	NA	NA	242	Electronic
LED243-FIXT	Light Emitting Diode (LED)	(1) 243W fixture, any bulb shape, any application	NA	NA	243	Electronic
LED244-FIXT	Light Emitting Diode (LED)	(1) 244W fixture, any bulb shape, any application	NA	NA	244	Electronic
LED245-FIXT	Light Emitting Diode (LED)	(1) 245W fixture, any bulb shape, any application	NA	NA	245	Electronic
LED246-FIXT	Light Emitting Diode (LED)	(1) 246W fixture, any bulb shape, any application	NA	NA	246	Electronic
LED247-FIXT	Light Emitting Diode (LED)	(1) 247W fixture, any bulb shape, any application	NA	NA	247	Electronic
LED248-FIXT	Light Emitting Diode (LED)	(1) 248W fixture, any bulb shape, any application	NA	NA	248	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED249-FIXT	Light Emitting Diode (LED)	(1) 249W fixture, any bulb shape, any application	NA	NA	249	Electronic
LED250-FIXT	Light Emitting Diode (LED)	(1) 250W fixture, any bulb shape, any application	NA	NA	250	Electronic
LED251-FIXT	Light Emitting Diode (LED)	(1) 251W fixture, any bulb shape, any application	NA	NA	251	Electronic
LED252-FIXT	Light Emitting Diode (LED)	(1) 252W fixture, any bulb shape, any application	NA	NA	252	Electronic
LED253-FIXT	Light Emitting Diode (LED)	(1) 253W fixture, any bulb shape, any application	NA	NA	253	Electronic
LED254-FIXT	Light Emitting Diode (LED)	(1) 254W fixture, any bulb shape, any application	NA	NA	254	Electronic
LED255-FIXT	Light Emitting Diode (LED)	(1) 255W fixture, any bulb shape, any application	NA	NA	255	Electronic
LED256-FIXT	Light Emitting Diode (LED)	(1) 256W fixture, any bulb shape, any application	NA	NA	256	Electronic
LED257-FIXT	Light Emitting Diode (LED)	(1) 257W fixture, any bulb shape, any application	NA	NA	257	Electronic
LED258-FIXT	Light Emitting Diode (LED)	(1) 258W fixture, any bulb shape, any application	NA	NA	258	Electronic
LED259-FIXT	Light Emitting Diode (LED)	(1) 259W fixture, any bulb shape, any application	NA	NA	259	Electronic
LED260-FIXT	Light Emitting Diode (LED)	(1) 260W fixture, any bulb shape, any application	NA	NA	260	Electronic
LED261-FIXT	Light Emitting Diode (LED)	(1) 261W fixture, any bulb shape, any application	NA	NA	261	Electronic
LED262-FIXT	Light Emitting Diode (LED)	(1) 262W fixture, any bulb shape, any application	NA	NA	262	Electronic
LED263-FIXT	Light Emitting Diode (LED)	(1) 263W fixture, any bulb shape, any application	NA	NA	263	Electronic
LED264-FIXT	Light Emitting Diode (LED)	(1) 264W fixture, any bulb shape, any application	NA	NA	264	Electronic
LED265-FIXT	Light Emitting Diode (LED)	(1) 265W fixture, any bulb shape, any application	NA	NA	265	Electronic
LED266-FIXT	Light Emitting Diode (LED)	(1) 266W fixture, any bulb shape, any application	NA	NA	266	Electronic
LED267-FIXT	Light Emitting Diode (LED)	(1) 267W fixture, any bulb shape, any application	NA	NA	267	Electronic
LED268-FIXT	Light Emitting Diode (LED)	(1) 268W fixture, any bulb shape, any application	NA	NA	268	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED269-FIXT	Light Emitting Diode (LED)	(1) 269W fixture, any bulb shape, any application	NA	NA	269	Electronic
LED270-FIXT	Light Emitting Diode (LED)	(1) 270W fixture, any bulb shape, any application	NA	NA	270	Electronic
LED271-FIXT	Light Emitting Diode (LED)	(1) 271W fixture, any bulb shape, any application	NA	NA	271	Electronic
LED272-FIXT	Light Emitting Diode (LED)	(1) 272W fixture, any bulb shape, any application	NA	NA	272	Electronic
LED273-FIXT	Light Emitting Diode (LED)	(1) 273W fixture, any bulb shape, any application	NA	NA	273	Electronic
LED274-FIXT	Light Emitting Diode (LED)	(1) 274W fixture, any bulb shape, any application	NA	NA	274	Electronic
LED275-FIXT	Light Emitting Diode (LED)	(1) 275W fixture, any bulb shape, any application	NA	NA	275	Electronic
LED276-FIXT	Light Emitting Diode (LED)	(1) 276W fixture, any bulb shape, any application	NA	NA	276	Electronic
LED277-FIXT	Light Emitting Diode (LED)	(1) 277W fixture, any bulb shape, any application	NA	NA	277	Electronic
LED278-FIXT	Light Emitting Diode (LED)	(1) 278W fixture, any bulb shape, any application	NA	NA	278	Electronic
LED279-FIXT	Light Emitting Diode (LED)	(1) 279W fixture, any bulb shape, any application	NA	NA	279	Electronic
LED280-FIXT	Light Emitting Diode (LED)	(1) 280W fixture, any bulb shape, any application	NA	NA	280	Electronic
LED281-FIXT	Light Emitting Diode (LED)	(1) 281W fixture, any bulb shape, any application	NA	NA	281	Electronic
LED282-FIXT	Light Emitting Diode (LED)	(1) 282W fixture, any bulb shape, any application	NA	NA	282	Electronic
LED283-FIXT	Light Emitting Diode (LED)	(1) 283W fixture, any bulb shape, any application	NA	NA	283	Electronic
LED284-FIXT	Light Emitting Diode (LED)	(1) 284W fixture, any bulb shape, any application	NA	NA	284	Electronic
LED285-FIXT	Light Emitting Diode (LED)	(1) 285W fixture, any bulb shape, any application	NA	NA	285	Electronic
LED286-FIXT	Light Emitting Diode (LED)	(1) 286W fixture, any bulb shape, any application	NA	NA	286	Electronic
LED287-FIXT	Light Emitting Diode (LED)	(1) 287W fixture, any bulb shape, any application	NA	NA	287	Electronic
LED288-FIXT	Light Emitting Diode (LED)	(1) 288W fixture, any bulb shape, any application	NA	NA	288	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED289-FIXT	Light Emitting Diode (LED)	(1) 289W fixture, any bulb shape, any application	NA	NA	289	Electronic
LED290-FIXT	Light Emitting Diode (LED)	(1) 290W fixture, any bulb shape, any application	NA	NA	290	Electronic
LED291-FIXT	Light Emitting Diode (LED)	(1) 291W fixture, any bulb shape, any application	NA	NA	291	Electronic
LED292-FIXT	Light Emitting Diode (LED)	(1) 292W fixture, any bulb shape, any application	NA	NA	292	Electronic
LED293-FIXT	Light Emitting Diode (LED)	(1) 293W fixture, any bulb shape, any application	NA	NA	293	Electronic
LED294-FIXT	Light Emitting Diode (LED)	(1) 294W fixture, any bulb shape, any application	NA	NA	294	Electronic
LED295-FIXT	Light Emitting Diode (LED)	(1) 295W fixture, any bulb shape, any application	NA	NA	295	Electronic
LED296-FIXT	Light Emitting Diode (LED)	(1) 296W fixture, any bulb shape, any application	NA	NA	296	Electronic
LED297-FIXT	Light Emitting Diode (LED)	(1) 297W fixture, any bulb shape, any application	NA	NA	297	Electronic
LED298-FIXT	Light Emitting Diode (LED)	(1) 298W fixture, any bulb shape, any application	NA	NA	298	Electronic
LED299-FIXT	Light Emitting Diode (LED)	(1) 299W fixture, any bulb shape, any application	NA	NA	299	Electronic
LED300-FIXT	Light Emitting Diode (LED)	(1) 300W fixture, any bulb shape, any application	NA	NA	300	Electronic
LED301-FIXT	Light Emitting Diode (LED)	(1) 301W fixture, any bulb shape, any application	NA	NA	301	Electronic
LED302-FIXT	Light Emitting Diode (LED)	(1) 302W fixture, any bulb shape, any application	NA	NA	302	Electronic
LED303-FIXT	Light Emitting Diode (LED)	(1) 303W fixture, any bulb shape, any application	NA	NA	303	Electronic
LED304-FIXT	Light Emitting Diode (LED)	(1) 304W fixture, any bulb shape, any application	NA	NA	304	Electronic
LED305-FIXT	Light Emitting Diode (LED)	(1) 305W fixture, any bulb shape, any application	NA	NA	305	Electronic
LED306-FIXT	Light Emitting Diode (LED)	(1) 306W fixture, any bulb shape, any application	NA	NA	306	Electronic
LED307-FIXT	Light Emitting Diode (LED)	(1) 307W fixture, any bulb shape, any application	NA	NA	307	Electronic
LED308-FIXT	Light Emitting Diode (LED)	(1) 308W fixture, any bulb shape, any application	NA	NA	308	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED309-FIXT	Light Emitting Diode (LED)	(1) 309W fixture, any bulb shape, any application	NA	NA	309	Electronic
LED310-FIXT	Light Emitting Diode (LED)	(1) 310W fixture, any bulb shape, any application	NA	NA	310	Electronic
LED311-FIXT	Light Emitting Diode (LED)	(1) 311W fixture, any bulb shape, any application	NA	NA	311	Electronic
LED312-FIXT	Light Emitting Diode (LED)	(1) 312W fixture, any bulb shape, any application	NA	NA	312	Electronic
LED313-FIXT	Light Emitting Diode (LED)	(1) 313W fixture, any bulb shape, any application	NA	NA	313	Electronic
LED314-FIXT	Light Emitting Diode (LED)	(1) 314W fixture, any bulb shape, any application	NA	NA	314	Electronic
LED315-FIXT	Light Emitting Diode (LED)	(1) 315W fixture, any bulb shape, any application	NA	NA	315	Electronic
LED316-FIXT	Light Emitting Diode (LED)	(1) 316W fixture, any bulb shape, any application	NA	NA	316	Electronic
LED317-FIXT	Light Emitting Diode (LED)	(1) 317W fixture, any bulb shape, any application	NA	NA	317	Electronic
LED318-FIXT	Light Emitting Diode (LED)	(1) 318W fixture, any bulb shape, any application	NA	NA	318	Electronic
LED319-FIXT	Light Emitting Diode (LED)	(1) 319W fixture, any bulb shape, any application	NA	NA	319	Electronic
LED320-FIXT	Light Emitting Diode (LED)	(1) 320W fixture, any bulb shape, any application	NA	NA	320	Electronic
LED321-FIXT	Light Emitting Diode (LED)	(1) 321W fixture, any bulb shape, any application	NA	NA	321	Electronic
LED322-FIXT	Light Emitting Diode (LED)	(1) 322W fixture, any bulb shape, any application	NA	NA	322	Electronic
LED323-FIXT	Light Emitting Diode (LED)	(1) 323W fixture, any bulb shape, any application	NA	NA	323	Electronic
LED324-FIXT	Light Emitting Diode (LED)	(1) 324W fixture, any bulb shape, any application	NA	NA	324	Electronic
LED325-FIXT	Light Emitting Diode (LED)	(1) 325W fixture, any bulb shape, any application	NA	NA	325	Electronic
LED326-FIXT	Light Emitting Diode (LED)	(1) 326W fixture, any bulb shape, any application	NA	NA	326	Electronic
LED327-FIXT	Light Emitting Diode (LED)	(1) 327W fixture, any bulb shape, any application	NA	NA	327	Electronic
LED328-FIXT	Light Emitting Diode (LED)	(1) 328W fixture, any bulb shape, any application	NA	NA	328	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED329-FIXT	Light Emitting Diode (LED)	(1) 329W fixture, any bulb shape, any application	NA	NA	329	Electronic
LED330-FIXT	Light Emitting Diode (LED)	(1) 330W fixture, any bulb shape, any application	NA	NA	330	Electronic
LED331-FIXT	Light Emitting Diode (LED)	(1) 331W fixture, any bulb shape, any application	NA	NA	331	Electronic
LED332-FIXT	Light Emitting Diode (LED)	(1) 332W fixture, any bulb shape, any application	NA	NA	332	Electronic
LED333-FIXT	Light Emitting Diode (LED)	(1) 333W fixture, any bulb shape, any application	NA	NA	333	Electronic
LED334-FIXT	Light Emitting Diode (LED)	(1) 334W fixture, any bulb shape, any application	NA	NA	334	Electronic
LED335-FIXT	Light Emitting Diode (LED)	(1) 335W fixture, any bulb shape, any application	NA	NA	335	Electronic
LED336-FIXT	Light Emitting Diode (LED)	(1) 336W fixture, any bulb shape, any application	NA	NA	336	Electronic
LED337-FIXT	Light Emitting Diode (LED)	(1) 337W fixture, any bulb shape, any application	NA	NA	337	Electronic
LED338-FIXT	Light Emitting Diode (LED)	(1) 338W fixture, any bulb shape, any application	NA	NA	338	Electronic
LED339-FIXT	Light Emitting Diode (LED)	(1) 339W fixture, any bulb shape, any application	NA	NA	339	Electronic
LED340-FIXT	Light Emitting Diode (LED)	(1) 340W fixture, any bulb shape, any application	NA	NA	340	Electronic
LED341-FIXT	Light Emitting Diode (LED)	(1) 341W fixture, any bulb shape, any application	NA	NA	341	Electronic
LED342-FIXT	Light Emitting Diode (LED)	(1) 342W fixture, any bulb shape, any application	NA	NA	342	Electronic
LED343-FIXT	Light Emitting Diode (LED)	(1) 343W fixture, any bulb shape, any application	NA	NA	343	Electronic
LED344-FIXT	Light Emitting Diode (LED)	(1) 344W fixture, any bulb shape, any application	NA	NA	344	Electronic
LED345-FIXT	Light Emitting Diode (LED)	(1) 345W fixture, any bulb shape, any application	NA	NA	345	Electronic
LED346-FIXT	Light Emitting Diode (LED)	(1) 346W fixture, any bulb shape, any application	NA	NA	346	Electronic
LED347-FIXT	Light Emitting Diode (LED)	(1) 347W fixture, any bulb shape, any application	NA	NA	347	Electronic
LED348-FIXT	Light Emitting Diode (LED)	(1) 348W fixture, any bulb shape, any application	NA	NA	348	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED349-FIXT	Light Emitting Diode (LED)	(1) 349W fixture, any bulb shape, any application	NA	NA	349	Electronic
LED350-FIXT	Light Emitting Diode (LED)	(1) 350W fixture, any bulb shape, any application	NA	NA	350	Electronic
LED351-FIXT	Light Emitting Diode (LED)	(1) 351W fixture, any bulb shape, any application	NA	NA	351	Electronic
LED352-FIXT	Light Emitting Diode (LED)	(1) 352W fixture, any bulb shape, any application	NA	NA	352	Electronic
LED353-FIXT	Light Emitting Diode (LED)	(1) 353W fixture, any bulb shape, any application	NA	NA	353	Electronic
LED354-FIXT	Light Emitting Diode (LED)	(1) 354W fixture, any bulb shape, any application	NA	NA	354	Electronic
LED355-FIXT	Light Emitting Diode (LED)	(1) 355W fixture, any bulb shape, any application	NA	NA	355	Electronic
LED356-FIXT	Light Emitting Diode (LED)	(1) 356W fixture, any bulb shape, any application	NA	NA	356	Electronic
LED357-FIXT	Light Emitting Diode (LED)	(1) 357W fixture, any bulb shape, any application	NA	NA	357	Electronic
LED358-FIXT	Light Emitting Diode (LED)	(1) 358W fixture, any bulb shape, any application	NA	NA	358	Electronic
LED359-FIXT	Light Emitting Diode (LED)	(1) 359W fixture, any bulb shape, any application	NA	NA	359	Electronic
LED360-FIXT	Light Emitting Diode (LED)	(1) 360W fixture, any bulb shape, any application	NA	NA	360	Electronic
LED361-FIXT	Light Emitting Diode (LED)	(1) 361W fixture, any bulb shape, any application	NA	NA	361	Electronic
LED362-FIXT	Light Emitting Diode (LED)	(1) 362W fixture, any bulb shape, any application	NA	NA	362	Electronic
LED363-FIXT	Light Emitting Diode (LED)	(1) 363W fixture, any bulb shape, any application	NA	NA	363	Electronic
LED364-FIXT	Light Emitting Diode (LED)	(1) 364W fixture, any bulb shape, any application	NA	NA	364	Electronic
LED365-FIXT	Light Emitting Diode (LED)	(1) 365W fixture, any bulb shape, any application	NA	NA	365	Electronic
LED366-FIXT	Light Emitting Diode (LED)	(1) 366W fixture, any bulb shape, any application	NA	NA	366	Electronic
LED367-FIXT	Light Emitting Diode (LED)	(1) 367W fixture, any bulb shape, any application	NA	NA	367	Electronic
LED368-FIXT	Light Emitting Diode (LED)	(1) 368W fixture, any bulb shape, any application	NA	NA	368	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED369-FIXT	Light Emitting Diode (LED)	(1) 369W fixture, any bulb shape, any application	NA	NA	369	Electronic
LED370-FIXT	Light Emitting Diode (LED)	(1) 370W fixture, any bulb shape, any application	NA	NA	370	Electronic
LED371-FIXT	Light Emitting Diode (LED)	(1) 371W fixture, any bulb shape, any application	NA	NA	371	Electronic
LED372-FIXT	Light Emitting Diode (LED)	(1) 372W fixture, any bulb shape, any application	NA	NA	372	Electronic
LED373-FIXT	Light Emitting Diode (LED)	(1) 373W fixture, any bulb shape, any application	NA	NA	373	Electronic
LED374-FIXT	Light Emitting Diode (LED)	(1) 374W fixture, any bulb shape, any application	NA	NA	374	Electronic
LED375-FIXT	Light Emitting Diode (LED)	(1) 375W fixture, any bulb shape, any application	NA	NA	375	Electronic
LED376-FIXT	Light Emitting Diode (LED)	(1) 376W fixture, any bulb shape, any application	NA	NA	376	Electronic
LED377-FIXT	Light Emitting Diode (LED)	(1) 377W fixture, any bulb shape, any application	NA	NA	377	Electronic
LED378-FIXT	Light Emitting Diode (LED)	(1) 378W fixture, any bulb shape, any application	NA	NA	378	Electronic
LED379-FIXT	Light Emitting Diode (LED)	(1) 379W fixture, any bulb shape, any application	NA	NA	379	Electronic
LED380-FIXT	Light Emitting Diode (LED)	(1) 380W fixture, any bulb shape, any application	NA	NA	380	Electronic
LED381-FIXT	Light Emitting Diode (LED)	(1) 381W fixture, any bulb shape, any application	NA	NA	381	Electronic
LED382-FIXT	Light Emitting Diode (LED)	(1) 382W fixture, any bulb shape, any application	NA	NA	382	Electronic
LED383-FIXT	Light Emitting Diode (LED)	(1) 383W fixture, any bulb shape, any application	NA	NA	383	Electronic
LED384-FIXT	Light Emitting Diode (LED)	(1) 384W fixture, any bulb shape, any application	NA	NA	384	Electronic
LED385-FIXT	Light Emitting Diode (LED)	(1) 385W fixture, any bulb shape, any application	NA	NA	385	Electronic
LED386-FIXT	Light Emitting Diode (LED)	(1) 386W fixture, any bulb shape, any application	NA	NA	386	Electronic
LED387-FIXT	Light Emitting Diode (LED)	(1) 387W fixture, any bulb shape, any application	NA	NA	387	Electronic
LED388-FIXT	Light Emitting Diode (LED)	(1) 388W fixture, any bulb shape, any application	NA	NA	388	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED389-FIXT	Light Emitting Diode (LED)	(1) 389W fixture, any bulb shape, any application	NA	NA	389	Electronic
LED390-FIXT	Light Emitting Diode (LED)	(1) 390W fixture, any bulb shape, any application	NA	NA	390	Electronic
LED391-FIXT	Light Emitting Diode (LED)	(1) 391W fixture, any bulb shape, any application	NA	NA	391	Electronic
LED392-FIXT	Light Emitting Diode (LED)	(1) 392W fixture, any bulb shape, any application	NA	NA	392	Electronic
LED393-FIXT	Light Emitting Diode (LED)	(1) 393W fixture, any bulb shape, any application	NA	NA	393	Electronic
LED394-FIXT	Light Emitting Diode (LED)	(1) 394W fixture, any bulb shape, any application	NA	NA	394	Electronic
LED395-FIXT	Light Emitting Diode (LED)	(1) 395W fixture, any bulb shape, any application	NA	NA	395	Electronic
LED396-FIXT	Light Emitting Diode (LED)	(1) 396W fixture, any bulb shape, any application	NA	NA	396	Electronic
LED397-FIXT	Light Emitting Diode (LED)	(1) 397W fixture, any bulb shape, any application	NA	NA	397	Electronic
LED398-FIXT	Light Emitting Diode (LED)	(1) 398W fixture, any bulb shape, any application	NA	NA	398	Electronic
LED399-FIXT	Light Emitting Diode (LED)	(1) 399W fixture, any bulb shape, any application	NA	NA	399	Electronic
LED400-FIXT	Light Emitting Diode (LED)	(1) 400W fixture, any bulb shape, any application	NA	NA	400	Electronic
LED401-FIXT	Light Emitting Diode (LED)	(1) 401W fixture, any bulb shape, any application	NA	NA	401	Electronic
LED402-FIXT	Light Emitting Diode (LED)	(1) 402W fixture, any bulb shape, any application	NA	NA	402	Electronic
LED403-FIXT	Light Emitting Diode (LED)	(1) 403W fixture, any bulb shape, any application	NA	NA	403	Electronic
LED404-FIXT	Light Emitting Diode (LED)	(1) 404W fixture, any bulb shape, any application	NA	NA	404	Electronic
LED405-FIXT	Light Emitting Diode (LED)	(1) 405W fixture, any bulb shape, any application	NA	NA	405	Electronic
LED406-FIXT	Light Emitting Diode (LED)	(1) 406W fixture, any bulb shape, any application	NA	NA	406	Electronic
LED407-FIXT	Light Emitting Diode (LED)	(1) 407W fixture, any bulb shape, any application	NA	NA	407	Electronic
LED408-FIXT	Light Emitting Diode (LED)	(1) 408W fixture, any bulb shape, any application	NA	NA	408	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED409-FIXT	Light Emitting Diode (LED)	(1) 409W fixture, any bulb shape, any application	NA	NA	409	Electronic
LED410-FIXT	Light Emitting Diode (LED)	(1) 410W fixture, any bulb shape, any application	NA	NA	410	Electronic
LED411-FIXT	Light Emitting Diode (LED)	(1) 411W fixture, any bulb shape, any application	NA	NA	411	Electronic
LED412-FIXT	Light Emitting Diode (LED)	(1) 412W fixture, any bulb shape, any application	NA	NA	412	Electronic
LED413-FIXT	Light Emitting Diode (LED)	(1) 413W fixture, any bulb shape, any application	NA	NA	413	Electronic
LED414-FIXT	Light Emitting Diode (LED)	(1) 414W fixture, any bulb shape, any application	NA	NA	414	Electronic
LED415-FIXT	Light Emitting Diode (LED)	(1) 415W fixture, any bulb shape, any application	NA	NA	415	Electronic
LED416-FIXT	Light Emitting Diode (LED)	(1) 416W fixture, any bulb shape, any application	NA	NA	416	Electronic
LED417-FIXT	Light Emitting Diode (LED)	(1) 417W fixture, any bulb shape, any application	NA	NA	417	Electronic
LED418-FIXT	Light Emitting Diode (LED)	(1) 418W fixture, any bulb shape, any application	NA	NA	418	Electronic
LED419-FIXT	Light Emitting Diode (LED)	(1) 419W fixture, any bulb shape, any application	NA	NA	419	Electronic
LED420-FIXT	Light Emitting Diode (LED)	(1) 420W fixture, any bulb shape, any application	NA	NA	420	Electronic
LED421-FIXT	Light Emitting Diode (LED)	(1) 421W fixture, any bulb shape, any application	NA	NA	421	Electronic
LED422-FIXT	Light Emitting Diode (LED)	(1) 422W fixture, any bulb shape, any application	NA	NA	422	Electronic
LED423-FIXT	Light Emitting Diode (LED)	(1) 423W fixture, any bulb shape, any application	NA	NA	423	Electronic
LED424-FIXT	Light Emitting Diode (LED)	(1) 424W fixture, any bulb shape, any application	NA	NA	424	Electronic
LED425-FIXT	Light Emitting Diode (LED)	(1) 425W fixture, any bulb shape, any application	NA	NA	425	Electronic
LED426-FIXT	Light Emitting Diode (LED)	(1) 426W fixture, any bulb shape, any application	NA	NA	426	Electronic
LED427-FIXT	Light Emitting Diode (LED)	(1) 427W fixture, any bulb shape, any application	NA	NA	427	Electronic
LED428-FIXT	Light Emitting Diode (LED)	(1) 428W fixture, any bulb shape, any application	NA	NA	428	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED429-FIXT	Light Emitting Diode (LED)	(1) 429W fixture, any bulb shape, any application	NA	NA	429	Electronic
LED430-FIXT	Light Emitting Diode (LED)	(1) 430W fixture, any bulb shape, any application	NA	NA	430	Electronic
LED431-FIXT	Light Emitting Diode (LED)	(1) 431W fixture, any bulb shape, any application	NA	NA	431	Electronic
LED432-FIXT	Light Emitting Diode (LED)	(1) 432W fixture, any bulb shape, any application	NA	NA	432	Electronic
LED433-FIXT	Light Emitting Diode (LED)	(1) 433W fixture, any bulb shape, any application	NA	NA	433	Electronic
LED434-FIXT	Light Emitting Diode (LED)	(1) 434W fixture, any bulb shape, any application	NA	NA	434	Electronic
LED435-FIXT	Light Emitting Diode (LED)	(1) 435W fixture, any bulb shape, any application	NA	NA	435	Electronic
LED436-FIXT	Light Emitting Diode (LED)	(1) 436W fixture, any bulb shape, any application	NA	NA	436	Electronic
LED437-FIXT	Light Emitting Diode (LED)	(1) 437W fixture, any bulb shape, any application	NA	NA	437	Electronic
LED438-FIXT	Light Emitting Diode (LED)	(1) 438W fixture, any bulb shape, any application	NA	NA	438	Electronic
LED439-FIXT	Light Emitting Diode (LED)	(1) 439W fixture, any bulb shape, any application	NA	NA	439	Electronic
LED440-FIXT	Light Emitting Diode (LED)	(1) 440W fixture, any bulb shape, any application	NA	NA	440	Electronic
LED441-FIXT	Light Emitting Diode (LED)	(1) 441W fixture, any bulb shape, any application	NA	NA	441	Electronic
LED442-FIXT	Light Emitting Diode (LED)	(1) 442W fixture, any bulb shape, any application	NA	NA	442	Electronic
LED443-FIXT	Light Emitting Diode (LED)	(1) 443W fixture, any bulb shape, any application	NA	NA	443	Electronic
LED444-FIXT	Light Emitting Diode (LED)	(1) 444W fixture, any bulb shape, any application	NA	NA	444	Electronic
LED445-FIXT	Light Emitting Diode (LED)	(1) 445W fixture, any bulb shape, any application	NA	NA	445	Electronic
LED446-FIXT	Light Emitting Diode (LED)	(1) 446W fixture, any bulb shape, any application	NA	NA	446	Electronic
LED447-FIXT	Light Emitting Diode (LED)	(1) 447W fixture, any bulb shape, any application	NA	NA	447	Electronic
LED448-FIXT	Light Emitting Diode (LED)	(1) 448W fixture, any bulb shape, any application	NA	NA	448	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED449-FIXT	Light Emitting Diode (LED)	(1) 449W fixture, any bulb shape, any application	NA	NA	449	Electronic
LED450-FIXT	Light Emitting Diode (LED)	(1) 450W fixture, any bulb shape, any application	NA	NA	450	Electronic
LED451-FIXT	Light Emitting Diode (LED)	(1) 451W fixture, any bulb shape, any application	NA	NA	451	Electronic
LED452-FIXT	Light Emitting Diode (LED)	(1) 452W fixture, any bulb shape, any application	NA	NA	452	Electronic
LED453-FIXT	Light Emitting Diode (LED)	(1) 453W fixture, any bulb shape, any application	NA	NA	453	Electronic
LED454-FIXT	Light Emitting Diode (LED)	(1) 454W fixture, any bulb shape, any application	NA	NA	454	Electronic
LED455-FIXT	Light Emitting Diode (LED)	(1) 455W fixture, any bulb shape, any application	NA	NA	455	Electronic
LED456-FIXT	Light Emitting Diode (LED)	(1) 456W fixture, any bulb shape, any application	NA	NA	456	Electronic
LED457-FIXT	Light Emitting Diode (LED)	(1) 457W fixture, any bulb shape, any application	NA	NA	457	Electronic
LED458-FIXT	Light Emitting Diode (LED)	(1) 458W fixture, any bulb shape, any application	NA	NA	458	Electronic
LED459-FIXT	Light Emitting Diode (LED)	(1) 459W fixture, any bulb shape, any application	NA	NA	459	Electronic
LED460-FIXT	Light Emitting Diode (LED)	(1) 460W fixture, any bulb shape, any application	NA	NA	460	Electronic
LED461-FIXT	Light Emitting Diode (LED)	(1) 461W fixture, any bulb shape, any application	NA	NA	461	Electronic
LED462-FIXT	Light Emitting Diode (LED)	(1) 462W fixture, any bulb shape, any application	NA	NA	462	Electronic
LED463-FIXT	Light Emitting Diode (LED)	(1) 463W fixture, any bulb shape, any application	NA	NA	463	Electronic
LED464-FIXT	Light Emitting Diode (LED)	(1) 464W fixture, any bulb shape, any application	NA	NA	464	Electronic
LED465-FIXT	Light Emitting Diode (LED)	(1) 465W fixture, any bulb shape, any application	NA	NA	465	Electronic
LED466-FIXT	Light Emitting Diode (LED)	(1) 466W fixture, any bulb shape, any application	NA	NA	466	Electronic
LED467-FIXT	Light Emitting Diode (LED)	(1) 467W fixture, any bulb shape, any application	NA	NA	467	Electronic
LED468-FIXT	Light Emitting Diode (LED)	(1) 468W fixture, any bulb shape, any application	NA	NA	468	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED469-FIXT	Light Emitting Diode (LED)	(1) 469W fixture, any bulb shape, any application	NA	NA	469	Electronic
LED470-FIXT	Light Emitting Diode (LED)	(1) 470W fixture, any bulb shape, any application	NA	NA	470	Electronic
LED471-FIXT	Light Emitting Diode (LED)	(1) 471W fixture, any bulb shape, any application	NA	NA	471	Electronic
LED472-FIXT	Light Emitting Diode (LED)	(1) 472W fixture, any bulb shape, any application	NA	NA	472	Electronic
LED473-FIXT	Light Emitting Diode (LED)	(1) 473W fixture, any bulb shape, any application	NA	NA	473	Electronic
LED474-FIXT	Light Emitting Diode (LED)	(1) 474W fixture, any bulb shape, any application	NA	NA	474	Electronic
LED475-FIXT	Light Emitting Diode (LED)	(1) 475W fixture, any bulb shape, any application	NA	NA	475	Electronic
LED476-FIXT	Light Emitting Diode (LED)	(1) 476W fixture, any bulb shape, any application	NA	NA	476	Electronic
LED477-FIXT	Light Emitting Diode (LED)	(1) 477W fixture, any bulb shape, any application	NA	NA	477	Electronic
LED478-FIXT	Light Emitting Diode (LED)	(1) 478W fixture, any bulb shape, any application	NA	NA	478	Electronic
LED479-FIXT	Light Emitting Diode (LED)	(1) 479W fixture, any bulb shape, any application	NA	NA	479	Electronic
LED480-FIXT	Light Emitting Diode (LED)	(1) 480W fixture, any bulb shape, any application	NA	NA	480	Electronic
LED481-FIXT	Light Emitting Diode (LED)	(1) 481W fixture, any bulb shape, any application	NA	NA	481	Electronic
LED482-FIXT	Light Emitting Diode (LED)	(1) 482W fixture, any bulb shape, any application	NA	NA	482	Electronic
LED483-FIXT	Light Emitting Diode (LED)	(1) 483W fixture, any bulb shape, any application	NA	NA	483	Electronic
LED484-FIXT	Light Emitting Diode (LED)	(1) 484W fixture, any bulb shape, any application	NA	NA	484	Electronic
LED485-FIXT	Light Emitting Diode (LED)	(1) 485W fixture, any bulb shape, any application	NA	NA	485	Electronic
LED486-FIXT	Light Emitting Diode (LED)	(1) 486W fixture, any bulb shape, any application	NA	NA	486	Electronic
LED487-FIXT	Light Emitting Diode (LED)	(1) 487W fixture, any bulb shape, any application	NA	NA	487	Electronic
LED488-FIXT	Light Emitting Diode (LED)	(1) 488W fixture, any bulb shape, any application	NA	NA	488	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED489-FIXT	Light Emitting Diode (LED)	(1) 489W fixture, any bulb shape, any application	NA	NA	489	Electronic
LED490-FIXT	Light Emitting Diode (LED)	(1) 490W fixture, any bulb shape, any application	NA	NA	490	Electronic
LED491-FIXT	Light Emitting Diode (LED)	(1) 491W fixture, any bulb shape, any application	NA	NA	491	Electronic
LED492-FIXT	Light Emitting Diode (LED)	(1) 492W fixture, any bulb shape, any application	NA	NA	492	Electronic
LED493-FIXT	Light Emitting Diode (LED)	(1) 493W fixture, any bulb shape, any application	NA	NA	493	Electronic
LED494-FIXT	Light Emitting Diode (LED)	(1) 494W fixture, any bulb shape, any application	NA	NA	494	Electronic
LED495-FIXT	Light Emitting Diode (LED)	(1) 495W fixture, any bulb shape, any application	NA	NA	495	Electronic
LED496-FIXT	Light Emitting Diode (LED)	(1) 496W fixture, any bulb shape, any application	NA	NA	496	Electronic
LED497-FIXT	Light Emitting Diode (LED)	(1) 497W fixture, any bulb shape, any application	NA	NA	497	Electronic
LED498-FIXT	Light Emitting Diode (LED)	(1) 498W fixture, any bulb shape, any application	NA	NA	498	Electronic
LED499-FIXT	Light Emitting Diode (LED)	(1) 499W fixture, any bulb shape, any application	NA	NA	499	Electronic
LED500-FIXT	Light Emitting Diode (LED)	(1) 500W fixture, any bulb shape, any application	NA	NA	500	Electronic
LED505-FIXT	Light Emitting Diode (LED)	(1) 505W fixture, any bulb shape, any application	NA	NA	505	Electronic
LED510-FIXT	Light Emitting Diode (LED)	(1) 510W fixture, any bulb shape, any application	NA	NA	510	Electronic
LED515-FIXT	Light Emitting Diode (LED)	(1) 515W fixture, any bulb shape, any application	NA	NA	515	Electronic
LED520-FIXT	Light Emitting Diode (LED)	(1) 520W fixture, any bulb shape, any application	NA	NA	520	Electronic
LED525-FIXT	Light Emitting Diode (LED)	(1) 525W fixture, any bulb shape, any application	NA	NA	525	Electronic
LED530-FIXT	Light Emitting Diode (LED)	(1) 530W fixture, any bulb shape, any application	NA	NA	530	Electronic
LED535-FIXT	Light Emitting Diode (LED)	(1) 535W fixture, any bulb shape, any application	NA	NA	535	Electronic
LED540-FIXT	Light Emitting Diode (LED)	(1) 540W fixture, any bulb shape, any application	NA	NA	540	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
LED545-FIXT	Light Emitting Diode (LED)	(1) 545W fixture, any bulb shape, any application	NA	NA	545	Electronic
LED550-FIXT	Light Emitting Diode (LED)	(1) 550W fixture, any bulb shape, any application	NA	NA	550	Electronic
CF2/1-SCRW	Integrated-ballast CFL Lamps	(1) 2W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	2	2	Mag. or Elec.
CF3/1-SCRW	Integrated-ballast CFL Lamps	(1) 3W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	3	3	Mag. or Elec.
CF4/1-SCRW	Integrated-ballast CFL Lamps	(1) 4W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	4	4	Mag. or Elec.
CF5/1-SCRW	Integrated-ballast CFL Lamps	(1) 5W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	5	5	Mag. or Elec.
CF6/1-SCRW	Integrated-ballast CFL Lamps	(1) 6W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	6	6	Mag. or Elec.
CF7/1-SCRW	Integrated-ballast CFL Lamps	(1) 7W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	7	7	Mag. or Elec.
CF8/1-SCRW	Integrated-ballast CFL Lamps	(1) 8W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	8	8	Mag. or Elec.
CF9/1-SCRW	Integrated-ballast CFL Lamps	(1) 9W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	9	9	Mag. or Elec.
CF10/1-SCRW	Integrated-ballast CFL Lamps	(1) 10W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	10	10	Mag. or Elec.
CF11/1-SCRW	Integrated-ballast CFL Lamps	(1) 11W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	11	11	Mag. or Elec.
CF12/1-SCRW	Integrated-ballast CFL Lamps	(1) 12W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	12	12	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF13/1-SCRW	Integrated-ballast CFL Lamps	(1) 13W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	13	13	Mag. or Elec.
CF14/1-SCRW	Integrated-ballast CFL Lamps	(1) 14W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	14	14	Mag. or Elec.
CF15/1-SCRW	Integrated-ballast CFL Lamps	(1) 15W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	15	15	Mag. or Elec.
CF16/1-SCRW	Integrated-ballast CFL Lamps	(1) 16W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	16	16	Mag. or Elec.
CF17/1-SCRW	Integrated-ballast CFL Lamps	(1) 17W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	17	17	Mag. or Elec.
CF18/1-SCRW	Integrated-ballast CFL Lamps	(1) 18W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	18	18	Mag. or Elec.
CF19/1-SCRW	Integrated-ballast CFL Lamps	(1) 19W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	19	19	Mag. or Elec.
CF20/1-SCRW	Integrated-ballast CFL Lamps	(1) 20W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	20	20	Mag. or Elec.
CF21/1-SCRW	Integrated-ballast CFL Lamps	(1) 21W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	21	21	Mag. or Elec.
CF22/1-SCRW	Integrated-ballast CFL Lamps	(1) 22W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	22	22	Mag. or Elec.
CF23/1-SCRW	Integrated-ballast CFL Lamps	(1) 23W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	23	23	Mag. or Elec.
CF24/1-SCRW	Integrated-ballast CFL Lamps	(1) 24W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	24	24	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF25/1-SCRW	Integrated-ballast CFL Lamps	(1) 25W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	25	25	Mag. or Elec.
CF26/1-SCRW	Integrated-ballast CFL Lamps	(1) 26W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	26	26	Mag. or Elec.
CF27/1-SCRW	Integrated-ballast CFL Lamps	(1) 27W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	27	27	Mag. or Elec.
CF28/1-SCRW	Integrated-ballast CFL Lamps	(1) 28W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	28	28	Mag. or Elec.
CF29/1-SCRW	Integrated-ballast CFL Lamps	(1) 29W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	29	29	Mag. or Elec.
CF30/1-SCRW	Integrated-ballast CFL Lamps	(1) 30W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	30	30	Mag. or Elec.
CF31/1-SCRW	Integrated-ballast CFL Lamps	(1) 31W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	31	31	Mag. or Elec.
CF32/1-SCRW	Integrated-ballast CFL Lamps	(1) 32W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	32	32	Mag. or Elec.
CF33/1-SCRW	Integrated-ballast CFL Lamps	(1) 33W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	33	33	Mag. or Elec.
CF34/1-SCRW	Integrated-ballast CFL Lamps	(1) 34W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	34	34	Mag. or Elec.
CF35/1-SCRW	Integrated-ballast CFL Lamps	(1) 35W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	35	35	Mag. or Elec.
CF36/1-SCRW	Integrated-ballast CFL Lamps	(1) 36W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	36	36	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF37/1-SCRW	Integrated-ballast CFL Lamps	(1) 37W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	37	37	Mag. or Elec.
CF38/1-SCRW	Integrated-ballast CFL Lamps	(1) 38W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	38	38	Mag. or Elec.
CF39/1-SCRW	Integrated-ballast CFL Lamps	(1) 39W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	39	39	Mag. or Elec.
CF40/1-SCRW	Integrated-ballast CFL Lamps	(1) 40W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	40	40	Mag. or Elec.
CF41/1-SCRW	Integrated-ballast CFL Lamps	(1) 41W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	41	41	Mag. or Elec.
CF42/1-SCRW	Integrated-ballast CFL Lamps	(1) 42W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	42	42	Mag. or Elec.
CF43/1-SCRW	Integrated-ballast CFL Lamps	(1) 43W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	43	43	Mag. or Elec.
CF44/1-SCRW	Integrated-ballast CFL Lamps	(1) 44W screw-in lamp/base w/permanent disk installed, any bulb shape	1	44	44	Mag. or Elec.
CF45/1-SCRW	Integrated-ballast CFL Lamps	(1) 45W screw-in lamp/base w/permanent disk installed, any bulb shape	1	45	45	Mag. or Elec.
CF46/1-SCRW	Integrated-ballast CFL Lamps	(1) 46W screw-in lamp/base w/permanent disk installed, any bulb shape	1	46	46	Mag. or Elec.
CF47/1-SCRW	Integrated-ballast CFL Lamps	(1) 47W screw-in lamp/base w/permanent disk installed, any bulb shape	1	47	47	Mag. or Elec.
CF48/1-SCRW	Integrated-ballast CFL Lamps	(1) 48W screw-in lamp/base w/permanent disk installed, any bulb shape	1	48	48	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF49/1-SCRW	Integrated-ballast CFL Lamps	(1) 49W screw-in lamp/base w/permanent disk installed, any bulb shape	1	49	49	Mag. or Elec.
CF50/1-SCRW	Integrated-ballast CFL Lamps	(1) 50W screw-in lamp/base w/permanent disk installed, any bulb shape	1	50	50	Mag. or Elec.
CF51/1-SCRW	Integrated-ballast CFL Lamps	(1) 51W screw-in lamp/base w/permanent disk installed, any bulb shape	1	51	51	Mag. or Elec.
CF52/1-SCRW	Integrated-ballast CFL Lamps	(1) 52W screw-in lamp/base w/permanent disk installed, any bulb shape	1	52	52	Mag. or Elec.
CF53/1-SCRW	Integrated-ballast CFL Lamps	(1) 53W screw-in lamp/base w/permanent disk installed, any bulb shape	1	53	53	Mag. or Elec.
CF54/1-SCRW	Integrated-ballast CFL Lamps	(1) 54W screw-in lamp/base w/permanent disk installed, any bulb shape	1	54	54	Mag. or Elec.
CF55/1-SCRW	Integrated-ballast CFL Lamps	(1) 55W screw-in lamp/base w/permanent disk installed, any bulb shape	1	55	55	Mag. or Elec.
CF56/1-SCRW	Integrated-ballast CFL Lamps	(1) 56W screw-in lamp/base w/permanent disk installed, any bulb shape	1	56	56	Mag. or Elec.
CF57/1-SCRW	Integrated-ballast CFL Lamps	(1) 57W screw-in lamp/base w/permanent disk installed, any bulb shape	1	57	57	Mag. or Elec.
CF58/1-SCRW	Integrated-ballast CFL Lamps	(1) 58W screw-in lamp/base w/permanent disk installed, any bulb shape	1	58	58	Mag. or Elec.
CF59/1-SCRW	Integrated-ballast CFL Lamps	(1) 59W screw-in lamp/base w/permanent disk installed, any bulb shape	1	59	59	Mag. or Elec.
CF60/1-SCRW	Integrated-ballast CFL Lamps	(1) 60W screw-in lamp/base w/permanent disk installed, any bulb shape	1	60	60	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF61/1-SCRW	Integrated-ballast CFL Lamps	(1) 61W screw-in lamp/base w/permanent disk installed, any bulb shape	1	61	61	Mag. or Elec.
CF62/1-SCRW	Integrated-ballast CFL Lamps	(1) 62W screw-in lamp/base w/permanent disk installed, any bulb shape	1	62	62	Mag. or Elec.
CF63/1-SCRW	Integrated-ballast CFL Lamps	(1) 63W screw-in lamp/base w/permanent disk installed, any bulb shape	1	63	63	Mag. or Elec.
CF64/1-SCRW	Integrated-ballast CFL Lamps	(1) 64W screw-in lamp/base w/permanent disk installed, any bulb shape	1	64	64	Mag. or Elec.
CF65/1-SCRW	Integrated-ballast CFL Lamps	(1) 65W screw-in lamp/base w/permanent disk installed, any bulb shape	1	65	65	Mag. or Elec.
CF66/1-SCRW	Integrated-ballast CFL Lamps	(1) 66W screw-in lamp/base w/permanent disk installed, any bulb shape	1	66	66	Mag. or Elec.
CF67/1-SCRW	Integrated-ballast CFL Lamps	(1) 67W screw-in lamp/base w/permanent disk installed, any bulb shape	1	67	67	Mag. or Elec.
CF68/1-SCRW	Integrated-ballast CFL Lamps	(1) 68W screw-in lamp/base w/permanent disk installed, any bulb shape	1	68	68	Mag. or Elec.
CF69/1-SCRW	Integrated-ballast CFL Lamps	(1) 69W screw-in lamp/base w/permanent disk installed, any bulb shape	1	69	69	Mag. or Elec.
CF70/1-SCRW	Integrated-ballast CFL Lamps	(1) 70W screw-in lamp/base w/permanent disk installed, any bulb shape	1	70	70	Mag. or Elec.
CF71/1-SCRW	Integrated-ballast CFL Lamps	(1) 71W screw-in lamp/base w/permanent disk installed, any bulb shape	1	71	71	Mag. or Elec.
CF72/1-SCRW	Integrated-ballast CFL Lamps	(1) 72W screw-in lamp/base w/permanent disk installed, any bulb shape	1	72	72	Mag. or Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CF73/1-SCRW	Integrated-ballast CFL Lamps	(1) 73W screw-in lamp/base w/permanent disk installed, any bulb shape	1	73	73	Mag. or Elec.
CF74/1-SCRW	Integrated-ballast CFL Lamps	(1) 74W screw-in lamp/base w/permanent disk installed, any bulb shape	1	74	74	Mag. or Elec.
CF75/1-SCRW	Integrated-ballast CFL Lamps	(1) 75W screw-in lamp/base w/permanent disk installed, any bulb shape	1	75	75	Mag. or Elec.
CF80/1-SCRW	Integrated-ballast CFL Lamps	(1) 80W screw-in lamp/base w/permanent disk installed, any bulb shape	1	80	80	Mag. or Elec.
CF85/1-SCRW	Integrated-ballast CFL Lamps	(1) 85W screw-in lamp/base w/permanent disk installed, any bulb shape	1	85	85	Mag. or Elec.
CF100/1-SCRW	Integrated-ballast CFL Lamps	(1) 100W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	100	100	Mag. or Elec.
CF125/1-SCRW	Integrated-ballast CFL Lamps	(1) 125W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	125	125	Mag. or Elec.
CF150/1-SCRW	Integrated-ballast CFL Lamps	(1) 150W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	150	150	Mag. or Elec.
CF200/1-SCRW	Integrated-ballast CFL Lamps	(1) 200W screw-in lamp/base w/ permanent disk installed, any bulb shape	1	200	200	Mag. or Elec.
CFC2/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 2W screw-in lamp/base w/ permanent locking device, any bulb shape	1	2	2	Electronic
CFC2/2-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (2) 2W screw-in lamp/base w/ permanent locking device, any bulb shape	2	2	4	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFC3/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 3W screw-in lamp/base w/ permanent locking device, any bulb shape	1	3	3	Electronic
CFC3/2-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (2) 3W screw-in lamp/base w/ permanent locking device, any bulb shape	2	3	6	Electronic
CFC4/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 4W screw-in lamp/base w/ permanent locking device, any bulb shape	1	4	4	Electronic
CFC4/2-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (2) 4W screw-in lamp/base w/ permanent locking device, any bulb shape	2	4	8	Electronic
CFC5/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 5W screw-in lamp/base w/ permanent locking device, any bulb shape	1	5	5	Electronic
CFC5/2-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (2) 5W screw-in lamp/base w/ permanent locking device, any bulb shape	2	5	10	Electronic
CFC8/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 8W screw-in lamp/base w/ permanent locking device, any bulb shape	1	8	8	Electronic
CFC8/2-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (2) 8W screw-in lamp/base w/ permanent locking device, any bulb shape	2	8	16	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFC13/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 13W screw-in lamp/base w/ permanent locking device, any bulb shape	1	13	13	Electronic
CFC18/1-SCRW	Integrated-ballast CCFL Lamps	Compact Fluorescent, Cold Cathode, (1) 18W screw-in lamp/base w/ permanent locking device, any bulb shape	1	18	18	Electronic
CFD10/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 10W lamp	1	10	16	Mag-STD
CFD10/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 10W lamp	1	10	14	Electronic
CFD16/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 16W lamp	1	16	26	Mag-STD
CFD16/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 16W lamp	1	16	18	Electronic
CFD21/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 21W lamp	1	21	26	Mag-STD
CFD21/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 21W lamp	1	21	22	Electronic
CFD28/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 28W lamp	1	28	35	Mag-STD
CFD28/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 28W lamp	1	28	29	Electronic
CFD38/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 38W lamp	1	38	46	Mag-STD
CFD38/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, 2D, (1) 38W lamp	1	38	32	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFG13/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 13W lamp	1	13	13	Electronic
CFG18/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 18W lamp	1	18	18	Electronic
CFG23/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 23W lamp	1	23	23	Electronic
CFG26/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 26W lamp	1	26	26	Electronic
CFG32/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 32W lamp	1	32	32	Electronic
CFG42/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, GU24 with Integrated Ballast, (1) 42W lamp	1	42	42	Electronic
CFM13/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 13W lamp	1	13	16	Electronic
CFM13/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (2) 13W lamps	2	13	30	Electronic
CFM15/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 15W lamp	1	15	18	Electronic
CFM18/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 18W lamp	1	18	20	Electronic
CFM18/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (2) 18W lamps	2	18	40	Electronic
CFM21/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 21W lamp	1	21	23	Electronic
CFM26/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 26W lamp	1	26	29	Electronic
CFM26/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (2) 26W lamps	2	26	51	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFM28/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 28W lamp	1	28	31	Electronic
CFM32/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 32W lamp	1	32	35	Electronic
CFM42/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 42W lamp	1	42	46	Electronic
CFM42/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (2) 42W lamps	2	42	93	Electronic
CFM42/8-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (8) 42W lamps, (4) 2-lamp ballasts	8	42	372	Electronic
CFM57/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 57W lamp	1	57	59	Electronic
CFM60/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 60W lamp	1	60	70	Electronic
CFM70/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 70W lamp	1	70	73	Electronic
CFM85/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 85W lamp	1	85	96	Electronic
CFM120/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, Multi, 4-pin, (1) 120W lamp	1	120	135	Electronic
CFQ9/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (1) 9W lamp	1	9	14	Mag-STD
CFQ9/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (2) 9W lamps	2	9	23	Mag-STD
CFQ10/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 10W lamp	1	10	15	Mag-STD
CFQ13/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 13W lamp	1	13	17	Mag-STD
CFQ13/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 13W lamp, BF=1.05	1	13	15	Electronic
CFQ13/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 13W lamps	2	13	31	Mag-STD
CFQ13/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 13W lamps, BF=1.0	2	13	28	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFQ13/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (3) 13W lamps	3	13	48	Mag-STD
CFQ15/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 15W lamp	1	15	20	Mag-STD
CFQ17/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 17W lamp	1	17	24	Mag-STD
CFQ17/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 17W lamps	2	17	48	Mag-STD
CFQ18/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 18W lamp	1	18	26	Mag-STD
CFQ18/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 18W lamp, BF=1.0	1	18	20	Electronic
CFQ18/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 18W lamps	2	18	45	Mag-STD
CFQ18/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 18W lamp, BF=1.0	2	18	38	Electronic
CFQ18/4	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (4) 18W lamps	2	18	90	Mag-STD
CFQ20/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 20W lamp	1	20	23	Mag-STD
CFQ20/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 20W lamps	2	20	46	Mag-STD
CFQ22/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (1) 22W lamp	1	22	24	Mag-STD
CFQ22/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (2) 22W lamps	2	22	48	Mag-STD
CFQ22/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (3) 22W lamps	3	22	72	Mag-STD
CFQ23/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (1) 23W lamp	1	23	27	Mag-STD
CFQ25/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (1) 25W lamp	1	25	33	Mag-STD
CFQ25/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, Quad, (2) 25W lamps	2	25	66	Mag-STD
CFQ26/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 26W lamp	1	26	33	Mag-STD

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFQ26/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 26W lamp, BF=0.95	1	26	27	Electronic
CFQ26/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 26W lamps	2	26	66	Mag-STD
CFQ26/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 26W lamps, BF=0.95	2	26	50	Electronic
CFQ26/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (3) 26W lamps	3	26	99	Mag-STD
CFQ26/6-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (6) 26W lamps, BF=0.95	6	26	150	Electronic
CFQ28/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 28W lamp	1	28	33	Mag-STD
CFQ28/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (1) 28W lamp	1	28	31	Electronic
CFQ28/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, quad, (2) 28W lamps	2	28	60	Electronic
CFT5/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 5W lamp	1	5	9	Mag-STD
CFT5/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (2) 5W lamps	2	5	18	Mag-STD
CFT7/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 7W lamp	1	7	10	Mag-STD
CFT7/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 7W lamps	2	7	21	Mag-STD
CFT9/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 9W lamp	1	9	12	Mag-STD
CFT9/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 9W lamps	2	9	23	Mag-STD
CFT9/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (3) 9 W lamps	3	9	34	Mag-STD
CFT13/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 13W lamp	1	13	17	Mag-STD
CFT13/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 13W lamp	1	13	15	Electronic
CFT13/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 13W lamps	2	13	31	Mag-STD

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFT13/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 13W lamps	2	13	28	Electronic
CFT13/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (3) 13 W lamps	3	13	48	Mag-STD
CFT18/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, Long twin., (1) 18W lamp	1	18	24	Mag-STD
CFT18/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 18W lamp	1	18	20	Electronic
CFT18/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 18 W lamps	2	18	38	Mag-STD
CFT22/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 22W lamp	1	22	27	Mag-STD
CFT22/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 22W lamps	2	22	54	Mag-STD
CFT22/4	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (4) 22W lamps	4	22	108	Mag-STD
CFT24/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 24W lamp	1	24	32	Mag-STD
CFT26/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 26W lamp	1	26	32	Mag-STD
CFT26/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 26W lamp	1	26	27	Electronic
CFT26/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 26W lamps	2	26	51	Electronic
CFT28/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 28W lamp	1	28	33	Mag-STD
CFT28/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 28W lamps	2	28	66	Mag-STD
CFT32/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (1) 32W lamp	1	32	34	Electronic
CFT32/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (2) 32W lamps	2	32	62	Electronic
CFT32/6-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, twin, (6) 32W lamps	6	32	186	Electronic
CFT36/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 36W lamp	1	36	51	Mag-STD
CFT40/1	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 40W lamp	1	40	46	Mag-STD
CFT40/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 40W lamp	1	40	43	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
CFT40/2	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (2) 40W lamps	2	40	85	Mag-STD
CFT40/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (2) 40W lamps	2	40	72	Electronic
CFT40/3	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (3) 40 W lamps	3	40	133	Mag-STD
CFT40/3-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (3) 40W lamps	3	40	105	Electronic
CFT40/5-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (5) 40W lamps	5	40	177	Electronic
CFT50/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 50W lamp	1	50	54	Electronic
CFT50/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (2) 50W lamps	1	50	108	Electronic
CFT55/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 55W lamp	1	55	58	Electronic
CFT55/2-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (2) 55W lamps	2	55	108	Electronic
CFT55/3-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (3) 55W lamps	3	55	168	Electronic
CFT55/4-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (4) 55W lamps	4	55	220	Electronic
CFT80/1-L	Modular CFL and CCFL Fixtures	Compact Fluorescent, long twin, (1) 80W lamp	1	80	90	Electronic
ECF5/1	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (1) 5W lamp	1	5	9	Mag-STD
ECF5/2	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (2) 5W lamps	2	5	20	Mag-STD
ECF6/1	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (1) 6W lamp	1	6	13	Mag-STD
ECF6/2	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (2) 6W lamps, (2) ballasts	2	6	26	Mag-STD
ECF7/1	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (1) 7W lamp	1	7	10	Mag-STD
ECF7/2	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (2) 7W lamps	2	7	21	Mag-STD
ECF9/1	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (1) 9W lamp	1	9	12	Mag-STD
ECF9/2	Exit Sign (Modular CFL/CCFL)	EXIT Compact Fluorescent, (2) 9W lamps	2	9	20	Mag-STD

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
EF2/2	Exit Sign (Modular CFL/CCFL)	EXIT Sub-Miniature T-1 Fluorescent, (2) lamps	2	2	5	Electronic
EF6/1	Exit Sign (Modular CFL/CCFL)	EXIT Miniature Bi-pin Fluorescent, (1) 6W lamp, (1) ballast	1	6	9	Mag-STD
EF6/2	Exit Sign (Modular CFL/CCFL)	EXIT Miniature Bi-pin Fluorescent, (2) 6W lamps, (2) ballasts	2	6	18	Mag-STD
EF8/1	Exit Sign (Modular CFL/CCFL)	EXIT T5 Fluorescent, (1) 8W lamp	1	8	12	Mag-STD
EF8/2	Exit Sign (Modular CFL/CCFL)	EXIT T5 Fluorescent, (2) 8W lamps	2	8	24	Mag-STD
EI5/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 5W lamp	1	5	5	NA
EI5/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 5W lamps	2	5	10	NA
EI7.5/1	Exit Sign (Halogen)	EXIT Tungsten, (1) 7.5 W lamp	1	7.5	8	NA
EI7.5/2	Exit Sign (Halogen)	EXIT Tungsten, (2) 7.5 W lamps	2	7.5	15	NA
EI10/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 10W lamps	2	10	20	NA
EI15/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 15W lamp	1	15	15	NA
EI15/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 15W lamps	2	15	30	NA
EI20/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 20W lamp	1	20	20	NA
EI20/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 20W lamps	2	20	40	NA
EI25/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 25W lamp	1	25	25	NA
EI25/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 25W lamps	2	25	50	NA
EI34/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 34W lamp	1	34	34	NA
EI34/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 34W lamps	2	34	68	NA
EI40/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 40W lamp	1	40	40	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
EI40/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 40W lamps	2	40	80	NA
EI50/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 50W lamps	2	50	100	NA
EI6/1	Exit Sign (Halogen)	EXIT Incandescent, (1) 6 W lamp	1	6	6	NA
EI6/2	Exit Sign (Halogen)	EXIT Incandescent, (2) 6 W lamps	2	6	12	NA
ELED2/1	Exit Sign (LED)	EXIT Light Emitting Diode, (1) 2W lamp, Single Sided	1	2	6	NA
ELED2/2	Exit Sign (LED)	EXIT Light Emitting Diode, (2) 2W lamps, Dual Sided	2	2	9	NA
ELED3	Exit Sign (LED)	EXIT Light Emitting Diode, (1) 3W lamp, Single Sided	1	3	3	NA
EP	Exit Sign (LED)	EXIT Photoluminescent, 0W	0	0	0	NA
F22PS	T5 Linear Fluorescent	Fluorescent, (2) 21", Preheat T5 lamps, (1) Magnetic ballasts with integral starter, (BF=0.80)	2	13	26	Mag-STD
F24PS	T5 Linear Fluorescent	Fluorescent, (4) 21", Preheat T5 lamps, (2) Magnetic ballasts with integral starter (BF=0.80)	4	13	53	Mag-STD
F21GPL-H	T5 Linear Fluorescent	Fluorescent (1) 22" (563mm) T-5 lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	14	18	PRS Elec.
F22GPL-H	T5 Linear Fluorescent	Fluorescent (2) 22" (563mm) T-5 lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	14	33	PRS Elec.
F23GPL-H	T5 Linear Fluorescent	Fluorescent (3) 22" (563mm) T-5 lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	3	14	50	PRS Elec.
F23GPL/2-H	T5 Linear Fluorescent	Fluorescent (3) 22" (563mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	3	14	51	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F24GPL/2-H	T5 Linear Fluorescent	Fluorescent (4) 22" (563mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	4	14	66	PRS Elec.
F31GPL-H	T5 Linear Fluorescent	Fluorescent (1) 34" (863mm) T-5 lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	21	25	PRS Elec.
F32GPL-H	T5 Linear Fluorescent	Fluorescent (2) 34" (863mm) T-5 lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	21	48	PRS Elec.
F33GPL/2-H	T5 Linear Fluorescent	Fluorescent (3) 34" (863mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	3	21	73	PRS Elec.
F34GPL/2-H	T5 Linear Fluorescent	Fluorescent (4) 34" (863mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	4	21	96	PRS Elec.
F21GPHL-H	T5 Linear Fluorescent	Fluorescent (1) 22" (563mm) T-5 HO lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	24	27	PRS Elec.
F22GPHL-H	T5 Linear Fluorescent	Fluorescent (2) 22" (563mm) T-5 HO lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	24	52	PRS Elec.
F23GPHL/2-H	T5 Linear Fluorescent	Fluorescent (3) 22" (563mm) T-5 HO lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	3	24	79	PRS Elec.
F24GPHL/2-H	T5 Linear Fluorescent	Fluorescent (4) 22" (563mm) T-5 HO lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	4	24	104	PRS Elec.
F41GPL-H	T5 Linear Fluorescent	Fluorescent (1) 45.8" (1163mm) T-5 lamp; (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	1	28	33	PRS Elec.
F41GPL/T2-H	T5 Linear Fluorescent	Fluorescent (1) 45.8" (1163mm) T-5 lamp; Tandem 2-lamp PRS Ballast, HLO (.95 < BF < 1.1)	1	28	32	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42GPL-H	T5 Linear Fluorescent	Fluorescent (2) 45.8" (1163mm) T-5 lamps; (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	2	28	63	PRS Elec.
F43GPL/2-H	T5 Linear Fluorescent	Fluorescent (3) 45.8" (1163mm) T-5 lamps; (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	3	28	96	PRS Elec.
F44GPL/2-H	T5 Linear Fluorescent	Fluorescent (4) 45.8" (1163mm) T-5 lamps; (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	4	28	126	PRS Elec.
F51GPL-H	T5 Linear Fluorescent	Fluorescent (1) 57.6" (1463mm) T-5 lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	35	40	PRS Elec.
F52GPL-H	T5 Linear Fluorescent	Fluorescent (2) 57.6" (1463mm) T-5 lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	35	78	PRS Elec.
F53GPL/2-H	T5 Linear Fluorescent	Fluorescent (3) 57.6" (1463mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	3	35	118	PRS Elec.
F54GPL/2-H	T5 Linear Fluorescent	Fluorescent (4) 57.6" (1463mm) T-5 lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	4	35	156	PRS Elec.
F31GPHL-H	T5 Linear Fluorescent	Fluorescent (1) 34" (863mm) T-5 HO lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	39	44	PRS Elec.
F32GPHL-H	T5 Linear Fluorescent	Fluorescent (2) 34" (863mm) T-5 HO lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	39	86	PRS Elec.
F33GPHL/2-H	T5 Linear Fluorescent	Fluorescent (3) 34" (863mm) T-5 HO lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	3	39	130	PRS Elec.
F34GPHL/2-H	T5 Linear Fluorescent	Fluorescent (4) 34" (863mm) T-5 HO lamps; (2) Prog.Start or PRS Ballasts, HLO (.95 < BF < 1.1)	4	39	172	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F46GPRL/2-H	T5 Linear Fluorescent	Fluorescent, (6) 45.8" T-5 HO reduced-wattage lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	6	54	332	PRS Elec.
F46GPRL/3-H	T5 Linear Fluorescent	Fluorescent, (6) 45.8" T-5 HO reduced-wattage lamps, (3) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	6	54	330	PRS Elec.
F41GPHL-H	T5 Linear Fluorescent	Fluorescent (1) 45.8" T-5 HO lamp, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	1	54	64	PRS Elec.
F41GPHL/T2-H	T5 Linear Fluorescent	Fluorescent (1) 45.8" T-5 HO lamp, Tandem 2-lamp PRS Ballast, HLO (.95 < BF < 1.1)	1	54	59	PRS Elec.
F42GPHL-H	T5 Linear Fluorescent	Fluorescent (2) 45.8" T-5 HO lamps, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	2	54	117	PRS Elec.
F43GPHL-H	T5 Linear Fluorescent	Fluorescent, (3) 45.8" T-5 HO lamps, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	3	54	181	PRS Elec.
F43GPHL/2-H	T5 Linear Fluorescent	Fluorescent (3) 45.8" T-5 HO lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	3	54	181	PRS Elec.
F44GPHL-H	T5 Linear Fluorescent	Fluorescent, (4) 45.8" T-5 HO lamps, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	4	54	230	PRS Elec.
F44GPHL/2-H	T5 Linear Fluorescent	Fluorescent (4) 45.8" T-5 HO lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	4	54	234	PRS Elec.
F45GPHL/2-H	T5 Linear Fluorescent	Fluorescent (5) 45.8" T-5 HO lamps, (2) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	5	54	298	PRS Elec.
F45GPRL/2-H	T5 Linear Fluorescent	Fluorescent (5) 45.2" T-5 HO reduced-wattage lamp, (2) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	5	47-51	276	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F46GPHL/2-H	T5 Linear Fluorescent	Fluorescent, (6) 45.8" T-5 HO lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	6	54	362	PRS Elec.
F46GPHL/3-H	T5 Linear Fluorescent	Fluorescent, (6) 45.8" T-5 HO lamps, (3) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	6	54	351	PRS Elec.
F48GPHL/2-H	T5 Linear Fluorescent	Fluorescent, (8) 45.8" T-5 HO lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	8	54	460	PRS Elec.
F48GPHL/4-H	T5 Linear Fluorescent	Fluorescent, (8) 45.8" T-5 HO lamps, (4) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	8	54	468	PRS Elec.
F410GPHL/3-H	T5 Linear Fluorescent	Fluorescent, (10) 45.8" T-5 HO lamps, (3) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	10	54	577	PRS Elec.
F410GPHL/5-H	T5 Linear Fluorescent	Fluorescent, (10) 45.8" T-5 HO lamps, (5) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	10	54	585	PRS Elec.
F412GPHL/3-H	T5 Linear Fluorescent	Fluorescent, (12) 45.8" T-5 HO lamps, (3) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	12	54	690	PRS Elec.
F412GPHL/6-H	T5 Linear Fluorescent	Fluorescent, (12) 45.8" T-5 HO lamps, (6) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	12	54	702	PRS Elec.
F41GPRL-H	T5 Linear Fluorescent	Fluorescent (1) 45.2" T-5 HO reduced-wattage lamp, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	1	47-51	61	PRS Elec.
F42GPRL-H	T5 Linear Fluorescent	Fluorescent (2) 45.2" T-5 HO reduced-wattage lamp, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	2	47-51	110	PRS Elec.
F43GPRL-H	T5 Linear Fluorescent	Fluorescent (3) 45.2" T-5 HO reduced-wattage lamp, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	3	47-51	166	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F44GPRL-H	T5 Linear Fluorescent	Fluorescent (4) 45.2" T-5 HO reduced-wattage lamp, (1) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	4	47-51	211	PRS Elec.
F48GPRL/2-H	T5 Linear Fluorescent	Fluorescent, (8) 45.8" T-5 HO reduced-wattage lamps, (2) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	8	50	428	PRS Elec.
F48GPRL/4-H	T5 Linear Fluorescent	Fluorescent, (8) 45.8" T-5 HO reduced-wattage lamps, (4) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	8	50	436	PRS Elec.
F410GPRL/3-H	T5 Linear Fluorescent	Fluorescent, (10) 45.8" T-5 HO reduced-wattage lamps, (3) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	10	50	537	PRS Elec.
F410GPRL/5-H	T5 Linear Fluorescent	Fluorescent, (10) 45.8" T-5 HO reduced-wattage lamps, (5) PRS Electronic Ballast, HLO (.95 < BF < 1.1)	10	50	545	PRS Elec.
F412GPRL/3-H	T5 Linear Fluorescent	Fluorescent, (12) 45.8" T-5 HO reduced-wattage lamps, (3) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	12	50	642	PRS Elec.
F412GPRL/6-H	T5 Linear Fluorescent	Fluorescent, (12) 45.8" T-5 HO reduced-wattage lamps, (6) PRS Electronic Ballasts, HLO (.95 < BF < 1.1)	12	50	654	PRS Elec.
F51GPHL-H	T5 Linear Fluorescent	Fluorescent (1) 57.6" (1463mm) T-5 HO lamp; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	1	80	90	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F52GPHL/2-H	T5 Linear Fluorescent	Fluorescent (2) 57.6" (1463mm) T-5 HO lamps; (1) Prog.Start or PRS Ballast, HLO (.95 < BF < 1.1)	2	80	180	PRS Elec.
F1.51LS	T8 Linear Fluorescent	Fluorescent, (1) 18" T-8 lamp	1	15	19	Mag-STD
F1.52LS	T8 Linear Fluorescent	Fluorescent, (2) 18" T-8 lamps	2	15	36	Mag-STD
F21GLL	T8 Linear Fluorescent	Fluorescent (1) 24" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	17	18	PRS Elec.
F21ILL	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	17	18	Electronic
F21ILL-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	17	17	Electronic
F21ILL/T2	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	17	17	Electronic
F21ILL/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	17	15	Electronic
F21ILL/T3	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	17	16	Electronic
F21ILL/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	17	14	Electronic
F21ILL/T4	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	17	15	Electronic
F21ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	17	13	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F21ILU	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	17	17	Prem. Elec.
F21ILU-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	17	15	Prem. Elec.
F21ILU-V	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	1	17	22	Prem. Elec.
F21LL	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	1	17	16	Electronic
F21LL-R	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Rapid Start Ballast, RLO (BF< 0.85)	1	17	15	Electronic
F21LL/T2	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 2-Lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	17	16	Electronic
F21LL/T3	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 3-Lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	17	17	Electronic
F21LL/T4	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Tandem 4-Lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	17	17	Electronic
F21SL	T8 Linear Fluorescent	Fluorescent, (1) 24", T-8 lamp, Standard Ballast	1	17	24	Mag-STD
F22GLL	T8 Linear Fluorescent	Fluorescent (2) 24" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	2	17	31	PRS Elec.
F22ILL	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	17	33	Electronic
F22ILL-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	2	17	30	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F22ILL/T4	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	17	30	Electronic
F22ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF<.85)	2	17	27	Electronic
F22ILU	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	17	30	Prem. Elec.
F22ILU-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	2	17	27	Prem. Elec.
F22ILU-V	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	17	41	Prem. Elec.
F22ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	17	26	Prem. Elec.
F22LL	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	2	17	31	Electronic
F22LL-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	2	17	28	Electronic
F22LL/T4	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	2	17	34	Electronic
F23GLL	T8 Linear Fluorescent	Fluorescent (3) 24" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	17	47	PRS Elec.
F23ILL	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	17	47	Electronic
F23ILL-H	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	3	17	51	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F23ILL-R	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	17	41	Electronic
F23ILU	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	17	45	Prem. Elec.
F23ILU-R	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	17	40	Prem. Elec.
F23ILU-V	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	17	59	Prem. Elec.
F22ILU-V	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	17	41	Prem. Elec.
F22ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	17	26	Prem. Elec.
F22LL	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	2	17	31	Electronic
F22LL-R	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	2	17	28	Electronic
F22LL/T4	T8 Linear Fluorescent	Fluorescent, (2) 24", T-8 lamps, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	2	17	34	Electronic
F23GLL	T8 Linear Fluorescent	Fluorescent (3) 24" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	17	47	PRS Elec.
F23ILL	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	17	47	Electronic
F23ILL-H	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	3	17	51	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F23ILL-R	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	17	41	Electronic
F23ILU	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	17	45	Prem. Elec.
F23ILU-R	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	17	40	Prem. Elec.
F23ILU-V	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	17	59	Prem. Elec.
F23LL	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	3	17	52	Electronic
F23LL-R	T8 Linear Fluorescent	Fluorescent, (3) 24", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	3	17	41	Electronic
F24GLL	T8 Linear Fluorescent	Fluorescent (4) 24" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	4	17	59	PRS Elec.
F24ILL	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	17	59	Electronic
F24ILL-R	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	4	17	53	Electronic
F24ILU	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	17	57	Prem. Elec.
F24ILU-R	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	4	17	52	Prem. Elec.
F24LL	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	4	17	68	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F24LL-R	T8 Linear Fluorescent	Fluorescent, (4) 24", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	4	17	57	Electronic
F31ILL	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	25	26	Electronic
F31ILL-H	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	1	25	28	Electronic
F31ILL-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	25	22	Electronic
F31ILL/T2	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	25	23	Electronic
F31ILL/T2-H	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 3-lamp IS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	1	25	26	Electronic
F31ILL/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	25	21	Electronic
F31ILL/T3	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	25	23	Electronic
F31ILL/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	25	20	Electronic
F31ILL/T4	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	25	22	Electronic
F31ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	25	20	Electronic
F31ILU	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	25	23	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F31ILU-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	25	20	Prem. Elec.
F31ILU/T2	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	25	22	Prem. Elec.
F31ILU/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	25	20	Prem. Elec.
F31ILU/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	25	19	Prem. Elec.
F31ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	25	19	Prem. Elec.
F31LL	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	1	25	24	Electronic
F31LL-H	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, HLO (0.95 < BF < 1.1)	1	25	26	Electronic
F31LL-R	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Rapid Start Ballast, RLO (BF< 0.85)	1	25	23	Electronic
F31LL/T2	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 2-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	25	23	Electronic
F31LL/T3	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 3-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	25	24	Electronic
F31LL/T4	T8 Linear Fluorescent	Fluorescent, (1) 36", T-8 lamp, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	25	22	Electronic
F32ILL	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	25	46	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F32ILL-H	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	2	25	52	Electronic
F32ILL-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	2	25	42	Electronic
F32ILL/2-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, (2) Instant Start Ballasts, RLO (BF< 0.85)	2	25	44	Electronic
F32ILL/T4	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	25	44	Electronic
F32ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	25	39	Electronic
F32ILU	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	25	44	Prem. Elec.
F32ILU-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	2	25	39	Prem. Elec.
F32ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	25	39	Prem. Elec.
F32LL	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	2	25	46	Electronic
F32LL-H	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Rapid Start Ballast, HLO (0.95 < BF < 1.1)	2	25	50	Electronic
F32LL-R	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	2	25	42	Electronic
F32LL-V	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Rapid Start Ballast, VHLO (BF > 1.1)	2	25	70	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F32LL/T4	T8 Linear Fluorescent	Fluorescent, (2) 36", T-8 lamps, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	2	25	45	Electronic
F33ILL	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	25	68	Electronic
F33ILL-R	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	25	61	Electronic
F33ILU	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	25	65	Prem. Elec.
F33ILU-R	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	3	25	58	Prem. Elec.
F33LL	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	3	25	72	Electronic
F33LL-R	T8 Linear Fluorescent	Fluorescent, (3) 36", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	3	25	62	Electronic
F34ILL	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	25	88	Electronic
F34ILL-R	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	4	25	78	Electronic
F34ILL/2-R	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, (2) Instant Start Ballasts, RLO (BF< 0.85)	4	25	84	Electronic
F34ILU	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	25	86	Prem. Elec.
F34ILU-R	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	4	25	77	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F34LL	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	4	25	89	Electronic
F34LL-R	T8 Linear Fluorescent	Fluorescent, (4) 36", T-8 lamps, Rapid Start Ballast, RLO (BF< 0.85)	4	25	84	Electronic
F36ILL/2	T8 Linear Fluorescent	Fluorescent, (6) 36", T-8 lamps, (2) Instant Start Ballasts, NLO (0.85 < BF < 0.95)	6	25	135	Electronic
F36ILL/2-R	T8 Linear Fluorescent	Fluorescent, (6) 36", T-8 lamps, (2) Instant Start Ballasts, RLO (BF< 0.85)	6	25	121	Electronic
F42GRLL-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Prog. Start or PRS Ballast, VHLO (BF > 1.1)	2	28	66	PRS Elec.
F43GRLL-V	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamps, Prog. Start or PRS Ballast, VHLO (BF > 1.1)	3	28	92	PRS Elec.
F41GLL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	32	30	PRS Elec.
F41GLL-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 lamp, Prog. Start or PRS Ballast, RLO (BF< 0.85)	1	32	25	PRS Elec.
F41ILL	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	32	31	Electronic
F41ILL-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	1	32	36	Electronic
F41ILL-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	32	27	Electronic
F41ILL/T2	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	29	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41ILL/T2-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp IS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	1	32	33	Electronic
F41ILL/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	32	26	Electronic
F41ILL/T3	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	28	Electronic
F41ILL/T3-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp IS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	1	32	31	Electronic
F41ILL/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	32	25	Electronic
F41ILL/T4	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	28	Electronic
F41ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	32	25	Electronic
F41ILU	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	32	28	Prem. Elec.
F41ILU-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	1	32	35	Prem. Elec.
F41ILU-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Instant Start Ballast, RLO (BF< 0.85)	1	32	25	Prem. Elec.
F41ILU/T2	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	27	Prem. Elec.
F41ILU/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	32	24	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41ILU/T3	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	27	Prem. Elec.
F41ILU/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	32	24	Prem. Elec.
F41ILU/T4	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	32	27	Prem. Elec.
F41ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	32	24	Prem. Elec.
F41LE	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp	1	32	35	Mag-ES
F41LL	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	1	32	32	Electronic
F41LL-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, HLO (0.95 < BF < 1.1)	1	32	39	Electronic
F41LL-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Rapid Start Ballast, RLO (BF< 0.85)	1	32	27	Electronic
F41LL/T2	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	32	30	Electronic
F41LL/T2-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp RS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	1	32	35	Electronic
F41LL/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 2-lamp RS Ballast, RLO (BF< 0.85)	1	32	27	Electronic
F41LL/T3	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	32	31	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41LL/T3-H	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp RS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	1	32	33	Electronic
F41LL/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 3-lamp RS Ballast, RLO (BF< 0.85)	1	32	25	Electronic
F41LL/T4	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	1	32	30	Electronic
F41LL/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 lamp, Tandem 4-lamp RS Ballast, RLO (BF< 0.85)	1	32	26	Electronic
F42GLL	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	2	32	59	PRS Elec.
F42GLL-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	2	32	47	PRS Elec.
F42GLL-V	T8 Linear Fluorescent	Fluorescent, (2) 48" T-8 lamps, Prog. Start or PRS Ballast, VHLO (BF > 1.1)	2	32	74	Electronic
F42ILL	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	32	58	Electronic
F42ILL-H	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	2	32	66	Electronic
F42ILL-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start Ballast, RLO (BF< 0.85)	2	32	51	Electronic
F42ILL-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	32	77	Electronic
F42ILL/2	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, (2) 1-lamp Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	32	62	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42ILL/2-R	T8 Linear Fluorescent	Fluorescent, (2) 48" T-8 lamps, (2) 1-lamp Instant Start Ballasts, RLO (BF< 0.85)	2	32	54	Electronic
F42ILL/T4	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	32	56	Electronic
F42ILL/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	32	49	Electronic
F42ILU	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	32	54	Prem. Elec.
F42ILU-H	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	2	32	64	Prem. Elec.
F42ILU-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start, RLO (BF< 0.85)	2	32	48	Prem. Elec.
F42ILU-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Instant Start, VHLO (BF> 1.1)	2	32	73	Prem. Elec.
F42ILU/T4	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	32	54	Prem. Elec.
F42ILU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	32	48	Prem. Elec.
F42LE	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp	2	32	71	Mag-ES
F42LL	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	2	32	60	Electronic
F42LL-H	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, HLO (0.95 < BF < 1.1)	2	32	70	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42LL-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF< 0.85)	2	32	54	Electronic
F42LL-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, VHLO (BF > 1.1)	2	32	85	Electronic
F42LL/2	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, (2) 1-lamp Rapid Start Ballasts, NLO (0.85 < BF < 0.95)	2	32	64	Electronic
F42LL/T4	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamps, Tandem 4-lamp RS Ballast, NLO (0.85 < BF < 0.95)	2	32	59	Electronic
F42LL/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 lamp, Tandem 4-lamp RS Ballast, RLO (BF< 0.85)	2	32	53	Electronic
F43GLL	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	32	88	PRS Elec.
F43GLL-R	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	3	32	72	PRS Elec.
F43GLL-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Prog. Start or PRS Ballast, VHLO (BF > 1.1)	3	32	108	Electronic
F43ILL	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	32	85	Electronic
F43ILL-H	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	3	32	93	Electronic
F43ILL-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	3	32	76	Electronic
F43ILL-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	32	112	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F43ILL/2	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, (2) Instant Start Ballasts, NLO (0.85 < BF < 0.95)	3	32	89	Electronic
F43ILL/2-H	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 lamps, (1) 2-lamp and (1) 3-lamp IS Ballast,1 lead capped, HLO (0.95 < BF < 1.1)	3	32	102	Electronic
F43ILL/2-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, (1) 1-lamp and (1) 2-lamp IS Ballast, RLO (BF < 0.85)	3	32	78	Electronic
F43ILU	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	32	81	Prem. Elec.
F43ILU-H	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	3	32	92	Prem. Elec.
F43ILU-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	3	32	72	Prem. Elec.
F43ILU-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	32	108	Prem. Elec.
F43LE	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamp	3	32	110	Mag-ES
F43LL	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	3	32	93	Electronic
F43LL-H	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, HLO (.95 < BF < 1.1)	3	32	98	Electronic
F43LL-R	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, RLO (BF < 0.85)	3	32	76	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F43LL/2	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 lamps, (1) 1-lamp and (1) 2-lamp RS Ballast, NLO (0.85 < BF < 0.95)	3	32	92	Electronic
F44GLL	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	4	32	115	PRS Elec.
F44GLL-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	4	32	92	PRS Elec.
F44GLL-V	T8 Linear Fluorescent	Fluorescent, (4) 48" T-8 lamps, Prog. Start or PRS Ballast, VHLO (BF > 1.1)	4	32	144	PRS Elec.
F44ILL	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	32	112	Electronic
F44ILL-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	4	32	98	Electronic
F44ILL-V	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	4	32	151	Electronic
F44ILL/2	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 2-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	4	32	116	Electronic
F44ILL/2-H	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 3-lamp IS Ballasts, 1 lead capped, HLO (.95 < BF < 1.1)	4	32	132	Electronic
F44ILL/2-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 2-lamp IS Ballasts, RLO (BF < 0.85)	4	32	102	Electronic
F44ILL/2-V	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 2-lamp IS Ballasts, VHLO (BF > 1.1)	4	32	154	Electronic
F44ILU	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	32	107	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F44ILU-H	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	4	32	121	Prem. Elec.
F44ILU-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	4	32	95	Prem. Elec.
F44ILU-V	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	4	32	146	Prem. Elec.
F44LE	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps	4	32	142	Mag-ES
F44LL	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Rapid Start Ballast, NLO (0.85 < BF < 0.95)	4	32	118	Electronic
F44LL-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Rapid Start Ballast, RLO (BF < 0.85)	4	32	105	Electronic
F44LL/2	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 2-lamp Rapid Start Ballast, NLO (0.85 < BF < 0.95)	4	32	120	Electronic
F45ILL/2	T8 Linear Fluorescent	Fluorescent, (5) 48", T-8 lamps, (1) 3-lamp and (1) 2-lamp IS ballast, NLO (0.85 < BF < 0.95)	5	32	143	Electronic
F45GLL/2-V	T8 Linear Fluorescent	Fluorescent, (5) 48", T-8 lamps, (1) 3-lamp and (1) 2-lamp Prog. Start Ballast, VHLO (BF > 1.1)	5	32	182	Electronic
F46GLL/2	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, NLO (0.85 < BF < 0.95)	6	32	175	PRS Elec.
F46GLL/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, RLO (BF < 0.85)	6	32	142	PRS Elec.
F46GLL/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, VHLO (BF > 1.1)	6	32	217	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F46ILL/2	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) IS Ballasts, NLO (0.85 < BF < 0.95)	6	32	170	Electronic
F46ILL/2-R	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	32	151	Electronic
F46ILL/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	32	226	Electronic
F46ILU/2	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, NLO (0.85 < BF < 0.95)	6	32	162	Prem. Elec.
F46ILU/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	32	144	Prem. Elec.
F46ILU/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	32	218	Prem. Elec.
F46LL/2	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) Rapid Start Ballasts, NLO (0.85 < BF < 0.95)	6	32	182	Electronic
F48GLL/2	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, NLO (0.85 < BF < 0.95)	8	32	230	PRS Elec.
F48GLL/2-R	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, RLO (BF < 0.85)	8	32	184	PRS Elec.
F48GLL/2-V	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, VHLO (BF > 1.1)	8	32	288	PRS Elec.
F48ILL/2	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	8	32	224	Electronic
F48ILL/2-R	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, RLO (BF < 0.85)	8	32	196	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F48ILU/2	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	8	32	214	Prem. Elec.
F48ILU/2-R	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, RLO (BF < 0.85)	8	32	190	Prem. Elec.
F48ILU/2-V	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, VHLO (BF > 1.1)	8	32	292	Prem. Elec.
F41GNLL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 25W lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	25	24	PRS Elec.
F44LL-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, Rapid Start Ballast, RLO (BF < 0.85)	4	32	105	Electronic
F44LL/2	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 lamps, (2) 2-lamp Rapid Start Ballast, NLO (0.85 < BF < 0.95)	4	32	120	Electronic
F45ILL/2	T8 Linear Fluorescent	Fluorescent, (5) 48", T-8 lamps, (1) 3-lamp and (1) 2-lamp IS ballast, NLO (0.85 < BF < 0.95)	5	32	143	Electronic
F45GLL/2-V	T8 Linear Fluorescent	Fluorescent, (5) 48", T-8 lamps, (1) 3-lamp and (1) 2-lamp Prog. Start Ballast, VHLO (BF > 1.1)	5	32	182	Electronic
F46GLL/2	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, NLO (0.85 < BF < 0.95)	6	32	175	PRS Elec.
F46GLL/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, RLO (BF < 0.85)	6	32	142	PRS Elec.
F46GLL/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, VHLO (BF > 1.1)	6	32	217	PRS Elec.
F46ILL/2	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) IS Ballasts, NLO (0.85 < BF < 0.95)	6	32	170	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F46ILL/2-R	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	32	151	Electronic
F46ILL/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	32	226	Electronic
F46ILU/2	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, NLO (0.85 < BF < 0.95)	6	32	162	Prem. Elec.
F46ILU/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	32	144	Prem. Elec.
F46ILU/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	32	218	Prem. Elec.
F46LL/2	T8 Linear Fluorescent	Fluorescent, (6) 48", T-8 lamps, (2) Rapid Start Ballasts, NLO (0.85 < BF < 0.95)	6	32	182	Electronic
F48GLL/2	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, NLO (0.85 < BF < 0.95)	8	32	230	PRS Elec.
F48GLL/2-R	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, RLO (BF < 0.85)	8	32	184	PRS Elec.
F48GLL/2-V	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 lamps, (2) Prog. Start or PRS Ballasts, VHLO (BF > 1.1)	8	32	288	PRS Elec.
F48ILL/2	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	8	32	224	Electronic
F48ILL/2-R	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, RLO (BF < 0.85)	8	32	196	Electronic
F48ILU/2	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	8	32	214	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F48ILU/2-R	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, RLO (BF < 0.85)	8	32	190	Prem. Elec.
F48ILU/2-V	T8 Linear Fluorescent	Fluorescent, (8) 48", T-8 lamps, (2) 4-lamp IS Ballasts, VHLO (BF > 1.1)	8	32	292	Prem. Elec.
F41GNLL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 25W lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	25	24	PRS Elec.
F41GNLL-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 25W lamp, Prog. Start or PRS Ballast, RLO (BF< 0.85)	1	25	21	PRS Elec.
F41INLL	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	25	24	Electronic
F41INLU	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 25W lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	25	23	Prem. Elec.
F41INLU-R	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 25W lamp, Instant Start Ballast, RLO (BF< 0.85)	1	25	21	Prem. Elec.
F41INLU-V	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 25W lamp, Instant Start Ballast, VHLO (BF > 1.1)	1	25	32	Prem. Elec.
F41INLU/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 25W lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	25	19	Prem. Elec.
F41INLU/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 25W lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	25	19	Prem. Elec.
F42GNLL	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	2	25	44	PRS Elec.
F42GNLL-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, RLO (BF< 0.85)	2	25	38	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42INLL	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	25	46	Electronic
F42INLL-V	T8 Linear Fluorescent	Fluorescent, (2) 48" T-8 @ 25W lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	25	65	Electronic
F42INLU	T8 Linear Fluorescent	Fluorescent, (2), T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	25	43	Prem. Elec.
F42INLU-R	T8 Linear Fluorescent	Fluorescent (2) 48" T8 @ 25W lamps, Instant Start Ballast, RLO (BF< 0.85)	2	25	38	Prem. Elec.
F42INLU-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 25W lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	25	60	Prem. Elec.
F42INLU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 25W lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	25	38	Prem. Elec.
F43GNLL	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	25	66	PRS Elec.
F43GNLL-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	3	25	56	PRS Elec.
F43INLL	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	25	66	Electronic
F43INLL-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 25W lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	25	95	Electronic
F43INLU	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps @ 25W, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	25	64	Prem. Elec.
F43INLU-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 25W lamps, Instant Start Ballast, RLO (BF < 0.85)	3	25	57	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F43INLU-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 25W lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	25	93	Prem. Elec.
F44GNLL	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	4	25	85	PRS Elec.
F44GNLL-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 25W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	4	25	73	PRS Elec.
F44INLL	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	25	86	Electronic
F44INLU	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 @ 25W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	25	85	Prem. Elec.
F44INLU-R	T8 Linear Fluorescent	Fluorescent, (4) 48" T-8 @ 25W lamps, Instant Start Ballast, RLO (BF < 0.85)	4	25	75	Prem. Elec.
F44INLU-V	T8 Linear Fluorescent	Fluorescent, (4) 48" T-8 @ 25W lamps, Instant Start Ballast, VHLO (BF > 1.1)	4	25	122	Prem. Elec.
F46INLU/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 25W lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	25	114	Prem. Elec.
F46INLU/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 25W lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	25	184	Prem. Elec.
F41GRLL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 28W lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	28	26	PRS Elec.
F41GRLL-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 28W lamp, Prog. Start or PRS Ballast, RLO (BF< 0.85)	1	28	22	PRS Elec.
F41IRLL	T8 Linear Fluorescent	Fluorescent, (1) 48" T-8 @ 28W lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	28	27	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41IRLL-V	T8 Linear Fluorescent	Fluorescent, (1) 48" T-8 @ 28W lamp, Instant Start Ballast, VHLO (BF > 1.1)	1	28	35	Electronic
F41IRLU	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 28W lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	28	25	Prem. Elec.
F41IRLU-R	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 28W lamp, Instant Start Ballast, RLO (BF< 0.85)	1	28	22	Prem. Elec.
F41IRLU-V	T8 Linear Fluorescent	Fluorescent, (1), T-8 @ 28W lamp, Instant Start Ballast, VHLO (BF > 1.1)	1	28	33	Prem. Elec.
F41IRLU/T3-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 28W lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	28	21	Prem. Elec.
F41IRLU/T4-R	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 28W lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	28	21	Prem. Elec.
F42GRLL	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	2	28	49	PRS Elec.
F42GRLL-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, RLO (BF< 0.85)	2	28	40	PRS Elec.
F42IRLL	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 28W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	28	52	Electronic
F42IRLL-V	T8 Linear Fluorescent	Fluorescent, (2) 48" T-8 @ 28W lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	28	68	Electronic
F42IRLU	T8 Linear Fluorescent	Fluorescent, (2), T-8 @ 28W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	28	48	Prem. Elec.
F42IRLU-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 28W lamps, Instant Start Ballast, RLO (BF< 0.85)	2	28	43	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42IRLU-V	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 28W lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	28	65	Prem. Elec.
F42IRLU/T4-R	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 @ 28W lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	28	42	Prem. Elec.
F43GRLL	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	28	75	PRS Elec.
F43GRLL-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	3	28	62	PRS Elec.
F43IRLL	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	28	76	Electronic
F43IRLL-H	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Instant Start Ballast, HLO (.95 < BF < 1.1)	3	28	82	Electronic
F43IRLL-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	28	97	Electronic
F43IRLU	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 lamps @ 28W, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	28	72	Prem. Elec.
F43IRLU-R	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Instant Start Ballast, RLO (BF < 0.85)	3	28	63	Prem. Elec.
F43IRLU-V	T8 Linear Fluorescent	Fluorescent, (3) 48" T-8 @ 28W lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	28	96	Prem. Elec.
F44GRLL	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	4	28	99	PRS Elec.
F44GRLL-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 28W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	4	28	80	PRS Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F44IRLL	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 @ 28W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	28	99	Electronic
F44IRLL-R	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 @ 28W lamps, Instant Start Ballast, RLO (BF < 0.85)	4	28	85	Electronic
F44IRLU	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 @ 28W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	28	94	Prem. Elec.
F44IRLU-R	T8 Linear Fluorescent	Fluorescent, (4) 48" T-8 @ 28W lamps, Instant Start Ballast, RLO (BF < 0.85)	4	28	83	Prem. Elec.
F44IRLU-V	T8 Linear Fluorescent	Fluorescent, (4) 48" T-8 @ 28W lamps, Instant Start Ballast, VHLO (BF > 1.1)	4	28	131	Prem. Elec.
F46IRLU/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 28W lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	28	126	Prem. Elec.
F46IRLU/2-V	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 28W lamps, (2) IS Ballasts, VHLO (BF > 1.1)	6	28	194	Prem. Elec.
F48IRLU/2-V	T8 Linear Fluorescent	Fluorescent (8) 48" T-8 @ 28W lamps, (2) IS Ballasts, VHLO (BF > 1.1)	8	28	250	Prem. Elec.
F41GELL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	1	30	28	PRS Elec.
F41GELL-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Prog. Start or PRS Ballast, RLO (BF < 0.85)	1	30	24	PRS Elec.
F41IELL	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	30	29	Electronic
F41IELL-H	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	1	30	34	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41IELL-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Instant Start Ballast, RLO (BF < 0.85)	1	30	26	Electronic
F41IELL/T2	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	28	Electronic
F41IELL/T3	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	27	Electronic
F41IELL/T4	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	27	Electronic
F41IELU	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 @ 30W lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	30	27	Prem. Elec.
F41IELU-H	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Instant Start Ballast, HLO (0.95 < BF < 1.1)	1	30	32	Prem. Elec.
F41IELU-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Instant Start Ballast, RLO (BF< 0.85)	1	30	24	Prem. Elec.
F41IELU/T2	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	26	Prem. Elec.
F41IELU/T2-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 2-lamp IS Ballast, RLO (BF< 0.85)	1	30	23	Prem. Elec.
F41IELU/T3	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	26	Prem. Elec.
F41IELU/T3-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 3-lamp IS Ballast, RLO (BF< 0.85)	1	30	23	Prem. Elec.
F41IELU/T4	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	30	25	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41IELU/T4-R	T8 Linear Fluorescent	Fluorescent (1) 48" T-8 @ 30W lamp, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	1	30	22	Prem. Elec.
F42GELL	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	2	30	56	PRS Elec.
F42GELL-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	2	30	43	PRS Elec.
F42IELL	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	30	55	Electronic
F42IELL-H	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	2	30	62	Electronic
F42IELL-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start Ballast, RLO (BF< 0.85)	2	30	49	Electronic
F42IELL/T4	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	30	53	Electronic
F42IELL/T4-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	30	46	Electronic
F42IELU	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	30	52	Prem. Elec.
F42IELU-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start, RLO (BF< 0.85)	2	30	45	Prem. Elec.
F42IELU-V	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Instant Start, VHLO (BF > 1.1)	2	30	70	Prem. Elec.
F42IELU/T4	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	30	51	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F42IELU/T4-R	T8 Linear Fluorescent	Fluorescent (2) 48" T-8 @ 30W lamps, Tandem 4-lamp IS Ballast, RLO (BF< 0.85)	2	30	45	Prem. Elec.
F43GELL	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	3	30	83	PRS Elec.
F43GELL-R	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	3	30	67	PRS Elec.
F43IELL	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	30	81	Electronic
F43IELL-H	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, Instant Start Ballast, HLO (0.95 < BF < 1.1)	3	30	86	Electronic
F43IELL-R	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, Instant Start Ballast, RLO (BF < 0.85)	3	30	71	Electronic
F43IELL/2	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, (1) 1-lamp and (1) 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	3	30	84	Electronic
F43IELL/2-H	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, (1) 2-lamp, (1) 3-lamp IS Ballast, 1 lead capped, HLO (0.95 < BF < 1.1)	3	30	96	Electronic
F43IELL/2-R	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30 W lamps, (1) 1-lamp and (1) 2-lamp IS Ballast, RLO (BF < 0.85)	3	30	75	Electronic
F43IELU	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	30	77	Prem. Elec.
F43IELU-R	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30W lamps, Instant Start Ballast, RLO (BF < 0.85)	3	30	68	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F43IELU-V	T8 Linear Fluorescent	Fluorescent (3) 48" T-8 @ 30W lamps, Instant Start Ballast, VHLO (BF > 1.1)	3	30	104	Prem. Elec.
F44GELL	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, NLO (0.85 < BF < 0.95)	4	30	109	PRS Elec.
F44GELL-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Prog. Start or PRS Ballast, RLO (BF < 0.85)	4	30	86	PRS Elec.
F44IELL	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	30	106	Electronic
F44IELL-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Instant Start Ballast, RLO (BF < 0.85)	4	30	92	Electronic
F44IELL/2	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, (2) 2-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	4	30	110	Electronic
F44IELL/2-H	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, (2) 3-lamp IS Ballasts, 1 lead capped, HLO (.95 < BF < 1.1)	4	30	124	Electronic
F44IELL/2-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, (2) 2-lamp IS Ballasts, RLO (BF< 0.85)	4	30	98	Electronic
F44IELU	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	30	101	Prem. Elec.
F44IELU-R	T8 Linear Fluorescent	Fluorescent (4) 48" T-8 @ 30W lamps, Instant Start Ballast, RLO (BF < 0.85)	4	30	89	Prem. Elec.
F46IELU/2	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 30W lamps, (2) IS Ballasts, NLO (0.85 < BF < 0.95)	6	30	154	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F46IELU/2-R	T8 Linear Fluorescent	Fluorescent (6) 48" T-8 @ 30W lamps, (2) IS Ballasts, RLO (BF < 0.85)	6	30	135	Prem. Elec.
F51ILL	T8 Linear Fluorescent	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	40	36	Electronic
F51ILL-R	T8 Linear Fluorescent	Fluorescent, (1) 60", T-8 lamp, Instant Start Ballast, RLO (BF < 0.85)	1	40	43	Electronic
F51ILL/T2	T8 Linear Fluorescent	Fluorescent, (1) 60", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	40	36	Electronic
F51ILL/T3	T8 Linear Fluorescent	Fluorescent, (1) 60", T-8 lamp, Tandem 3-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	40	35	Electronic
F51ILL/T4	T8 Linear Fluorescent	Fluorescent, (1) 60", T-8 lamp, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	40	34	Electronic
F52ILL	T8 Linear Fluorescent	Fluorescent, (2) 60", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	40	72	Electronic
F52ILL-H	T8 Linear Fluorescent	Fluorescent, (2) 60", T-8 lamps, Instant Start Ballast, HILO (.95 < BF < 1.1)	2	40	80	Electronic
F52ILL-R	T8 Linear Fluorescent	Fluorescent, (2) 60", T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	2	40	73	Electronic
F52ILL/T4	T8 Linear Fluorescent	Fluorescent, (2) 60", T-8 lamps, Tandem 4-lamp IS Ballast, NLO (0.85 < BF < 0.95)	2	40	67	Electronic
F53ILL	T8 Linear Fluorescent	Fluorescent, (3) 60", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	40	106	Electronic
F53ILL-H	T8 Linear Fluorescent	Fluorescent, (3) 60", T-8 lamps, Instant Start Ballast, HILO (.95 < BF < 1.1)	3	40	108	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F54ILL	T8 Linear Fluorescent	Fluorescent, (4) 60", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	40	134	Electronic
F54ILL-H	T8 Linear Fluorescent	Fluorescent, (4) 60", T-8 lamps, Instant Start Ballast, HLO (.95 < BF < 1.1)	4	40	126	Electronic
F41LHL	T8 Linear Fluorescent	Fluorescent, (1) 48", T-8 HO lamps, (1) Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	44	59	Electronic
F42LHL	T8 Linear Fluorescent	Fluorescent, (2) 48", T-8 HO lamps, (1) Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	44	98	Electronic
F43LHL	T8 Linear Fluorescent	Fluorescent, (3) 48", T-8 HO lamps, (2) Instant Start Ballasts, NLO (0.85 < BF < 0.95)	3	44	141	Electronic
F44LHL	T8 Linear Fluorescent	Fluorescent, (4) 48", T-8 HO lamps, (2) Instant Start Ballasts, NLO (0.85 < BF < 0.95)	4	44	168	Electronic
F81ILL	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	59	69	Electronic
F81ILL-H	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, HILO (.95 < BF < 1.1)	1	59	70	Electronic
F81ILL-R	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, RLO (BF < 0.85)	1	59	67	Electronic
F81ILL-V	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Instant Start Ballast, VHLO (BF > 1.1)	1	59	72	Electronic
F81ILL/T2	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Tandem 2-lamp IS Ballast, NLO (0.85 < BF < 0.95)	1	59	55	Electronic
F81ILL/T2-R	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 lamp, Tandem 2-lamp IS Ballast, RLO (BF < 0.85)	1	59	50	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F81ILU	T8 Linear Fluorescent	Fluorescent, (1) 96" T-8 lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	59	67	Prem. Elec.
F82ILL	T8 Linear Fluorescent	Fluorescent, (2) 96", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	59	110	Electronic
F82ILL-R	T8 Linear Fluorescent	Fluorescent, (2) 96", T-8 lamps, Instant Start Ballast, RLO (BF < 0.85)	2	59	100	Electronic
F82ILL-V	T8 Linear Fluorescent	Fluorescent, (2) 96", T-8 lamps, Instant Start Ballast, VHLO (BF > 1.1)	2	59	149	Electronic
F82ILU	T8 Linear Fluorescent	Fluorescent, (2) 96" T-8 ES lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	59	107	Prem. Elec.
F83ILL	T8 Linear Fluorescent	Fluorescent, (3) 96", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	3	59	179	Electronic
F84ILL	T8 Linear Fluorescent	Fluorescent, (4) 96", T-8 lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	4	59	219	Electronic
F84ILL/2-V	T8 Linear Fluorescent	Fluorescent, (4) 96", T-8 lamps, (2) Instant Start Ballasts, VHLO (BF > 1.1)	4	59	298	Electronic
F86ILL	T8 Linear Fluorescent	Fluorescent, (6) 96", T-8 lamps, (2) 3-lamp IS Ballasts, NLO (0.85 < BF < 0.95)	6	59	330	Electronic
F81LHL/T2	T8 Linear Fluorescent	Fluorescent, (1) 96", T-8 HO lamp, Tandem 2-lamp Ballast	1	86	80	Electronic
F82LHL	T8 Linear Fluorescent	Fluorescent, (2) 96", T-8 HO lamps	2	86	160	Electronic
F84LHL	T8 Linear Fluorescent	Fluorescent, (4) 96", T-8 HO lamps	4	86	320	Electronic
F81IERU	T8 Linear Fluorescent	Fluorescent, (1) 96" T-8 reduced-wattage lamp, Instant Start Ballast, NLO (0.85 < BF < 0.95)	1	54	61	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F82IERU	T8 Linear Fluorescent	Fluorescent, (2) 96" T-8 @ reduced-wattage lamps, Instant Start Ballast, NLO (0.85 < BF < 0.95)	2	54	93	Prem. Elec.
F41T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 48" T12 lamp (T8 Baseline)	1	32	31	Mag/Elec
F42T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 48" T12 lamps (T8 Baseline)	2	32	58	Mag/Elec
F43T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (3) 48" T12 lamps (T8 Baseline)	3	32	85	Mag/Elec
F44T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (4) 48" T12 lamps (T8 Baseline)	4	32	112	Mag/Elec
F46T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 48" T12 lamps (T8 Baseline)	6	32	170	Mag/Elec
F48T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 48" T12 lamps (T8 Baseline)	8	32	224	Mag/Elec
F41T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 48" T12 HO lamp (T8 Baseline)	1	32	31	Mag/Elec
F42T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 48" T12 HO lamps (T8 Baseline)	2	32	58	Mag/Elec
F43T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (3) 48" T12 HO lamps (T8 Baseline)	3	32	85	Mag/Elec
F44T12-HO	T12 Linear Fluorescent	Fluorescent, (4) 48" T12 HO lamps (T8 Baseline)	4	32	112	Mag/Elec

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
	(T8 Baseline)					
F46T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 48" T12 HO lamps (T8 Baseline)	6	32	170	Mag/Elec
F48T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 48" T12 HO lamps (T8 Baseline)	8	32	224	Mag/Elec
F41T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 48" T12 VHO lamp (T8 Baseline)	1	32	31	Mag/Elec
F42T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 48" T12 VHO lamps (T8 Baseline)	2	32	58	Mag/Elec
F43T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (3) 48" T12 VHO lamps (T8 Baseline)	3	32	85	Mag/Elec
F44T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (4) 48" T12 VHO lamps (T8 Baseline)	4	32	112	Mag/Elec
F46T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 48" T12 VHO lamps (T8 Baseline)	6	32	170	Mag/Elec
F48T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 48" T12 VHO lamps (T8 Baseline)	8	32	224	Mag/Elec
F81T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 96", T12 lamp (T8 Baseline)	1	59	69	Mag/Elec
F82T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 96", T12 lamps (T8 Baseline)	2	59	110	Mag/Elec
F83T12	T12 Linear Fluorescent	Fluorescent, (3) 96", T12 lamps (T8 Baseline)	3	59	179	Mag/Elec

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
	(T8 Baseline)					
F84T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (4) 96", T12 lamps (T8 Baseline)	4	59	219	Mag/Elec
F86T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 96", T12 lamps (T8 Baseline)	6	59	330	Mag/Elec
F88T12	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 96", T12 lamps (T8 Baseline)	8	59	438	Mag/Elec
F81T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 96", T12 HO lamp (T8 Baseline)	1	86	101	Mag/Elec
F82T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 96", T12 HO lamps (T8 Baseline)	2	86	160	Mag/Elec
F83T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (3) 96", T12 HO lamps (T8 Baseline)	3	86	261	Mag/Elec
F84T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (4) 96", T12 HO lamps (T8 Baseline)	4	86	319	Mag/Elec
F86T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 96", T12 HO lamps (T8 Baseline)	6	86	481	Mag/Elec
F88T12-HO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 96", T12 HO lamps (T8 Baseline)	8	86	638	Mag/Elec
F81T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (1) 96", T12 VHO lamp (T8 Baseline)	1	86	101	Mag/Elec

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F82T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (2) 96", T12 VHO lamps (T8 Baseline)	2	86	160	Mag/Elec
F83T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (3) 96", T12 VHO lamps (T8 Baseline)	3	86	261	Mag/Elec
F84T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (4) 96", T12 VHO lamps (T8 Baseline)	4	86	319	Mag/Elec
F86T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (6) 96", T12 VHO lamps (T8 Baseline)	6	86	481	Mag/Elec
F88T12-VHO	T12 Linear Fluorescent (T8 Baseline)	Fluorescent, (8) 96", T12 VHO lamps (T8 Baseline)	8	86	638	Mag/Elec
F1.51SS	T12 Linear Fluorescent	Fluorescent, (1) 18" T12 lamp	1	15	19	Mag-STD
F1.52SS	T12 Linear Fluorescent	Fluorescent, (2) 18", T12 lamps	2	15	36	Mag-STD
F21SS	T12 Linear Fluorescent	Fluorescent, (1) 24", STD lamp	1	20	25	Mag-STD
F22SS	T12 Linear Fluorescent	Fluorescent, (2) 24", STD lamps	2	20	50	Mag-STD
F23SS	T12 Linear Fluorescent	Fluorescent, (3) 24", STD lamps	3	20	71	Mag-STD
F24SS	T12 Linear Fluorescent	Fluorescent, (4) 24", STD lamps	4	20	100	Mag-STD
F26SS/2	T12 Linear Fluorescent	Fluorescent, (6) 24", STD lamps, (2) ballasts	6	20	146	Mag-STD
F21HS	T12 Linear Fluorescent	Fluorescent, (1) 24", HO lamp	1	35	62	Mag-STD
F22HS	T12 Linear Fluorescent	Fluorescent, (2) 24", HO lamps	2	35	90	Mag-STD
F31EE/T2	T12 Linear Fluorescent	Fluorescent, (1) 36", ES lamp, Tandem 2-lamp ballast	1	25	33	Mag-ES

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F31EL	T12 Linear Fluorescent	Fluorescent, (1) 36", ES lamp	1	25	26	Electronic
F31ES	T12 Linear Fluorescent	Fluorescent, (1) 36", ES lamp	1	25	42	Mag-STD
F31ES/T2	T12 Linear Fluorescent	Fluorescent, (1) 36", ES lamp, Tandem 2-lamp ballast	1	25	33	Mag-STD
F31SE/T2	T12 Linear Fluorescent	Fluorescent, (1) 36", STD lamp, Tandem 2-lamp ballast	1	30	37	Mag-ES
F31SHS	T12 Linear Fluorescent	Fluorescent, (1) 36", HO lamp	1	50	70	Mag-STD
F31SL	T12 Linear Fluorescent	Fluorescent, (1) 36", STD lamp	1	30	31	Electronic
F31SS	T12 Linear Fluorescent	Fluorescent, (1) 36", STD lamp	1	30	46	Mag-STD
F31SS/T2	T12 Linear Fluorescent	Fluorescent, (1) 36", STD lamp, Tandem 2-lamp ballast	1	30	41	Mag-STD
F32EE	T12 Linear Fluorescent	Fluorescent, (2) 36", ES lamp	2	25	66	Mag-ES
F32EL	T12 Linear Fluorescent	Fluorescent, (2) 36", ES lamps	2	25	50	Electronic
F32EL/T4	T12 Linear Fluorescent	Fluorescent, (2) 36" ES lamps, Tandem 4-lamp ballast, NLO (0.85 < BF < 0.95)	2	25	50	Electronic
F32ES	T12 Linear Fluorescent	Fluorescent, (2) 36", ES lamps	2	25	73	Mag-STD
F32SE	T12 Linear Fluorescent	Fluorescent, (2) 36", STD lamps	2	30	74	Mag-ES
F32SHS	T12 Linear Fluorescent	Fluorescent, (2) 36", HO, lamps	2	50	114	Mag-STD
F32SL	T12 Linear Fluorescent	Fluorescent, (2) 36", STD lamps	2	30	58	Electronic
F32SS	T12 Linear Fluorescent	Fluorescent, (2) 36", STD lamps	2	30	75	Mag-STD
F33ES	T12 Linear Fluorescent	Fluorescent, (3) 36", ES lamps	3	25	115	Mag-STD

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F33SE	T12 Linear Fluorescent	Fluorescent, (3) 36", STD lamps, (1) STD ballast and (1) ES ballast	3	30	120	Mag-ES
F33SS	T12 Linear Fluorescent	Fluorescent, (3) 36", STD lamps	3	30	127	Mag-STD
F34EE	T12 Linear Fluorescent	Fluorescent, (4) 36", ES lamps	4	25	132	Mag-ES
F34SE	T12 Linear Fluorescent	Fluorescent, (4) 36", STD lamps	4	30	148	Mag-ES
F34SL	T12 Linear Fluorescent	Fluorescent, (4) 36", STD lamps	4	30	116	Electronic
F34SS	T12 Linear Fluorescent	Fluorescent, (4) 36", STD lamps	4	30	150	Mag-STD
F36EE	T12 Linear Fluorescent	Fluorescent, (6) 36", ES lamps	6	30	198	Mag-ES
F36ES	T12 Linear Fluorescent	Fluorescent, (6) 36", ES lamps	6	30	219	Mag-STD
F36SE	T12 Linear Fluorescent	Fluorescent, (6) 36", STD lamps	6	30	213	Mag-ES
F36SS	T12 Linear Fluorescent	Fluorescent, (6) 36", STD lamps	6	30	225	Mag-STD
F41EE	T12 Linear Fluorescent	Fluorescent, (1) 48", ES lamp	1	34	43	Mag-ES
F41EE/2	T12 Linear Fluorescent	Fluorescent, (1) 48", ES lamp, 2 ballast	1	34	43	Mag-ES
F41EE/T2	T12 Linear Fluorescent	Fluorescent, (1) 48", ES lamp, Tandem 2-lamp ballast	1	34	36	Mag-ES
F41EL	T12 Linear Fluorescent	Fluorescent, (1) 48", T12 ES lamp, Electronic Ballast	1	34	32	Electronic
F41IAL	T12 Linear Fluorescent	Fluorescent, (1) 48", F25T12 lamp, Instant Start Ballast	1	25	25	Electronic
F41IAL/T2-R	T12 Linear Fluorescent	Fluorescent, (1) 48", F25T12 lamp, Tandem 2-Lamp IS ballast, RLO (BF < 0.85)	1	25	19	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41IAL/T3-R	T12 Linear Fluorescent	Fluorescent, (1) 48", F25T12 lamp, Tandem 3-Lamp IS ballast, RLO (BF < 0.85)	1	25	20	Electronic
F41IAL/T4-R	T12 Linear Fluorescent	Fluorescent, (1) 48", F25T12 lamp, Tandem 4-Lamp IS ballast, RLO (BF < 0.85)	1	25	20	Electronic
F41SIL	T12 Linear Fluorescent	Fluorescent, (1) 48", STD IS lamp, Electronic ballast	1	39	46	Electronic
F41SIL/T2	T12 Linear Fluorescent	Fluorescent, (1) 48", STD IS lamp, Tandem 2-lamp IS ballast	1	39	37	Electronic
F41TS	T12 Linear Fluorescent	Fluorescent, (1) 48", T-10 lamp	1	40	51	Mag-STD
F42EE	T12 Linear Fluorescent	Fluorescent, (2) 48", ES lamp	2	34	72	Mag-ES
F42EE/2	T12 Linear Fluorescent	Fluorescent, (2) 48", ES lamps, (2) 1-lamp ballasts	2	34	86	Mag-ES
F42EE/D2	T12 Linear Fluorescent	Fluorescent, (2) 48", ES lamps, 2 Ballasts (delamped)	2	34	76	Mag-ES
F42EL	T12 Linear Fluorescent	Fluorescent, (2) 48", T12 ES lamps, Electronic Ballast	2	34	60	Electronic
F42IAL-R	T12 Linear Fluorescent	Fluorescent, (2) 48", F25T12 lamps, Instant Start Ballast, RLO (BF < 0.85)	2	25	39	Electronic
F42IAL/T4-R	T12 Linear Fluorescent	Fluorescent, (2) 48", F25T12 lamps, Tandem 4-lamp IS Ballast, RLO (BF < 0.85)	2	25	40	Electronic
F42SIL	T12 Linear Fluorescent	Fluorescent, (2) 48", STD IS lamps, Electronic ballast	2	39	74	Electronic
F43EE	T12 Linear Fluorescent	Fluorescent, (3) 48", ES lamps	3	34	115	Mag-ES

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F43EE/T2	T12 Linear Fluorescent	Fluorescent, (3) 48", ES lamps, Tandem 2-lamp ballasts	3	34	108	Mag-ES
F43EL	T12 Linear Fluorescent	Fluorescent, (3) 48", T12 ES lamps, Electronic Ballast	3	34	92	Electronic
F43IAL-R	T12 Linear Fluorescent	Fluorescent, (3) 48", F25T12 lamps, Instant Start Ballast, RLO (BF < 0.85)	3	25	60	Electronic
F43SIL	T12 Linear Fluorescent	Fluorescent, (3) 48", STD IS lamps, Electronic ballast	3	39	120	Electronic
F44EE	T12 Linear Fluorescent	Fluorescent, (4) 48", ES lamps	4	34	144	Mag-ES
F44EE/D3	T12 Linear Fluorescent	Fluorescent, (4) 48", ES lamps, 3 Ballasts (delamped)	4	34	148	Mag-ES
F44EE/D4	T12 Linear Fluorescent	Fluorescent, (4) 48", ES lamps, 4 Ballasts (delamped)	4	34	152	Mag-ES
F44EL	T12 Linear Fluorescent	Fluorescent, (4) 48", T12 ES lamps, Electronic Ballast	4	34	120	Electronic
F44IAL-R	T12 Linear Fluorescent	Fluorescent, (4) 48", F25T12 lamps, Instant Start Ballast, RLO (BF < 0.85)	4	25	80	Electronic
F46EE	T12 Linear Fluorescent	Fluorescent, (6) 48", ES lamps	6	34	216	Mag-ES
F46EL	T12 Linear Fluorescent	Fluorescent, (6) 48", ES lamps	6	34	180	Electronic
F48EE	T12 Linear Fluorescent	Fluorescent, (8) 48", ES lamps	8	34	288	Mag-ES
F42EHS	T12 Linear Fluorescent	Fluorescent, (2) 42", HO lamps (3.5' lamp)	2	55	135	Mag-STD
F43EHS	T12 Linear Fluorescent	Fluorescent, (3) 42", HO lamps (3.5' lamp)	3	55	215	Mag-STD

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F41EIS	T12 Linear Fluorescent	Fluorescent, (1) 48" ES Instant Start lamp. Magnetic ballast	1	30	51	Mag-STD
F42EIS	T12 Linear Fluorescent	Fluorescent, (2) 48" ES Instant Start lamps. Magnetic ballast	2	30	82	Mag-STD
F43EIS	T12 Linear Fluorescent	Fluorescent, (3) 48" ES Instant Start lamps. Magnetic ballast	3	30	133	Mag-STD
F44EIS	T12 Linear Fluorescent	Fluorescent, (4) 48" ES Instant Start lamps. Magnetic ballast	4	30	164	Mag-STD
F41SHS	T12 Linear Fluorescent	Fluorescent, (1) 48", STD HO lamp	1	60	85	Mag-STD
F42SHS	T12 Linear Fluorescent	Fluorescent, (2) 48", STD HO lamps	2	60	145	Mag-STD
F43SHS	T12 Linear Fluorescent	Fluorescent, (3) 48", STD HO lamps	3	60	230	Mag-STD
F44SHS	T12 Linear Fluorescent	Fluorescent, (4) 48", STD HO lamps	4	60	290	Mag-STD
F41EHS	T12 Linear Fluorescent	Fluorescent, (1) 48", ES HO lamp	1	55	80	Mag-STD
F44EHS	T12 Linear Fluorescent	Fluorescent, (4) 48", ES HO lamps	4	55	270	Mag-STD
F41SVS	T12 Linear Fluorescent	Fluorescent, (1) 48", STD VHO lamp	1	110	140	Mag-STD
F42SVS	T12 Linear Fluorescent	Fluorescent, (2) 48", STD VHO lamps	2	110	252	Mag-STD
F43SVS	T12 Linear Fluorescent	Fluorescent, (3) 48", STD VHO lamps	3	110	377	Mag-STD
F44SVS	T12 Linear Fluorescent	Fluorescent, (4) 48", STD VHO lamps	4	110	484	Mag-STD
F44EVS	T12 Linear Fluorescent	Fluorescent, (4) 48", VHO ES lamps	4	100	420	Mag-STD
F44SIL	T12 Linear Fluorescent	Fluorescent, (4) 48", STD IS lamps, Electronic ballast	4	39	148	Electronic
F46SL	T12 Linear Fluorescent	Fluorescent, (6) 48", STD lamps	6	40	186	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F51SL	T12 Linear Fluorescent	Fluorescent, (1) 60", STD lamp	1	50	44	Electronic
F51SS	T12 Linear Fluorescent	Fluorescent, (1) 60", STD lamp	1	50	63	Mag-STD
F52SL	T12 Linear Fluorescent	Fluorescent, (2) 60", STD lamps	2	50	88	Electronic
F52SS	T12 Linear Fluorescent	Fluorescent, (2) 60", STD lamps	2	50	128	Mag-STD
F51SHE	T12 Linear Fluorescent	Fluorescent, (1) 60", STD HO lamp	1	75	88	Mag-ES
F51SHL	T12 Linear Fluorescent	Fluorescent, (1) 60", STD HO lamp	1	75	69	Electronic
F51SHS	T12 Linear Fluorescent	Fluorescent, (1) 60", STD HO lamp	1	75	92	Mag-STD
F51SVS	T12 Linear Fluorescent	Fluorescent, (1) 60", VHO ES lamp	1	135	165	Mag-STD
F52SHE	T12 Linear Fluorescent	Fluorescent, (2) 60", STD HO lamps	2	75	176	Mag-ES
F52SHL	T12 Linear Fluorescent	Fluorescent, (2) 60", STD HO lamps	2	75	138	Electronic
F52SHS	T12 Linear Fluorescent	Fluorescent, (2) 60", STD HO lamps	2	75	168	Mag-STD
F52SVS	T12 Linear Fluorescent	Fluorescent, (2) 60", VHO ES lamps	2	135	310	Mag-STD
F61ISL	T12 Linear Fluorescent	Fluorescent, (1) 72", STD lamp, IS electronic ballast	1	55	68	Electronic
F61SHS	T12 Linear Fluorescent	Fluorescent, (1) 72", STD HO lamp	1	85	106	Mag-STD
F61SS	T12 Linear Fluorescent	Fluorescent, (1) 72", STD lamp	1	55	76	Mag-STD
F62ISL	T12 Linear Fluorescent	Fluorescent, (2) 72", STD lamps, IS electronic ballast	2	55	108	Electronic
F62SE	T12 Linear Fluorescent	Fluorescent, (2) 72", STD lamps	2	55	122	Mag-ES
F62SHE	T12 Linear Fluorescent	Fluorescent, (2) 72", STD HO lamps	2	85	194	Mag-ES
F62SHL	T12 Linear Fluorescent	Fluorescent, (2) 72", STD HO lamps	2	85	167	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F62SHS	T12 Linear Fluorescent	Fluorescent, (2) 72", STD HO lamps	2	85	200	Mag-STD
F62SL	T12 Linear Fluorescent	Fluorescent, (2) 72", STD lamps	2	55	108	Electronic
F62SS	T12 Linear Fluorescent	Fluorescent, (2) 72", STD lamps	2	55	142	Mag-STD
F63ISL	T12 Linear Fluorescent	Fluorescent, (3) 72", STD lamps, IS electronic ballast	3	55	176	Electronic
F63SS	T12 Linear Fluorescent	Fluorescent, (3) 72", STD lamps	3	55	202	Mag-STD
F64ISL	T12 Linear Fluorescent	Fluorescent, (4) 72", STD lamps, IS electronic ballast	4	55	216	Electronic
F64SE	T12 Linear Fluorescent	Fluorescent, (4) 72", STD lamps	4	55	244	Mag-ES
F64SS	T12 Linear Fluorescent	Fluorescent, (4) 72", STD lamps	4	56	244	Mag-STD
F64SHE	T12 Linear Fluorescent	Fluorescent, (4) 72", HO lamps	4	85	388	Mag-ES
F61SVS	T12 Linear Fluorescent	Fluorescent, (1) 72", VHO lamp	1	160	180	Mag-STD
F62SVS	T12 Linear Fluorescent	Fluorescent, (2) 72", VHO lamps	2	160	330	Mag-STD
F71HS	T12 Linear Fluorescent	Fluorescent, (1) 84", HO lamp	1	100	104	Mag-ES
F72HS	T12 Linear Fluorescent	Fluorescent, (2) 84", HO lamp	2	100	198	Mag-ES
F81EE	T12 Linear Fluorescent	Fluorescent, (1) 96" ES lamp	1	60	75	Mag-ES
F81EE/T2	T12 Linear Fluorescent	Fluorescent, (1) 96", ES lamp, Tandem 2-lamp ballast	1	60	62	Mag-ES
F81EHL	T12 Linear Fluorescent	Fluorescent, (1) 96", ES HO lamp	1	95	80	Electronic
F81EHS	T12 Linear Fluorescent	Fluorescent, (1) 96", ES HO lamp	1	95	113	Mag-STD
F81EL	T12 Linear Fluorescent	Fluorescent, (1) 96", ES lamp	1	60	69	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F81EL/T2	T12 Linear Fluorescent	Fluorescent, (1) 96", ES lamp, Tandem 2-lamp ballast	1	60	55	Electronic
F81EVS	T12 Linear Fluorescent	Fluorescent, (1) 96", ES VHO lamp	1	185	205	Mag-STD
F81SGS	T17 Linear Fluorescent	Fluorescent, (1) 96", T17 Grooved lamp	1	215	235	Mag-STD
F81SHS	T12 Linear Fluorescent	Fluorescent, (1) 96", STD HO lamp	1	110	121	Mag-STD
F81SL	T12 Linear Fluorescent	Fluorescent, (1) 96", STD lamp	1	75	69	Electronic
F81SL/T2	T12 Linear Fluorescent	Fluorescent, (1) 96", STD lamp, Tandem 2-lamp ballast	1	75	55	Electronic
F81SVS	T12 Linear Fluorescent	Fluorescent, (1) 96", STD VHO lamp	1	215	205	Mag-STD
F82EE	T12 Linear Fluorescent	Fluorescent, (2) 96", ES lamps	2	60	123	Mag-ES
F82EHE	T12 Linear Fluorescent	Fluorescent, (2) 96", ES HO lamps	2	95	207	Mag-ES
F82EHL	T12 Linear Fluorescent	Fluorescent, (2) 96", ES HO lamps	2	95	173	Electronic
F82EHS	T12 Linear Fluorescent	Fluorescent, (2) 96", ES HO lamps	2	95	207	Mag-STD
F82EL	T12 Linear Fluorescent	Fluorescent, (2) 96", ES lamps	2	60	110	Electronic
F82EVS	T12 Linear Fluorescent	Fluorescent, (2) 96", ES VHO lamps	2	195	380	Mag-STD
F82SHE	T12 Linear Fluorescent	Fluorescent, (2) 96", STD HO lamps	2	110	207	Mag-ES
F82SHL	T12 Linear Fluorescent	Fluorescent, (2) 96", STD HO lamps	2	110	173	Electronic
F82SHS	T12 Linear Fluorescent	Fluorescent, (2) 96", STD HO lamps	2	110	207	Mag-STD
F82SL	T12 Linear Fluorescent	Fluorescent, (2) 96", STD lamps	2	75	110	Electronic
F82SVS	T12 Linear Fluorescent	Fluorescent, (2) 96", STD VHO lamps	2	215	380	Mag-STD
F83EE	T12 Linear Fluorescent	Fluorescent, (3) 96", ES lamps	3	60	198	Mag-ES

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F83EHE	T12 Linear Fluorescent	Fluorescent, (3) 96", ES HO lamps, (1) 2-lamp ES Ballast and (1) 1-lamp STD Ballast	3	95	319	Mag-ES/STD
F83EHS	T12 Linear Fluorescent	Fluorescent, (3) 96", ES HO lamps	3	95	319	Mag-STD
F83EL	T12 Linear Fluorescent	Fluorescent, (3) 96", ES lamps	3	60	179	Electronic
F83EVS	T12 Linear Fluorescent	Fluorescent, (3) 96", ES VHO lamps	3	185	585	Mag-STD
F83SHE	T12 Linear Fluorescent	Fluorescent, (3) 96", STD HO lamps	3	110	319	Mag-ES
F83SHS	T12 Linear Fluorescent	Fluorescent, (3) 96", STD HO lamps	3	110	319	Mag-STD
F83SL	T12 Linear Fluorescent	Fluorescent, (3) 96", STD lamps	3	75	179	Electronic
F83SVS	T12 Linear Fluorescent	Fluorescent, (3) 96", STD VHO lamps	3	215	585	Mag-STD
F84EE	T12 Linear Fluorescent	Fluorescent, (4) 96", ES lamps	4	60	246	Mag-ES
F84EHE	T12 Linear Fluorescent	Fluorescent, (4) 96", ES HO lamps	4	95	414	Mag-ES
F84EHL	T12 Linear Fluorescent	Fluorescent, (4) 96", ES HO lamps	4	95	346	Electronic
F84EHS	T12 Linear Fluorescent	Fluorescent, (4) 96", ES HO lamps	4	95	414	Mag-STD
F84EL	T12 Linear Fluorescent	Fluorescent, (4) 96", ES lamps	4	60	220	Electronic
F84EVS	T12 Linear Fluorescent	Fluorescent, (4) 96", ES VHO lamps	4	185	760	Mag-STD
F84SHE	T12 Linear Fluorescent	Fluorescent, (4) 96", STD HO lamps	4	110	414	Mag-ES
F84SHL	T12 Linear Fluorescent	Fluorescent, (4) 96", STD HO lamps	4	110	346	Electronic
F84SHS	T12 Linear Fluorescent	Fluorescent, (4) 96", STD HO lamps	4	110	414	Mag-STD
F84SL	T12 Linear Fluorescent	Fluorescent, (4) 96", STD lamps	4	75	220	Electronic
F84SVS	T12 Linear Fluorescent	Fluorescent, (4) 96", STD VHO lamps	4	215	760	Mag-STD
F86EE	T12 Linear Fluorescent	Fluorescent, (6) 96", ES lamps	6	60	369	Mag-ES

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
F86EHS	T12 Linear Fluorescent	Fluorescent, (6) 96", ES HO lamps	6	95	519	Mag-STD
F88EHE	T12 Linear Fluorescent	Fluorescent, (8) 96", ES HO lamps	8	95	828	Mag-ES
F88SHS	T12 Linear Fluorescent	Fluorescent, (8) 96", STD HO lamps	8	110	828	Mag-STD
F40SE/D1	Other Linear Fluorescent	Fluorescent, (0) 48" lamps, Completely delamped fixture with (1) hot ballast	1	0	4	Mag-ES
F40SE/D2	Other Linear Fluorescent	Fluorescent, (0) 48" lamps, Completely delamped fixture with (2) hot ballast	1	0	8	Mag-ES
FC6/1	Circline Fluorescent	Fluorescent, (1) 6" circular lamp, RS ballast	1	20	25	Mag-STD
FC8/1	Circline Fluorescent	Fluorescent, (1) 8" circular lamp, RS ballast	1	22	26	Mag-STD
FC8/2	Circline Fluorescent	Fluorescent, (2) 8" circular lamps, RS ballast	2	22	52	Mag-STD
FC20	Circline Fluorescent	Fluorescent, Circline, (1) 20W lamp, preheat ballast	1	20	20	Mag-STD
FC22	Circline Fluorescent	Fluorescent, Circline, (1) 22W lamp, preheat ballast	1	22	20	Mag-STD
FC12/1	Circline Fluorescent	Fluorescent, (1) 12" circular lamp, RS ballast	1	32	31	Mag-STD
FC12/2	Circline Fluorescent	Fluorescent, (2) 12" circular lamps, RS ballast	2	32	62	Mag-STD
FC32	Circline Fluorescent	Fluorescent, Circline, (1) 32W lamp, preheat ballast	1	32	40	Mag-STD
FC16/1	Circline Fluorescent	Fluorescent, (1) 16" circular lamp	1	40	35	Mag-STD
FC40	Circline Fluorescent	Fluorescent, Circline, (1) 32W lamp, preheat ballast	1	32	42	Mag-STD
FEI40/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 40W lamp	1	40	44	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
FEI55/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 55W lamp	1	55	59	Electronic
FEI70/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 70W lamp	1	70	74	Electronic
FEI80/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 80W lamp	1	80	84	Electronic
FEI85/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 85W lamp	1	85	89	Electronic
FEI100/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 100W lamp	1	100	105	Electronic
FEI125/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 125W lamp	1	125	131	Electronic
FEI150/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 150W lamp	1	150	157	Electronic
FEI165/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 165W lamp	1	165	173	Electronic
FEI200/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 200W lamp	1	200	210	Electronic
FEI250/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 250W lamp	1	250	263	Electronic
FEI300/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 300W lamp	1	300	315	Electronic
FEI400/1	Electrodeless Induction Fluorescent	Electrodeless Fluorescent System, (1) 400W lamp	1	400	420	Electronic
FU1ILL	U-Tube Fluorescent	Fluorescent, (1) U-Tube, T-8 lamp, Instant Start ballast	1	32	31	Electronic
FU1LL	U-Tube Fluorescent	Fluorescent, (1) U-Tube, T-8 lamp	1	32	32	Electronic
FU1LL-R	U-Tube Fluorescent	Fluorescent, (1) U-Tube, T-8 lamp, RLO (BF < 0.85)	1	31	27	Electronic
FU2ILL	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Instant Start Ballast	2	32	59	Electronic
FU2ILL-H	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Instant Start HLO Ballast	2	32	65	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
FU2ILL-R	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Instant Start RLO Ballast	2	32	52	Electronic
FU2ILL/T4	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Instant Start Ballast, Tandem 4-lamp ballast	2	32	56	Electronic
FU2ILL/T4-R	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Instant Start Ballast, RLO, Tandem 4-lamp ballast	2	32	49	Electronic
FU2LL	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps	2	32	60	Electronic
FU2LL-R	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, RLO (BF< 0.85)	2	31	54	Electronic
FU2LL/T2	U-Tube Fluorescent	Fluorescent, (2) U-Tube, T-8 lamps, Tandem 4-lamp ballast	2	32	59	Electronic
FU3ILL	U-Tube Fluorescent	Fluorescent, (3) U-Tube, T-8 lamps, Instant Start Ballast	3	32	89	Electronic
FU3ILL-R	U-Tube Fluorescent	Fluorescent, (3) U-Tube, T-8 lamps, Instant Start RLO Ballast	3	32	78	Electronic
FU1ILU	U-Tube Fluorescent	Fluorescent, (1) 6" spacing U-Tube, T-8 lamp, IS Ballast, NLO (0.85 < BF < 0.95)	1	32	29	Prem. Elec.
FU1ILU-H	U-Tube Fluorescent	Fluorescent, (1) 6" spacing U-Tube, T-8 lamp, IS Ballast, HLO (.95 < BF < 1.1)	1	32	34	Prem. Elec.
FU2ILU	U-Tube Fluorescent	Fluorescent, (2) 6" spacing U-Tube, T-8 lamps, IS Ballast, NLO (0.85 < BF < 0.95)	2	32	55	Prem. Elec.
FU2ILU-R	U-Tube Fluorescent	Fluorescent, (2) 6" spacing U-Tube, T-8 lamps, IS Ballast, RLO (BF < 0.85)	2	32	48	Prem. Elec.

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
FU2ILU-V	U-Tube Fluorescent	Fluorescent, (2) 6" spacing U-Tube, T-8 lamps, IS Ballast, VHLO (BF > 1.1)	2	32	73	Prem. Elec.
FU3ILU	U-Tube Fluorescent	Fluorescent, (3) 6" spacing U-Tube, T-8 lamps, IS Ballast, NLO (0.85 < BF < 0.95)	3	32	81	Prem. Elec.
FU3ILU-R	U-Tube Fluorescent	Fluorescent, (3) 6" spacing U-Tube, T-8 lamps, IS Ballast, RLO (BF < 0.85)	3	32	73	Prem. Elec.
FU1T12	U-Tube Fluorescent	Fluorescent, (1) U-Tube T12 lamp (T8 Baseline)	1	32	32	Mag/Elec
FU2T12	U-Tube Fluorescent	Fluorescent, (2) U-Tube T12 lamps (T8 Baseline)	2	32	60	Mag/Elec
FU3T12	U-Tube Fluorescent	Fluorescent, (3) U-Tube T12 lamps (T8 Baseline)	3	32	89	Mag/Elec
FU1SE	U-Tube Fluorescent	Fluorescent, (1) U-Tube, STD lamp	1	40	43	Mag-ES
FU1SS	U-Tube Fluorescent	Fluorescent, (1) U-Tube, ES Lamp	1	40	43	Mag-STD
FU2SE	U-Tube Fluorescent	Fluorescent, (2) U-Tube, STD lamps	2	40	72	Mag-ES
FU2SL	U-Tube Fluorescent	Fluorescent (2) 48" U-bent Standard lamps, Electronic ballast, NLO (0.85 < BF < 0.95)	2	40	63	Electronic
FU2SS	U-Tube Fluorescent	Fluorescent, (1) U-Tube, STD lamp, STD Mag Ballast	2	40	72	Mag-STD
FU3SE	U-Tube Fluorescent	Fluorescent, (3) U-Tube, STD lamp	3	40	115	Mag-ES
FU1EE	U-Tube Fluorescent	Fluorescent, (1) U-Tube, ES lamp	1	35	43	Mag-ES
FU1ES	U-Tube Fluorescent	Fluorescent, (1) U-Tube, ES Lamp	1	34	43	Mag-STD
FU2EE	U-Tube Fluorescent	Fluorescent, (2) U-Tube, ES lamp	2	35	72	Mag-ES
FU2EL	U-Tube Fluorescent	Fluorescent (2) 48" U-bent ES lamp, Electronic ballast, NLO (0.85 < BF < 0.95)	2	34	63	Electronic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
FU2ES	U-Tube Fluorescent	Fluorescent, (2) U-Tube, ES lamp	1	35	72	Mag-STD
FU3EE	U-Tube Fluorescent	Fluorescent, (3) U-Tube, ES lamp	3	35	115	Mag-ES
H20/1	Halogen	Halogen, (1) 20W lamp	1	20	20	NA
H21/1	Halogen	Halogen, (1) 21W lamp	1	21	21	NA
H22/1	Halogen	Halogen, (1) 22W lamp	1	22	22	NA
H23/1	Halogen	Halogen, (1) 23W lamp	1	23	23	NA
H24/1	Halogen	Halogen, (1) 24W lamp	1	24	24	NA
H25/1	Halogen	Halogen, (1) 25W lamp	1	25	25	NA
H26/1	Halogen	Halogen, (1) 26W lamp	1	26	26	NA
H27/1	Halogen	Halogen, (1) 27W lamp	1	27	27	NA
H28/1	Halogen	Halogen, (1) 28W lamp	1	28	28	NA
H29/1	Halogen	Halogen, (1) 29W lamp	1	29	29	NA
H30/1	Halogen	Halogen, (1) 30W lamp	1	30	30	NA
H31/1	Halogen	Halogen, (1) 31W lamp	1	31	31	NA
H32/1	Halogen	Halogen, (1) 32W lamp	1	32	32	NA
H33/1	Halogen	Halogen, (1) 33W lamp	1	33	33	NA
H34/1	Halogen	Halogen, (1) 34W lamp	1	34	34	NA
H35/1	Halogen	Halogen, (1) 35W lamp	1	35	35	NA
H36/1	Halogen	Halogen, (1) 36W lamp	1	36	36	NA
H37/1	Halogen	Halogen, (1) 37W lamp	1	37	37	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
H38/1	Halogen	Halogen, (1) 38W lamp	1	38	38	NA
H39/1	Halogen	Halogen, (1) 39W lamp	1	39	39	NA
H40/1	Halogen	Halogen, (1) 40W lamp	1	40	40	NA
H41/1	Halogen	Halogen, (1) 41W lamp	1	41	41	NA
H42/1	Halogen	Halogen, (1) 42W lamp	1	42	42	NA
H43/1	Halogen	Halogen, (1) 43W lamp	1	43	43	NA
H44/1	Halogen	Halogen, (1) 44W lamp	1	44	44	NA
H45/1	Halogen	Halogen, (1) 45W lamp	1	45	45	NA
H46/1	Halogen	Halogen, (1) 46W lamp	1	46	46	NA
H47/1	Halogen	Halogen, (1) 47W lamp	1	47	47	NA
H48/1	Halogen	Halogen, (1) 48W lamp	1	48	48	NA
H49/1	Halogen	Halogen, (1) 49W lamp	1	49	49	NA
H50/1	Halogen	Halogen, (1) 50W lamp	1	50	50	NA
H51/1	Halogen	Halogen, (1) 51W lamp	1	51	51	NA
H52/1	Halogen	Halogen, (1) 52W lamp	1	52	52	NA
H53/1	Halogen	Halogen, (1) 53W lamp	1	53	53	NA
H54/1	Halogen	Halogen, (1) 54W lamp	1	54	54	NA
H55/1	Halogen	Halogen, (1) 55W lamp	1	55	55	NA
H56/1	Halogen	Halogen, (1) 56W lamp	1	56	56	NA
H57/1	Halogen	Halogen, (1) 57W lamp	1	57	57	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
H58/1	Halogen	Halogen, (1) 58W lamp	1	58	58	NA
H59/1	Halogen	Halogen, (1) 59W lamp	1	59	59	NA
H60/1	Halogen	Halogen, (1) 60W lamp	1	60	60	NA
H61/1	Halogen	Halogen, (1) 61W lamp	1	61	61	NA
H62/1	Halogen	Halogen, (1) 62W lamp	1	62	62	NA
H63/1	Halogen	Halogen, (1) 63W lamp	1	63	63	NA
H64/1	Halogen	Halogen, (1) 64W lamp	1	64	64	NA
H65/1	Halogen	Halogen, (1) 65W lamp	1	65	65	NA
H66/1	Halogen	Halogen, (1) 66W lamp	1	66	66	NA
H67/1	Halogen	Halogen, (1) 67W lamp	1	67	67	NA
H68/1	Halogen	Halogen, (1) 68W lamp	1	68	68	NA
H69/1	Halogen	Halogen, (1) 69W lamp	1	69	69	NA
H70/1	Halogen	Halogen, (1) 70W lamp	1	70	70	NA
H71/1	Halogen	Halogen, (1) 71W lamp	1	71	71	NA
H72/1	Halogen	Halogen, (1) 72W lamp	1	72	72	NA
H73/1	Halogen	Halogen, (1) 73W lamp	1	73	73	NA
H74/1	Halogen	Halogen, (1) 74W lamp	1	74	74	NA
H75/1	Halogen	Halogen, (1) 75W lamp	1	75	75	NA
H80/1	Halogen	Halogen, (1) 80W lamp	1	80	80	NA
H90/1	Halogen	Halogen, (1) 90W lamp	1	90	90	NA

FIXTURE CODE	**LAMP TYPE**	**DESCRIPTION**	**LAMP/ FIXT**	**WATT/ LAMP**	**WATT/ FIXT**	**BALLAST**
H100/1	Halogen	Halogen, (1) 100W lamp	1	100	100	NA
H150/1	Halogen	Halogen, (1) 150W lamp	1	150	150	NA
H250/1	Halogen	Halogen, (1) 250W lamp	1	250	250	NA
H300/1	Halogen	Halogen, (1) 300W lamp	1	300	300	NA
H500/1	Halogen	Halogen, (1) 500W lamp	1	500	500	NA
I7.5/1	Incandescent	Tungsten exit light, (1) 7.5 W lamp, used in night light application	1	7.5	8	NA
I10/1	Incandescent	Incandescent, (1) 10W lamp	1	10	10	NA
I11/1	Incandescent	Incandescent, (1) 11W lamp	1	11	11	NA
I12/1	Incandescent	Incandescent, (1) 12W lamp	1	12	12	NA
I13/1	Incandescent	Incandescent, (1) 13W lamp	1	13	13	NA
I14/1	Incandescent	Incandescent, (1) 14W lamp	1	14	14	NA
I15/1	Incandescent	Incandescent, (1) 15W lamp	1	15	15	NA
I16/1	Incandescent	Incandescent, (1) 16W lamp	1	16	16	NA
I17/1	Incandescent	Incandescent, (1) 17W lamp	1	17	17	NA
I18/1	Incandescent	Incandescent, (1) 18W lamp	1	18	18	NA
I19/1	Incandescent	Incandescent, (1) 19W lamp	1	19	19	NA
I20/1	Incandescent	Incandescent, (1) 20W lamp	1	20	20	NA
I21/1	Incandescent	Incandescent, (1) 21W lamp	1	21	21	NA
I22/1	Incandescent	Incandescent, (1) 22W lamp	1	22	22	NA
I23/1	Incandescent	Incandescent, (1) 23W lamp	1	23	23	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
I24/1	Incandescent	Incandescent, (1) 24W lamp	1	24	24	NA
I25/1	Incandescent	Incandescent, (1) 25W lamp	1	25	25	NA
I26/1	Incandescent	Incandescent, (1) 26W lamp	1	26	26	NA
I27/1	Incandescent	Incandescent, (1) 27W lamp	1	27	27	NA
I28/1	Incandescent	Incandescent, (1) 28W lamp	1	28	28	NA
I29/1	Incandescent	Incandescent, (1) 29W lamp	1	29	29	NA
I30/1	Incandescent	Incandescent, (1) 30W lamp	1	30	30	NA
I31/1	Incandescent	Incandescent, (1) 31W lamp	1	31	31	NA
I32/1	Incandescent	Incandescent, (1) 32W lamp	1	32	32	NA
I33/1	Incandescent	Incandescent, (1) 33W lamp	1	33	33	NA
I34/1	Incandescent	Incandescent, (1) 34W lamp	1	34	34	NA
I35/1	Incandescent	Incandescent, (1) 35W lamp	1	35	35	NA
I36/1	Incandescent	Incandescent, (1) 36W lamp	1	36	36	NA
I37/1	Incandescent	Incandescent, (1) 37W lamp	1	37	37	NA
I38/1	Incandescent	Incandescent, (1) 38W lamp	1	38	38	NA
I39/1	Incandescent	Incandescent, (1) 39W lamp	1	39	39	NA
I40/1	Incandescent	Incandescent, (1) 40W lamp – EISA Compliant	1	29	29	NA
I40S/1	Incandescent	Incandescent, (1) 40W lamp – Specialty	1	40	40	NA
I40E/1	Incandescent	Incandescent, (1) 40W ES lamp	1	34	34	NA
I40EL/1	Incandescent	Incandescent, (1) 40W ES/LL lamp	1	34	34	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
I41/1	Incandescent	Incandescent, (1) 41W lamp	1	41	41	NA
I42/1	Incandescent	Incandescent, (1) 42W lamp	1	42	42	NA
I43/1	Incandescent	Incandescent, (1) 43W lamp	1	43	43	NA
I44/1	Incandescent	Incandescent, (1) 44W lamp	1	44	44	NA
I45/1	Incandescent	Incandescent, (1) 45W lamp	1	45	45	NA
I46/1	Incandescent	Incandescent, (1) 46W lamp	1	46	46	NA
I47/1	Incandescent	Incandescent, (1) 47W lamp	1	47	47	NA
I48/1	Incandescent	Incandescent, (1) 48W lamp	1	48	48	NA
I49/1	Incandescent	Incandescent, (1) 49W lamp	1	49	49	NA
I50/1	Incandescent	Incandescent, (1) 50W lamp	1	50	50	NA
I51/1	Incandescent	Incandescent, (1) 51W lamp	1	51	51	NA
I52/1	Incandescent	Incandescent, (1) 52W lamp	1	52	52	NA
I53/1	Incandescent	Incandescent, (1) 53W lamp	1	53	53	NA
I54/1	Incandescent	Incandescent, (1) 54W lamp	1	54	54	NA
I55/1	Incandescent	Incandescent, (1) 55W lamp	1	55	55	NA
I56/1	Incandescent	Incandescent, (1) 56W lamp	1	56	56	NA
I57/1	Incandescent	Incandescent, (1) 57W lamp	1	57	57	NA
I58/1	Incandescent	Incandescent, (1) 58W lamp	1	58	58	NA
I59/1	Incandescent	Incandescent, (1) 59W lamp	1	59	59	NA
I60/1	Incandescent	Incandescent, (1) 60W lamp – EISA Compliant	1	43	43	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
I60S/1	Incandescent	Incandescent, (1) 60W lamp – Specialty	1	60	60	NA
I60E/1	Incandescent	Incandescent, (1) 60W ES lamp	1	52	52	NA
I60EL/1	Incandescent	Incandescent, (1) 60W ES/LL lamp	1	52	52	NA
I61/1	Incandescent	Incandescent, (1) 61W lamp	1	61	61	NA
I62/1	Incandescent	Incandescent, (1) 62W lamp	1	62	62	NA
I63/1	Incandescent	Incandescent, (1) 63W lamp	1	63	63	NA
I64/1	Incandescent	Incandescent, (1) 64W lamp	1	64	64	NA
I65/1	Incandescent	Incandescent, (1) 65W lamp	1	65	65	NA
I66/1	Incandescent	Incandescent, (1) 66W lamp	1	66	66	NA
I67/1	Incandescent	Incandescent, (1) 67W lamp	1	67	67	NA
I68/1	Incandescent	Incandescent, (1) 68W lamp	1	68	68	NA
I69/1	Incandescent	Incandescent, (1) 69W lamp	1	69	69	NA
I70/1	Incandescent	Incandescent, (1) 70W lamp	1	70	70	NA
I71/1	Incandescent	Incandescent, (1) 71W lamp	1	71	71	NA
I72/1	Incandescent	Incandescent, (1) 72W lamp	1	72	72	NA
I73/1	Incandescent	Incandescent, (1) 73W lamp	1	73	73	NA
I74/1	Incandescent	Incandescent, (1) 74W lamp	1	74	74	NA
I75/1	Incandescent	Incandescent, (1) 75W lamp – EISA Compliant	1	53	53	NA
I75S/1	Incandescent	Incandescent, (1) 75W lamp – Specialty	1	75	75	NA
I75E/1	Incandescent	Incandescent, (1) 75W ES lamp	1	67	67	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
I75EL/1	Incandescent	Incandescent, (1) 75W ES/LL lamp	1	67	67	NA
I80/1	Incandescent	Incandescent, (1) 80W lamp	1	80	80	NA
I85/1	Incandescent	Incandescent, (1) 85W lamp	1	85	85	NA
I90/1	Incandescent	Incandescent, (1) 90W lamp	1	90	90	NA
I93/1	Incandescent	Incandescent, (1) 93W lamp	1	93	93	NA
I95/1	Incandescent	Incandescent, (1) 95W lamp	1	95	95	NA
I100/1	Incandescent	Incandescent, (1) 100W lamp – EISA Compliant	1	72	72	NA
I100S/1	Incandescent	Incandescent, (1) 100W lamp – Specialty	1	100	100	NA
I100E/1	Incandescent	Incandescent, (1) 100W ES lamp	1	90	90	NA
I100EL/1	Incandescent	Incandescent, (1) 100W ES/LL lamp	1	90	90	NA
I110/1	Incandescent	Incandescent, (1) 110W lamp	1	110	110	NA
I116/1	Incandescent	Incandescent, (1) 116W lamp	1	116	116	NA
I120/1	Incandescent	Incandescent, (1) 120W lamp	1	120	120	NA
I125/1	Incandescent	Incandescent, (1) 125W lamp	1	125	125	NA
I130/1	Incandescent	Incandescent, (1) 130W lamp	1	130	130	NA
I135/1	Incandescent	Incandescent, (1) 135W lamp	1	135	135	NA
I150/1	Incandescent	Incandescent, (1) 150W lamp	1	150	150	NA
I150E/1	Incandescent	Incandescent, (1) 150W ES lamp	1	135	135	NA
I150EL/1	Incandescent	Incandescent, (1) 150W ES/LL lamp	1	135	135	NA
I160/1	Incandescent	Incandescent, (1) 160W lamp	1	160	160	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
I170/1	Incandescent	Incandescent, (1) 170W lamp	1	170	170	NA
I200/1	Incandescent	Incandescent, (1) 200W lamp	1	200	200	NA
I200L/1	Incandescent	Incandescent, (1) 200W LL lamp	1	200	200	NA
I250/1	Incandescent	Incandescent, (1) 250W lamp	1	250	250	NA
I300/1	Incandescent	Incandescent, (1) 300W lamp	1	300	300	NA
I400/1	Incandescent	Incandescent, (1) 400W lamp	1	400	400	NA
I448/1	Incandescent	Incandescent, (1) 448W lamp	1	448	448	NA
I500/1	Incandescent	Incandescent, (1) 500W lamp	1	500	500	NA
I750/1	Incandescent	Incandescent, (1) 750W lamp	1	750	750	NA
I1000/1	Incandescent	Incandescent, (1) 1000W lamp	1	1000	1000	NA
I1500/1	Incandescent	Incandescent, (1) 1500W lamp	1	1500	1500	NA
I2000/1	Incandescent	Incandescent, (1) 2000W lamp	1	2000	2000	NA
HPS35/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 35W lamp	1	35	46	NA
HPS50/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 50W lamp	1	50	66	NA
HPS70/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 70W lamp	1	70	95	NA
HPS100/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 100W lamp	1	100	138	NA
HPS150/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 150W lamp	1	150	188	NA
HPS200/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 200W lamp	1	200	250	NA
HPS250/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 250W lamp	1	250	295	NA
HPS310/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 310W lamp	1	310	365	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
HPS360/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 360W lamp	1	360	414	NA
HPS400/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 400W lamp	1	400	465	NA
HPS1000/1	High Intensity Discharge (HID)	High Pressure Sodium, (1) 1000W lamp	1	1000	1100	NA
MH20/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 20W lamp	1	20	23	Electronic
MH22/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 22W lamp	1	22	26	Electronic
MH32/1	High Intensity Discharge (HID)	Metal Halide, (1) 32W lamp, Magnetic ballast	1	32	42	Magnetic
MH39/1	High Intensity Discharge (HID)	Metal Halide, (1) 39W lamp, Magnetic ballast	1	39	51	Magnetic
MH39/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 39W lamp	1	39	44	Electronic
MH50/1	High Intensity Discharge (HID)	Metal Halide, (1) 50W lamp, Magnetic ballast	1	50	64	Magnetic
MH50/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 50W lamp	1	50	56	Electronic
MH70/1	High Intensity Discharge (HID)	Metal Halide, (1) 70W lamp, Magnetic ballast	1	70	91	Magnetic
MH70/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 70W lamp	1	70	78	Electronic
MH100/1	High Intensity Discharge (HID)	Metal Halide, (1) 100W lamp, Magnetic ballast	1	100	124	Magnetic
MH100/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 100W lamp	1	100	108	Electronic
MH125/1	High Intensity Discharge (HID)	Metal Halide, (1) 125W lamp, Magnetic ballast	1	125	148	Magnetic
MH150/1	High Intensity Discharge (HID)	Metal Halide, (1) 150W lamp, Magnetic ballast	1	150	183	Magnetic
MH150/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 150W lamp	1	150	163	Electronic
MH175/1	High Intensity Discharge (HID)	Metal Halide, (1) 175W lamp, Magnetic ballast	1	175	208	Magnetic
MH175/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 175W lamp	1	175	196	Electronic
MH200/1	High Intensity Discharge (HID)	Metal Halide, (1) 200W lamp, Magnetic ballast	1	200	228	Magnetic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
MH200/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 200W lamp	1	200	219	Electronic
MH250/1	High Intensity Discharge (HID)	Metal Halide, (1) 250W lamp, Magnetic ballast	1	250	288	Magnetic
MH250/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 250W lamp	1	250	275	Electronic
MH320/1	High Intensity Discharge (HID)	Metal Halide, (1) 320W lamp, Magnetic ballast	1	320	362	Magnetic
MH320/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 320W lamp	1	320	343	Electronic
MH350/1	High Intensity Discharge (HID)	Metal Halide, (1) 350W lamp, Magnetic ballast	1	350	391	Magnetic
MH350/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 350W lamp	1	350	375	Electronic
MH360/1	High Intensity Discharge (HID)	Metal Halide, (1) 360W lamp, Magnetic ballast	1	360	418	Magnetic
MH400/1	High Intensity Discharge (HID)	Metal Halide, (1) 400W lamp, Magnetic ballast	1	400	453	Magnetic
MH400/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 400W lamp	1	400	429	Electronic
MH450/1	High Intensity Discharge (HID)	Metal Halide, (1) 450W lamp, Magnetic ballast	1	450	499	Magnetic
MH450/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 450W lamp	1	450	486	Electronic
MH575/1	High Intensity Discharge (HID)	Metal Halide, (1) 575W lamp, Magnetic ballast	1	575	630	Magnetic
MH750/1	High Intensity Discharge (HID)	Metal Halide, (1) 750W lamp, Magnetic ballast	1	750	812	Magnetic
MH775/1	High Intensity Discharge (HID)	Metal Halide, (1) 775W lamp, Magnetic ballast	1	775	843	Magnetic
MH875/1	High Intensity Discharge (HID)	Metal Halide, (1) 875W lamp	1	875	939	Magnetic
MH1000/1	High Intensity Discharge (HID)	Metal Halide, (1) 1000W lamp, Magnetic ballast	1	1000	1078	Magnetic
MH1000/1-L	High Intensity Discharge (HID)	Metal Halide, (1) 1000W lamp	1	1000	1067	Electronic
MH1500/1	High Intensity Discharge (HID)	Metal Halide, (1) 1500W lamp, Magnetic ballast	1	1500	1605	Magnetic
MH1650/1	High Intensity Discharge (HID)	Metal Halide, (1) 1650W lamp	1	1650	1765	Magnetic

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
MH2000/1	High Intensity Discharge (HID)	Metal Halide, (1) 2000W lamp	1	2000	2140	Magnetic
MV40/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 40W lamp	1	40	50	NA
MV50/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 50W lamp	1	50	74	NA
MV75/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 75W lamp	1	75	93	NA
MV100/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 100W lamp	1	100	125	NA
MV160/1	High Intensity Discharge (HID)	Mercury Vapor, Self-Ballasted, (1) 160W self-ballasted lamp	1	160	160	NA
MV175/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 175W lamp	1	175	205	NA
MV250/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 250W lamp	1	250	290	NA
MV400/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 400W lamp	1	400	455	NA
MV700/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 700W lamp	1	700	780	NA
MV1000/1	High Intensity Discharge (HID)	Mercury Vapor, (1) 1000W lamp	1	1000	1075	NA
NEONEPH	Modular CFL and CCFL Fixtures	NEON E (lectonic ballast) P(edestrian) H(and)	1	26	26	NA
NEONEPP	Modular CFL and CCFL Fixtures	NEON E (lectonic ballast) P(edestrian) P(erson)	1	26	26	NA
NEONMPDW	Modular CFL and CCFL Fixtures	NEON M (agnetic transformer) P(edestrian) D(on't)W(alk)	1	81	81	NA
NEONMPH	Modular CFL and CCFL Fixtures	NEON M (agnetic transformer) P(edestrian) H(and)	1	45	45	NA
NEONMPP	Modular CFL and CCFL Fixtures	NEON M (agnetic transformer) P(edestrian) P(erson)	1	38	38	NA
TI12RB	Incandescent Traffic Signal	12” Red Incandescent Ball	1	149	149	NA

FIXTURE CODE	LAMP TYPE	DESCRIPTION	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT	BALLAST
TI12YB	Incandescent Traffic Signal	12” Yellow Incandescent Ball	1	149	149	NA
TI12GB	Incandescent Traffic Signal	12” Green Incandescent Ball	1	149	149	NA
TI8RB	Incandescent Traffic Signal	8” Red Incandescent Ball	1	86	86	NA
TI8YB	Incandescent Traffic Signal	8” Yellow Incandescent Ball	1	86	86	NA
TI8GB	Incandescent Traffic Signal	8” Green Incandescent Ball	1	86	86	NA
TI12RA	Incandescent Traffic Signal	12” Red Incandescent Arrow	1	128	128	NA
TI12YA	Incandescent Traffic Signal	12” Yellow Incandescent Arrow	1	128	128	NA
TI12GA	Incandescent Traffic Signal	12” Green Incandescent Arrow	1	128	128	NA
TILPEDCT	Incandescent Traffic Signal	Large (16” x 18”) Incandescent Pedestrian Signal with Countdown	1	149	149	NA
TISMPEDCT	Incandescent Traffic Signal	Small (12” x 12”) Incandescent Pedestrian Signal with Countdown	1	107	107	NA
TILGPED	Incandescent Traffic Signal	Large (16” x 18”) Incandescent Pedestrian Signal without Countdown	1	116	116	NA
TISMPED	Incandescent Traffic Signal	Small (12” x 12”) Incandescent Pedestrian Signal without Countdown	1	68	68	NA
TLED12RB	LED Traffic Signal	12” Red LED Ball	1	9	9	NA
TLED12YB	LED Traffic Signal	12” Yellow LED Ball	1	17	17	NA
TLED12GB	LED Traffic Signal	12” Green LED Ball	1	11	11	NA
TLED8RB	LED Traffic Signal	8” Red LED Ball	1	6	6	NA
TLED8YB	LED Traffic Signal	8” Yellow LED Ball	1	12	12	NA

FIXTURE CODE	**LAMP TYPE**	**DESCRIPTION**	**LAMP/ FIXT**	**WATT/ LAMP**	**WATT/ FIXT**	**BALLAST**
TLED8GB	LED Traffic Signal	8” Green LED Ball	1	6	6	NA
TLED12RA	LED Traffic Signal	12” Red LED Arrow	1	5	5	NA
TLED12YA	LED Traffic Signal	12” Yellow LED Arrow	1	8	8	NA
TLED12GA	LED Traffic Signal	12” Green LED Arrow	1	5	5	NA
TLEDLPEDCT	LED Traffic Signal	Large (16” x 18”) LED Pedestrian Signal with Countdown	1	17	17	NA
TLEDSMPEDCT	LED Traffic Signal	Small (12” x 12”) LED Pedestrian Signal with Countdown	1	10	10	NA
TLEDLGPED	LED Traffic Signal	Large (16” x 18”) LED Pedestrian Signal without Countdown	1	6	6	NA
TLEDSMPED	LED Traffic Signal	Small (12” x 12”) LED Pedestrian Signal without Countdown	1	5	5	NA
Removed	Removed	Fixture completely removed from service	0	0	0	NA

Appendix F: Lighting Power Densities

Table F1: ASHRAE 90.1-2007 Lighting Power Densities (LPD) – Building Area Method[14]

Building Area Type	Entire Building LPD (W/ft^2)
Automotive Facility	0.9
Convention Center	1.2
Courthouse	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Health-Care Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2

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[14] ANSI/ASHRAE/IESNA Standard 90.1-2007, Table 9.5.1

Building Area Type	Entire Building LPD (W/ft^2)
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

Table F2: ASHRAE 90.1-2007 Lighting Power Densities (LPD) – Space-by-Space Method by Space Types[15]

Common Space Types[16]	LPD (W/ft^2)
Office—Enclosed	1.1
Office—Open Plan	1.1
Conference/Meeting/Multipurpose	1.3
Classroom/Lecture/Training	1.4
For Penitentiary	1.3
Lobby	1.3
For Hotel	1.1
For Performing Arts Center	3.3
For Motion Picture Theater	1.1
Audiences/Seating Area	0.9
For Gymnasium	0.4
For Exercise Center	0.3
Audiences/Seating Area (Continued)	0.9
For Convention Center	0.7
For Penitentiary	0.7
For Religious Building	1.7
For Sports Arena	0.4
For Performing Arts Theater	2.6
For Motion Picture Theater	1.2
For Transportation	0.5
Atrium—First Three Floors	0.6
Atrium—Each Additional Floor	0.2
Lounge/Recreation	1.2
For Hospital	0.8

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[15] ANSI/ASHRAE/IESNA Standard 90.1-2007, Table 9.6.1

[16] In cases where both a common space type and a building-specific space type are listed, the building-specific space type shall apply.

Common Space Types[16]	**LPD (W/ft^2)**
Dining Area	0.9
For Penitentiary	1.3
For Hotel	1.3
For Motel	1.2
For Bar Lounge/Leisure Dining	1.4
For Family Dining	2.1
Food Preparation	1.2
Laboratory	1.4
Restrooms	0.9
Dressing/Locker/Fitting Room	0.6
Corridor/Transition	0.5
For Hospital	1.0
For Manufacturing Facility	0.5
Stairs—Active	0.6
Active Storage	0.8
For Hospital	0.9
Inactive Storage	0.3
For Museum	0.8
Electrical/Mechanical	1.5
Workshop	1.9
Sales Area (for accent lighting)	1.7

Table F3: ASHRAE 90.1-2007 Lighting Power Densities (LPD) – Space-by-Space Method by Building-Specific Space Types[17]

Building-Specific Space Types[18]	LPD (W/ft^2)
Gymnasium/Exercise Center	
Playing Area	1.4
Exercise Area	0.9
Courthouse/Police Station/Penitentiary	
Courtroom	1.9
Confinement Cells	0.9
Judges' Chambers	1.3
Fire Stations	
Engine Room	0.8
Sleeping Quarters	0.3
Post Office—Sorting Area	1.2
Convention Center—Exhibit Space	1.3
Library	
Card File and Cataloging	1.1
Stacks	1.7
Reading Area	1.2
Hospital	
Emergency	2.7
Recovery	0.8
Nurses' Station	1.0
Exam/Treatment	1.5
Pharmacy	1.2
Patient Room	0.7
Operating Room	2.2
Nursery	0.6
Medical Supply	1.4
Physical Therapy	0.9
Radiology	0.4
Laundry—Washing	0.6
Automotive—Service/Repair	0.7
Manufacturing	
Low Bay (< 25 ft. Floor to Ceiling Height)	1.2

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[17] ANSI/ASHRAE/IESNA Standard 90.1-2007, Table 9.6.1

[18] In cases where both a common space type and a building-specific space type are listed, the building-specific space type shall apply.

Building-Specific Space Types[18]	**LPD (W/ft^2)**
Manufacturing (Continued)	
High Bay (≥ 25 ft. Floor to Ceiling Height)	1.7
Detailed Manufacturing	2.1
Equipment Room	1.2
Control Room	0.5
Hotel/Motel Guest Rooms	1.1
Dormitory—Living Quarters	1.1
Museum	
General Exhibition	1.0
Restoration	1.7
Bank/Office—Banking Activity Area	1.5
Religious Building	
Worship Pulpit, Choir	2.4
Fellowship Hall	0.9
Retail	
Sales Area (for accent lighting)	1.7
Mall Concourse	1.7
Sports Arena	
Ring Sports Area	2.7
Court Sports Area	2.3
Indoor Playing Field Area	1.4
Warehouse	
Fine Material Storage	1.4
Medium/Bulky Material Storage	0.9
Parking Garage—Garage Area	0.2
Transportation	
Airport—Concourse	0.6
Air/Train/Bus—Baggage Area	1.0
Terminal—Ticket Counter	1.5

Table F4: ASHRAE 90.1-2007 Lighting Power Densities (LPD) – Building Exteriors[19]

Tradable/ Nontradable	Exterior Space Type	LPD
Tradable Surfaces	**Uncovered Parking Areas**	
	Parking lots and drives	0.15 W/ft^2
	Building Grounds	
	Walkways < 10 ft. wide	1.0 W/linear ft.
	Walkways ≥ 10 ft. wide, Plaza areas, and Special feature areas	0.2 W/ft^2
	Stairways	1.0 W/ft^2
	Building Entrances and Exits	
	Main entries	30 W/linear ft. (of door width)
	Other doors	20 W/linear ft. (of door width)
	Canopies and Overhangs	
	Canopies (free standing, attached, & overhangs)	1.25 W/ft^2
	Outdoor Sales	
	Open areas (including vehicle sales lots)	0.5 W/ft^2
	Street frontage for vehicle sales lots (in addition to above)	20 W/linear ft.
Nontradable Surfaces	**Building Facades**	
	For each illuminated wall or surface OR	0.2 W/ft^2
	For each illuminated wall or surface length	5.0 W/linear ft.
	Automated Teller Machines and Night Depositories	
	Per location	270 W
	Per additional ATM per location	90 W
	Entrances and Gatehouse Inspection Stations at Guarded Facilities	
	Uncovered areas (for covered areas use Canopies/Overhangs)	1.25 W/ft^2
	Loading Areas for Emergency Service Vehicles	
	Uncovered areas (for covered areas use Canopies/Overhangs)	0.5 W/ft^2
	Drive-up Windows at Fast Food Restaurants	
	Per drive-through	400 W
	Parking Near 24-hour Retail Entrances	
	Per main entry	800 W

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[19] ANSI/ASHRAE/IESNA Standard 90.1-2007, Table 9.4.5

Appendix G: Estimation of Gas Peak Day Savings

Typical Meteorological Year (TMY) data used in building simulation models to estimate energy savings for certain measures in the TRM are not appropriate for estimating peak day gas savings consistent with gas utility capacity planning procedures. TMY datasets are drawn from the past 15-30 years of weather data, with months selected to represent the most typical conditions seen in the recent historical record for the weather station for which the TMY series is being developed. The "typical month" format of TMY data includes commonly observed temperature and wind extremes, whereas utility gas planning models identify "peak days" by applying the most extreme temperature and wind conditions observed over the past 25 to 30 years.

For those measures for which energy savings have been estimated using building simulation models, peak day gas savings are estimated using a regression analysis that relates the daily gas savings predicted by the simulation models to the more extreme conditions that drive gas utility capacity planning. Simulations performed for early versions of the TRM relied on TMY2 data: measures incorporated later, or updated in subsequent versions of the TRM, have been simulated using TMY3 data. The regression approach used to estimate gas savings under peak day conditions is independent of the source of TMY data used in simulation.

Overview

The regression analysis relates model-estimated daily gas savings for a given energy efficiency measure to weather conditions on that day in the TMY data used in the simulation that produced the savings estimates. The regression is performed for each measure in each weather zone: the peak gas savings due to each measure on a 25 or 30-year peak day are then estimated by extrapolating from the derived relationship.

Time series of hourly heating degree days (HDD) and average daily wind speeds (W) were constructed from the TMY files for each weather zone. The heating degree days (HDD) were found by subtracting the daily average temperature (in degrees Fahrenheit) from 65° F. (All days with an average temperature above 65° F were assigned an HDD of 0.) The hourly gas savings for each measure in each weather zone are summed for each day to give daily total gas savings (G).

Regression

It was found that daily gas savings are typically well described as a quadratic function in the two variables, heating degree days (HDD) and daily average wind speed (W):

$$G = A \times HDD + B \times HDD^2 + C \times W + D \times W^2 + E \times HDD \times W + F$$

(1)

The coefficients A, B, C, D, E, and F are found using Microsoft Excel's Regression tool with a Y-input of G and X-inputs of HDD, HDD^2, W, W^2, and HDD × W. Only data points from days on which the average temperature in the TMY data was below 65° F, i.e., only data points from days with HDD>0, were used in the regression.

Once the coefficients have been estimated for a given measure in a given weather zone, Equation 1 is used to calculate the predicted daily gas savings for that measure by applying the estimated coefficients to the HDD and average wind speed of the 25- or 30-year peak day for that weather zone. The peak day HDD and wind speed values, as supplied by the gas utilities, are provided in Table G1, below. For Zone 8, three different peak days were provided, two of which did not specify an average wind speed. The average of daily wind speeds for days with HDD > 0 in the TMY data was used to calculate the predicted gas savings for those two peak days.

Table G1: Design Day Weather Conditions for Arkansas Gas Utilities

Zone	Region	Gas Company	Day	Years Hist.	HDD	AVG. Wind Speed (knots)	City
9	Northern	Black Hills	12/25/1983	25	71	12	Fayetteville[20]
8	NE/NC	Black Hills	12/22/1989	25	63	14	Blytheville
8	NE/NC	AOG	12/24/1983	25	61	7	Fort Smith
8	NE/NC	CP	12/22/1989	30	63	7	Jonesboro
7	Central	CP	12/24/1983	30	59	14	Little Rock - Adams Field
6	South	CP	12/25/1983	30	56	7	El Dorado

Example:

Using the simulation model outputs and weather data for the wall insulation measure in Zone 6, the regression described above produces the values A = 0.048, B = 0.00013, C = 0.013, D = -0.00067, E = 0.0014, and F = 0.23. The predicted peak day gas savings are calculated, using 56 for HDD and 7 for the wind speed (from the table), as:

$$G = 0.048 \times 56 + 0.00013 \times 56^2 + 0.013 \times 7 - 0.00067 \times 7^2 + 0.0014 \times 56 \times 7 + 0.23 \\ = 3.93$$

The peak day gas savings (G) are then divided by the wall area to give the value reported in the deemed savings report. (The peak gas savings for wall insulation is reported in therms per square foot. The wall area used in the calculation is 952 square feet, so the reported value is 3.93/952 = 0.00413.)

The relationships found using this method were very good in most cases. The coefficient of determination, R^2, which gives the fraction of the variability in the data that is accounted for by the derived relationship, is a good indicator of the reliability of the predictions made with this relationship. The regressions for most modeled measures had coefficients of determination above 0.5, indicating that the majority of the variability in the data was described by the specified explanatory variables.[21]

To illustrate how the coefficient of determination relates to the reliability of the fit, a graph of daily gas savings versus heating degree days is provided in Figure G1 for the wall insulation measure in

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[20] Consistent with Table 1: Arkansas Weather Zones and Design Weather Data, data for Rogers is taken from Fayetteville as data specific to Rogers are not available.

[21] An alternate method was used to establish peak day gas savings for those measures for which the regression fits were not good (R-squared coefficient below 0.5). It is discussed in the last section of this appendix.

Zone 7. It shows the daily savings as estimated by the building simulation model (indicated as an 'x' in the figures) and the projected savings according to the derived regression relationship (indicated as a dot [•]). The projected savings are shown for those days used in the simulations as well as for the relevant gas utilities' design day weather conditions from Table G1.

For relationships with coefficients of determination very close to the number 1, the calculated points lie very close to the projected points. For the lower coefficients of determination, there is more noticeable error, but the projections still reasonably reflect the general flow of the simulated values.

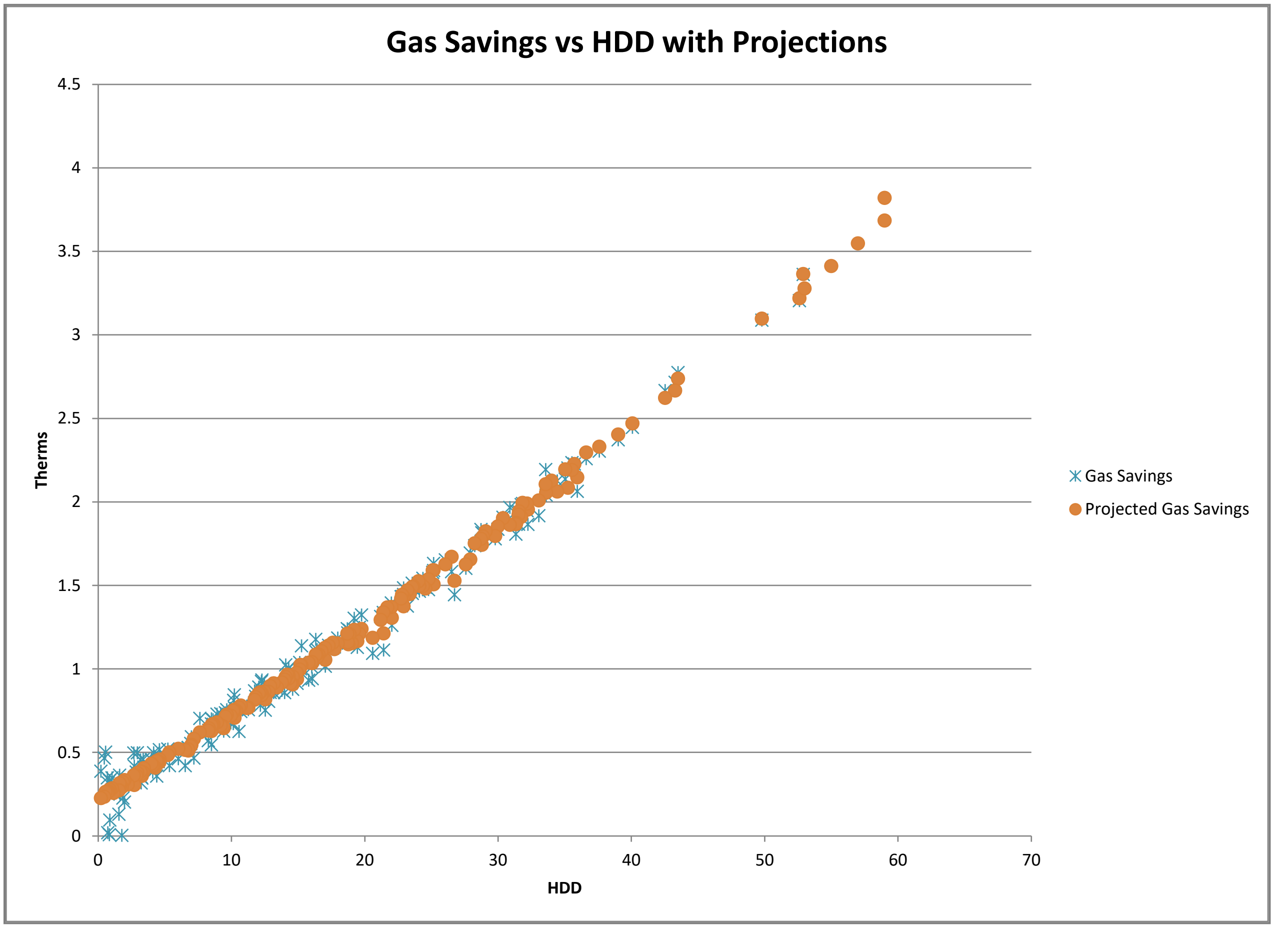

Figure G1: Gas Savings vs. HDD with Projections

Regression Results

Coefficients of determination and regression variable coefficients for the measures for which regression ***models*** have been used to estimate peak day gas savings are provided in the following tables.

Table G2: Coefficients of Determination (R^2)

Measure	Zone 6	Zone 7	Zone 8	Zone 9
Air Infiltration	0.988	0.995	0.994	0.995
R19 Attic Knee Wall	0.931	0.960	0.957	0.955
R30 Attic Knee Wall	0.930	0.960	0.957	0.955
R38 Ceiling Insulation (R0-1 Base)	0.878	0.924	0.907	0.967
R38 Ceiling Insulation (R2-4 Base)	0.864	0.918	0.865	0.962
R38 Ceiling Insulation (R5-8 Base)	0.864	0.887	0.907	0.959
R38 Ceiling Insulation (R9-14 Base)	0.861	0.857	0.704	0.958
R38 Ceiling Insulation (R15-22 Base)	0.784	0.75	0.592	0.953
R49 Ceiling Insulation (R0-1 Base)	0.939	0.965	0.961	0.951
R49 Ceiling Insulation (R2-4 Base)	0.931	0.959	0.955	0.943
R49 Ceiling Insulation (R5-8 Base)	0.928	0.956	0.952	0.939
R49 Ceiling Insulation (R9-14 Base)	0.924	0.954	0.948	0.937
R49 Ceiling Insulation (R15-22 Base)	0.91	0.946	0.941	0.926
Crawlspace Insulation	0.811	0.772	0.797	0.693
ENERGY STAR® Windows Double to Double	0.640	0.829	0.659	0.883
ENERGY STAR® Windows Single to Double	0.585	0.799	0.703	0.734
Gas Furnace Replacement ENERGY STAR®	0.906	0.936	0.939	0.95
Gas Furnace Replacement Federal Tax Credit	0.906	0.936	0.939	0.95
Gas Furnace Tune-Up	0.906	0.936	0.939	0.95
Radiant Barrier R12	0.53	0.649	0.387	0.706
Radiant Barrier R22	0.353	0.364	0.419	0.669
R19 Roof Deck Insulation (R0-1 Base)	0.948	0.974	0.970	0.964
R19 Roof Deck Insulation (R2-4 Base)	0.940	0.974	0.971	0.962
R19 Roof Deck Insulation (R5-8 Base)	0.928	0.973	0.971	0.959
R19 Roof Deck Insulation (R9-14 Base)	0.902	0.964	0.964	0.945
R19 Roof Deck Insulation R15-22 Base)	0.836	0.939	0.931	0.893
R38 Roof Deck Insulation (R0-1 Base)	0.943	0.971	0.967	0.959
R38 Roof Deck Insulation (R2-4 Base)	0.934	0.970	0.967	0.955
R38 Roof Deck Insulation (R5-8 Base)	0.925	0.970	0.967	0.953

Measure	Zone 6	Zone 7	Zone 8	Zone 9
R38 Roof Deck Insulation (R9-14 Base)	0.910	0.967	0.965	0.946
R38 Roof Deck Insulation (R15-22 Base)	0.875	0.956	0.955	0.923
R13 Wall Insulation	0.973	0.987	0.984	0.986
R23 Wall Insulation	0.973	0.987	0.984	0.953

Table G3: Regression Coefficients by Measure

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
Air Infiltration	Intercept	0.32329	0.22621	0.35788	0.03526
	HDD	0.02374	0.0168	0.01793	0.02895
	HDD^2	0.00094	0.00086	0.00085	0.00076
	AVG Wind Speed (knots)	-0.08053	-0.04536	-0.08976	-0.0249
	(AVG Wind Speed)^2	0.00737	0.00424	0.00762	0.00315
	HDD x AVG Wind Speed	0.00206	0.00222	0.00174	0.00164
R19 Attic Knee Wall	Intercept	0.08138	0.05323	0.05827	0.00835
	HDD	0.00828	0.00939	0.00833	0.01125
	HDD^2	0.00003	0.00004	0.00002	0
	AVG Wind Speed (knots)	-0.0065	-0.00171	-0.00141	0.00096
	(AVG Wind Speed)^2	-0.00004	-0.00002	-0.00036	0.00005
	HDD x AVG Wind Speed	0.00027	0.00005	0.00032	-0.00004
R30 Attic Knee Wall	Intercept	0.08597	0.05627	0.06148	0.0087
	HDD	0.00878	0.00996	0.00884	0.01193
	HDD^2	0.00003	0.00004	0.00002	0
	AVG Wind Speed (knots)	-0.00678	-0.00178	-0.00143	0.00105
	(AVG Wind Speed)^2	-0.00006	-0.00002	-0.00038	0.00006
	HDD x AVG Wind Speed	0.00029	0.00006	0.00034	-0.00004
R38 Ceiling Insulation (R0 - R1 Base)	Intercept	0.34131	0.21702	0.38637	0.09136
	HDD	0.05137	0.04461	0.03967	0.11867
	HDD^2	0.00061	0.00098	0.00065	0.00022
	AVG Wind Speed (knots)	-0.02309	0.00309	-0.04476	0.01446
	(AVG Wind Speed)^2	0.00071	-0.00064	-0.00022	0.0005
	HDD x AVG Wind Speed	-0.00068	-0.00043	0.00233	-0.00038

Measure	**Variable**	**Zone 6**	**Zone 7**	**Zone 8**	**Zone 9**
R38 Ceiling Insulation (R2 - R4 Base)	Intercept	0.22286	0.20072	0.3533	0.05007
	HDD	0.03734	0.02676	0.03156	0.06961
	HDD^2	0.00028	0.00061	0.00037	0.00004
	AVG Wind Speed (knots)	-0.0134	-0.00668	-0.07097	0.00678
	(AVG Wind Speed)^2	0.00029	-0.00031	0.00338	0.00038
	HDD x AVG Wind Speed	-0.00052	0.00017	0.00098	-0.0004
R38 Ceiling Insulation ((R5 - R8 Base)	Intercept	0.14271	0.17964	0.38637	0.03864
	HDD	0.02556	0.01796	0.03967	0.04265
	HDD^2	0.00006	0.00029	0.00065	0
	AVG Wind Speed (knots)	-0.01116	-0.01849	-0.04476	0.00252
	(AVG Wind Speed)^2	0.00025	0.00043	-0.00022	0.00031
	HDD x AVG Wind Speed	-0.0002	0.00046	0.00233	-0.00028
R38 Ceiling Insulation (R9 - R14 Base)	Intercept	0.09739	0.09341	0.12369	0.03508
	HDD	0.01678	0.01352	0.01962	0.02586
	HDD^2	0	0.00012	0.00004	0
	AVG Wind Speed (knots)	-0.00962	-0.00612	-0.03401	0.00015
	(AVG Wind Speed)^2	0.00031	-0.00023	0.00249	0.00025
	HDD x AVG Wind Speed	-0.00014	0.00041	-0.00049	-0.00016
R38 Ceiling Insulation (R15 - R22 Base)	Intercept	0.04279	0.04859	0.08668	0.00844
	HDD	0.00868	0.00863	0.01317	0.01322
	HDD^2	-0.00001	0	-0.00004	-0.00001
	AVG Wind Speed (knots)	-0.00279	-0.00507	-0.0308	0.00086
	(AVG Wind Speed)^2	0.00001	-0.0002	0.0021	0.0001
	HDD x AVG Wind Speed	-0.0002	0.00039	-0.00001	-0.00012
R49 Ceiling Insulation (R0 - R1 Base)	Intercept	0.93274	0.61208	0.68316	0.30108
	HDD	0.08498	0.09868	0.08885	0.10599
	HDD^2	0.00048	0.00057	0.00031	0.00034
	AVG Wind Speed (knots)	-0.06950	-0.01701	-0.02132	0.02937
	(AVG Wind Speed)^2	-0.00067	-0.00034	-0.00358	-0.00080
	HDD x AVG Wind Speed	0.00314	0.00069	0.00361	0.00057

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
R49 Ceiling Insulation (R2 - R4 Base)	Intercept	0.52247	0.34253	0.38130	0.15285
	HDD	0.05212	0.05986	0.05431	0.06373
	HDD^2	0.00017	0.00023	0.00008	0.00010
	AVG Wind Speed (knots)	-0.03786	-0.01060	-0.01322	0.02047
	(AVG Wind Speed)^2	-0.00059	-0.00017	-0.00200	-0.00067
	HDD x AVG Wind Speed	0.00161	0.00022	0.00188	0.00013
R49 Ceiling Insulation ((R5 - R8 Base)	Intercept	0.33577	0.22763	0.24665	0.09643
	HDD	0.03364	0.03762	0.03472	0.04018
	HDD^2	0.00006	0.00011	0.00002	0.00004
	AVG Wind Speed (knots)	-0.02689	-0.00996	-0.01144	0.01303
	(AVG Wind Speed)^2	-0.00013	0.00004	-0.00104	-0.00046
	HDD x AVG Wind Speed	0.00095	0.00013	0.00110	0.00004
R49 Ceiling Insulation (R9 - R14 Base)	Intercept	0.23309	0.16444	0.17140	0.07298
	HDD	0.02162	0.02355	0.02227	0.02542
	HDD^2	0.00001	0.00006	0.00000	0.00002
	AVG Wind Speed (knots)	-0.02165	-0.00951	-0.01022	0.00696
	(AVG Wind Speed)^2	0.00022	0.00016	-0.00048	-0.00026
	HDD x AVG Wind Speed	0.00063	0.00013	0.00068	0.00004
R49 Ceiling Insulation (R15 - R22 Base)	Intercept	0.11436	0.07803	0.08231	0.02982
	HDD	0.01210	0.01328	0.01239	0.01429
	HDD^2	0.00001	0.00003	-0.00001	0.00000
	AVG Wind Speed (knots)	-0.00900	-0.00343	-0.00367	0.00493
	(AVG Wind Speed)^2	-0.00010	-0.00001	-0.00039	-0.00018
	HDD x AVG Wind Speed	0.00028	0.00002	0.00036	-0.00002
Crawlspace Insulation	Intercept	-0.07946	-0.27065	-0.20881	-0.06864
	HDD	0.04504	0.05127	0.05018	0.04351
	HDD^2	-0.00020	-0.00021	-0.00030	-0.00028
	AVG Wind Speed (knots)	0.06410	0.09567	0.08442	0.06301
	(AVG Wind Speed)^2	-0.00340	-0.00490	-0.00510	-0.00299
	HDD x AVG Wind Speed	-0.00155	-0.00273	-0.00170	-0.00187

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
ENERGY STAR® Windows Double to Double	Intercept	-0.02108	-0.02894	0.00473	0.06349
	HDD	-0.00248	-0.00174	-0.00062	-0.00767
	HDD^2	0.00021	0.00035	0.00017	0.00038
	AVG Wind Speed (knots)	0.01635	0.00659	-0.00746	-0.00357
	(AVG Wind Speed)^2	-0.00229	-0.00033	0.0001	-0.00065
	HDD x AVG Wind Speed	0.00117	0.00015	0.00082	0.00148
ENERGY STAR® Windows Single to Double	Intercept	-0.03729	0.00105	0.00733	0.05211
	HDD	-0.00595	-0.00602	-0.0054	-0.00748
	HDD^2	0.00034	0.00046	0.00035	0.00029
	AVG Wind Speed (knots)	0.02488	-0.00234	-0.00905	-0.0068
	(AVG Wind Speed)^2	-0.00346	-0.00008	0.00007	-0.00135
	HDD x AVG Wind Speed	0.00165	0.00068	0.00113	0.00255
Radiant Barrier R12	Intercept	0.03156	0.00394	0.03209	0.00561
	HDD	-0.00056	0.00009	-0.00226	0.00318
	HDD^2	0.00006	0.00012	0.0001	0.00003
	AVG Wind Speed (knots)	-0.00268	0.00204	-0.00147	-0.0026
	(AVG Wind Speed)^2	-0.00035	-0.00016	-0.00044	0.00015
	HDD x AVG Wind Speed	0.00027	-0.00016	0.00026	-0.00006
Radiant Barrier R22	Intercept	0.01932	0.01335	0.04388	0.00087
	HDD	0.00008	0.00041	-0.00333	0.00143
	HDD^2	0.00003	0.00006	0.00017	0.00003
	AVG Wind Speed (knots)	-0.0024	-0.00331	-0.0082	-0.00171
	(AVG Wind Speed)^2	-0.00014	0.00022	0.00051	0.00011
	HDD x AVG Wind Speed	0.00005	-0.00015	-0.00009	-0.00005
R19 Roof Deck Ins. (R0-1 Base)	Intercept	0.8960	0.6830	0.7480	0.4860
	HDD	0.0870	0.0930	0.0850	0.0950
	HDD^2	0.0010	0.0010	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0580	-0.0220	-0.0320	0.0150
	(AVG Wind Speed)^2	0.0000	0.0000	-0.0020	0.0000
	HDD x AVG Wind Speed	0.0030	0.0020	0.0040	0.0020

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
R19 Roof Deck Ins. (R2-4 Base)	Intercept	0.5290	0.4040	0.4530	0.3450
	HDD	0.0510	0.0530	0.0480	0.0520
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0390	-0.0130	-0.0240	0.0010
	$(AVG Wind Speed)^2$	0.0010	0.0000	0.0000	0.0000
	HDD x AVG Wind Speed	0.0020	0.0010	0.0020	0.0010
R19 Roof Deck Ins. (R5-8 Base)	Intercept	0.3760	0.2770	0.3170	0.2940
	HDD	0.0300	0.0300	0.0280	0.0280
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0370	-0.0090	-0.0220	-0.0090
	$(AVG Wind Speed)^2$	0.0020	0.0000	0.0000	0.0000
	HDD x AVG Wind Speed	0.0010	0.0010	0.0020	0.0010
R19 Roof Deck Ins. (R9-14 Base)	Intercept	0.2950	0.2060	0.2420	0.2690
	HDD	0.0170	0.0160	0.0150	0.0130
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0380	-0.0070	-0.0210	-0.0160
	$(AVG Wind Speed)^2$	0.0030	0.0000	0.0010	0.0010
	HDD x AVG Wind Speed	0.0010	0.0010	0.0010	0.0010
R19 Roof Deck Ins. (R15-22 Base)	Intercept	0.2080	0.1140	0.2040	0.2240
	HDD	0.0060	0.0050	0.0010	0.0020
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0330	0.0000	-0.0230	-0.0180
	$(AVG Wind Speed)^2$	0.0030	0.0000	0.0010	0.0010
	HDD x AVG Wind Speed	0.0010	0.0010	0.0010	0.0010
R38 Roof Deck Ins. (R0-1 Base)	Intercept	0.8930	0.6860	0.7540	4.4540
	HDD	0.0930	0.1000	0.0900	1.0350
	HDD^2	0.0010	0.0010	0.0000	0.0040
	AVG Wind Speed (knots)	-0.0500	-0.0220	-0.0310	0.2240
	$(AVG Wind Speed)^2$	-0.0010	0.0000	-0.0020	-0.0070
	HDD x AVG Wind Speed	0.0030	0.0010	0.0040	0.0150

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
R38 Roof Deck Ins. (R2-4 Base)	Intercept	0.5260	0.4080	0.4590	0.3050
	HDD	0.0570	0.0590	0.0540	0.0600
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0320	-0.0120	-0.0240	0.0090
	$(AVG Wind Speed)^2$	0.0000	0.0000	-0.0010	0.0000
	HDD x AVG Wind Speed	0.0020	0.0010	0.0030	0.0010
R38 Roof Deck Ins. (R5-8 Base)	Intercept	0.3740	0.2810	0.3230	0.2530
	HDD	0.0360	0.0360	0.0340	0.0360
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0300	-0.0090	-0.0210	-0.0020
	$(AVG Wind Speed)^2$	0.0010	0.0000	0.0000	0.0000
	HDD x AVG Wind Speed	0.0010	0.0010	0.0020	0.0010
R38 Roof Deck Ins. (R9-14 Base)	Intercept	0.2920	0.2100	0.2480	0.2280
	HDD	0.0230	0.0220	0.0210	0.0210
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0300	-0.0070	-0.0200	-0.0080
	$(AVG Wind Speed)^2$	0.0020	0.0000	0.0010	0.0000
	HDD x AVG Wind Speed	0.0010	0.0010	0.0010	0.0010
R38 Roof Deck Ins. (R15-22 Base)	Intercept	0.2050	0.1180	0.2160	0.1830
	HDD	0.0120	0.0120	0.0060	0.0100
	HDD^2	0.0000	0.0000	0.0000	0.0000
	AVG Wind Speed (knots)	-0.0260	0.0010	-0.0240	-0.0110
	$(AVG Wind Speed)^2$	0.0020	0.0000	0.0010	0.0000
	HDD x AVG Wind Speed	0.0010	0.0010	0.0010	0.0010
R13 Wall Insulation	Intercept	0.25318	0.14165	0.18163	0.02344
	HDD	0.04133	0.04527	0.04164	0.05622
	HDD^2	0.00015	0.00018	0.00012	0.00007
	AVG Wind Speed (knots)	-0.00089	0.02307	0.01984	0.0237
	$(AVG Wind Speed)^2$	-0.00042	-0.00141	-0.00202	-0.00077
	HDD x AVG Wind Speed	0.00114	0.00042	0.00118	0.00033

Measure	Variable	Zone 6	Zone 7	Zone 8	Zone 9
R23 Wall Insulation	Intercept	0.32563	0.18556	0.24193	0.24391
	HDD	0.04920	0.05616	0.05175	0.05234
	HDD^2	0.00013	0.00011	0.00004	0.00008
	AVG Wind Speed (knots)	0.00998	0.03127	0.02481	0.02419
	(AVG Wind Speed)^2	-0.00151	-0.00185	-0.00259	-0.00146
	HDD x AVG Wind Speed	0.00124	0.00031	0.00139	0.00080

Alternate (fall-back) Method for Estimating Peak Day Gas Savings

Regressions for certain measures, particularly those that affect the solar heat gain in buildings, had low coefficients of determination and thus did not provide reasonable predictions of peak day gas savings. Some measures were also not well-described by a quadratic function in heating degree days, leading to illogical predictions. This is not surprising for measures that primarily affect the solar heat gain of buildings. The statistical method attempts to explain gas usage in terms of wind speed and temperature only, which are not necessarily correlated to the solar indicators that affect solar heat gain. Therefore, by not accounting for solar heat gains directly, this statistical method produced low coefficients of determination.

For measures for which regressions produced poor fits ($R^2 < 0.5$, as described above), peak gas impacts were estimated using the simulated daily savings from extreme days identified in the TMY3 weather data that were consistent with expectations of coincident peak gas usage days. Given that TMY3 weather data are less extreme than gas utility peak planning data, this is a conservative approach; however, it should be noted that many of the affected measures actually increase gas usage such that more extreme winter weather conditions could translate into greater gas consumption (more negative gas savings) than what is captured by the deemed peak gas savings values reported in this document.

In these cases, peak day gas savings were estimated from the sum total of the hourly gas savings for the coldest weekday in January according to the TMY data. Peak days utilized in those cases were the following:

Table G4: Peak Days from TMY3 Data by Climate Zone:

Peak-Therm Days	Julian Date	Day Name	Month	Day Number	Min Dry Bulb Temp (deg F)
Zone 9 (Rogers)	11	Fri	January	11	2
Zone 8	19	Wed	January	19	8
Zone 7	11	Tue	January	11	3
Zone 6	13	Thu	January	13	24

Appendix H: Peak Demand Multipliers Methodology for Arkansas Weatherization Program

Introduction

The Arkansas Weatherization Program, (AWP) is a unique energy efficiency program targeting the hard-to-reach sector. The Residential Deemed Savings Estimates included in the current TRM may be used for the Arkansas Weatherization Program (AWP) measures, provided the measures conform to TRM requirements.

Depending on programmatic decisions and designs, the launch of the new statewide weatherization program in 2016 may require the implementers to use TRM-compliant savings values for all measures included in the TRM.

The deemed energy savings for Replacement Appliances and Windows, and for all other measures for which savings are not stipulated by the TRM or that differ from those in the TRM due to the nature of the treatment population in the AWP, may be determined by using National Energy Audit Tool (NEAT) software or Manufactured Housing Energy Audit (MHEA) software. The NEAT and MHEA software do not, however, provide deemed savings values for peak demand reduction.

In order to determine the deemed savings values for peak demand reduction, multipliers that give peak demand reduction from annual energy savings have been derived for each of the Replacement Appliances and Windows measures. These multipliers were derived from the peak demand reduction and annual energy savings values in the Frontier Associates' Residential Deemed Savings Report for measures similar to the Replacement Appliances and Windows measures.

The multipliers will be used to determine the peak demand reduction for a given Replacement Appliances and Windows measure by multiplying these figures by the deemed energy savings determined through use of NEAT or MHEA software.

Multipliers have been determined for each weather zone and, in certain cases, for different specifications of the measures. For replacements of central air conditioners, window air conditioners and heat pumps, there are multipliers for a variety of capacities for each weather zone.

A similar methodology will be used for the following AWP measures, which are not currently included in Frontier Associates' Residential Deemed Savings Report:

- Sillbox insulation
- Foundation insulation
- Storm windows
- Smart thermostats

For these four measures, there are multipliers for different combinations of heating and cooling types for each weather zone. Both gas and electric water heater replacement measures have a multiplier for each of three tank sizes for each weather zone.

Multipliers

Table H1: Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings

Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings for filing in Docket No. 07-152-TF				
SAVINGS MEASURE	**ZONE**	**SPECIFICATION**	**ELECTRIC MULTIPLIERS**	**GAS MULTIPLIERS**
Gas Furnace Replacement	9	All	NA	0.01512195122
	8	All	NA	0.01814059
	7	All	NA	0.017913593
	6	All	NA	0.024492652
Central AC Replacement	9	1.5 tons; ARI 15000-20999 BTU/hr	0.000722222	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000708333	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000702341	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000696379	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.00071599	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000709812	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000701169	NA
	8	1.5 tons; ARI 15000-20999 BTU/hr	0.000526316	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000561056	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.00055409	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000549451	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000546139	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000543657	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000540184	NA
	7	1.5 tons; ARI 15000-20999 BTU/hr	0.000550847	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000539683	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000532995	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000528541	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000544465	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000539683	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000532995	NA
	6	1.5 tons; ARI 15000-20999 BTU/hr	0.000469314	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000459459	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000454545	NA
		3 tons; ARI 33000-38999 BTU/hr	0.00045045	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000463679	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000459459	NA

Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings for filing in Docket No. 07-152-TF				
SAVINGS MEASURE	**ZONE**	**SPECIFICATION**	**ELECTRIC MULTIPLIERS**	**GAS MULTIPLIERS**
		5 tons; ARI 57000-62999 BTU/hr	0.000454054	NA
Heat Pump Replacement	9	1.5 tons; ARI 15000-20999 BTU/hr	0.000714286	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000758929	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.00075	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000744048	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000739796	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000736607	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000732143	NA
	8	1.5 tons; ARI 15000-20999 BTU/hr	0.000560748	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000594406	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000588235	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000582751	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.00058	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000576923	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000587413	NA
	7	1.5 tons; ARI 15000-20999 BTU/hr	0.000542986	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000576271	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000569106	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000565611	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000562016	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000559322	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000556309	NA
	6	1.5 tons; ARI 15000-20999 BTU/hr	0.00046332	NA
		2 tons; ARI 21000-26999 BTU/hr	0.000492754	NA
		2.5 tons; ARI 27000-32999 BTU/hr	0.000486111	NA
		3 tons; ARI 33000-38999 BTU/hr	0.000482625	NA
		3.5 tons; ARI 39000-44999 BTU/hr	0.000479339	NA
		4 tons; ARI 45000-56999 BTU/hr	0.000477569	NA
		5 tons; ARI 57000-62999 BTU/hr	0.000474537	NA

Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings for filing in Docket No. 07-152-TF

SAVINGS MEASURE	ZONE	SPECIFICATION	ELECTRIC MULTIPLIERS	GAS MULTIPLIERS
Window Air Conditioning	9	Less than 6,000 BTU/hr	0.001121951	NA
		6,000-7,999 BTU/hr	0.001113636	NA
		8,000-13,999 BTU/hr	0.001144578	NA
		14,000-19,999 BTU/hr	0.001133929	NA
		20,000 BTU/hr and above	0.001129534	NA
	8	Less than 6,000 BTU/hr	0.000851852	NA
		6,000-7,999 BTU/hr	0.000844828	NA
		8,000-13,999 BTU/hr	0.000855856	NA
		14,000-19,999 BTU/hr	0.000846667	NA
		20,000 BTU/hr and above	0.000848249	NA
	7	Less than 6,000 BTU/hr	0.000851852	NA
		6,000-7,999 BTU/hr	0.000844828	NA
		8,000-13,999 BTU/hr	0.000855856	NA
		14,000-19,999 BTU/hr	0.000846667	NA
		20,000 BTU/hr and above	0.000848249	NA
	6	Less than 6,000 BTU/hr	0.000676471	NA
		6,000-7,999 BTU/hr	0.000671233	NA
		8,000-13,999 BTU/hr	0.000683453	NA
		14,000-19,999 BTU/hr	0.000679144	NA
		20,000 BTU/hr and above	0.000679128	NA
Sillbox, Foundation Insulation	9	Electric AC with Gas Heat	NA or Negligible	0.012839506
		Gas Heat Only (no AC)	NA or Negligible	0.012839506
		Electric AC with Electric Resistance Heat	NA or Negligible	NA or Negligible
		Electric AC with Heat Pump	NA or Negligible	NA or Negligible
	8	Electric AC with Gas Heat	NA or Negligible	0.014404762
		Gas Heat Only (no AC)	NA or Negligible	0.014491018
		Electric AC with Electric Resistance Heat	NA or Negligible	NA or Negligible
		Electric AC with Heat Pump	NA or Negligible	NA or Negligible
	7	Electric AC with Gas Heat	NA or Negligible	0.0129375
		Gas Heat Only (no AC)	NA or Negligible	0.013018868
		Electric AC with Electric Resistance Heat	NA or Negligible	NA or Negligible
		Electric AC with Heat Pump	NA or Negligible	NA or Negligible
	6	Electric AC with Gas Heat	NA or Negligible	0.01887931
		Gas Heat Only (no AC)	NA or Negligible	0.019043478
		Electric AC with Electric Resistance Heat	NA or Negligible	NA or Negligible
		Electric AC with Heat Pump	NA or Negligible	NA or Negligible

Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings for filing in Docket No. 07-152-TF

SAVINGS MEASURE	ZONE	SPECIFICATION		ELECTRIC MULTIPLIERS	GAS MULTIPLIERS
Replacement / Storm Windows	9	Electric AC with Gas Heat		0.000776952	0.034267913
		Gas Heat Only (no AC)		NA or Negligible	0.034267913
		Electric AC with Electric Resistance Heat		0.000234305	NA or Negligible
		Electric AC with Heat Pump		0.000288674	NA or Negligible
	8	Electric AC with Gas Heat		0.000579125	0.050970874
		Gas Heat Only (no AC)		NA or Negligible	0.0525
		Electric AC with Electric Resistance Heat		0.000261494	NA or Negligible
		Electric AC with Heat Pump		0.000311111	NA or Negligible
	7	Electric AC with Gas Heat		0.000577181	0.039320388
		Gas Heat Only (no AC)		NA or Negligible	0.0405
		Electric AC with Electric Resistance Heat		0.000260745	NA or Negligible
		Electric AC with Heat Pump		0.000310051	NA or Negligible
	6	Electric AC with Gas Heat		0.000457831	0.052205882
		Gas Heat Only (no AC)		NA or Negligible	0.054615385
		Electric AC with Electric Resistance Heat		0.000272425	NA or Negligible
		Electric AC with Heat Pump		0.000317829	NA or Negligible
Refrigerators		Replacement on Burnout		0.000136364	NA
		Multifamily Replacement		0.000139073	NA
		Single Family Replacement		0.000139057	NA
Gas/Electric Water Heaters - Replacements, High Efficiency Gas and Electric		Storage Tank Electric Water Heater Replacements	80 gallons	NA or Negligible	NA
			50 gallons	NA or Negligible	NA
			30 gallons	NA or Negligible	NA
		Gas Storage Tank Water Heater Replacements	80 gallons	NA	0.003
			50 gallons	NA	NA or Negligible
			30 gallons	NA	NA or Negligible

Multipliers for Estimating Peak Demand Reductions from Annual Energy Savings for filing in Docket No. 07-152-TF				
SAVINGS MEASURE	**ZONE**	**SPECIFICATION**	**ELECTRIC MULTIPLIERS**	**GAS MULTIPLIERS**
Smart Thermostats	9	Electric AC with Gas Heat	TBD	TBD
		Gas Heat Only (no AC)	TBD	TBD
		Electric AC with Electric Resistance Heat	TBD	TBD
		Electric AC with Heat Pump	TBD	TBD
	8	Electric AC with Gas Heat	TBD	TBD
		Gas Heat Only (no AC)	TBD	TBD
		Electric AC with Electric Resistance Heat	TBD	TBD
		Electric AC with Heat Pump	TBD	TBD
	7	Electric AC with Gas Heat	TBD	TBD
		Gas Heat Only (no AC)	TBD	TBD
		Electric AC with Electric Resistance Heat	TBD	TBD
		Electric AC with Heat Pump	TBD	TBD
	6	Electric AC with Gas Heat	TBD	TBD
		Gas Heat Only (no AC)	TBD	TBD
		Electric AC with Electric Resistance Heat	TBD	TBD
		Electric AC with Heat Pump	TBD	TBD

Example Calculation

If a weatherization project in a city in Zone 7 consists of upgrading a two-ton central air-conditioning unit to the DOE standard and the NEAT/MHEA determined annual energy savings is 250 kWh, the multiplier for (Central AC Replacement, in Zone 7, two-ton system) is 0.0005397. The deemed peak demand reduction for this measure would then be 250 × 0.0005397 = 0.1349 kW.

Appendix I: Lighting Interactive Effects Derivation

Reduction in lighting load in air conditioned and refrigerated spaces reduces heat to the space, decreasing the cooling requirement during the cooling season and increasing the heating requirement during the heating season. This reduction in heat load has the effect of reducing electricity used for cooling and increasing electricity or gas used for heating.

Commercial deemed interactive effects factors for both demand and energy savings are shown in Table I1 and Table I2. Residential deemed interactive effects factors are available in Table I3. These factors represent the percentage increase or decrease in energy savings for the refrigeration system's electric load attributed to the heat dissipated by the more efficient lighting system. For example, a factor of 1.20 indicates a 20% increase in savings.

Table I1: Commercial Conditioned and Refrigerated Space Interactive Effects Factors

Building Type	Temperature Description	Heating Type	IEF_D	IEF_E[22]
All building types (Except Outdoor & Parking Structure)	Air Conditioned Space – Normal Temps. (> 41°F)	Gas	1.20	1.09
		Electric Resistance		0.87
		Heat Pump		1.02
		Heating Unknown[23]		0.98
	Refrigerated Space – Med. Temps. (33-41°F)	All	1.25	1.25
	Refrigerated Space – Low Temps. (-10-10°F)	All	1.30	1.30

Table I2: Commercial Conditioned Space Gas Heating Penalty

Building Type	Heating Type	IEF_G (Therms/kWh)
All building types (Except Outdoor & Parking Structure)	Gas	- 0.008
	Heating Unknown[24]	- 0.004

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[22] Electric heating penalties (if applicable) are incorporated into the interactive effects presented in this table.

[23] These values should be used for programs where heat type cannot be determined. Weighted average based on Commercial Building Energy Consumption Survey (CBECS) 2003 data. http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=microdata.

[24] These values should be used for programs where heat type cannot be determined. Weighted average based on Commercial Building Energy Consumption Survey (CBECS) 2003 data. http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=microdata.

Table I3: Residential Conditioned Space Interactive Effects Factors[25]

Building Type	Heating Type	IEF_D	IEF_E [26]	IEF_G (Therms/kWh)
Residential	Gas Heat with AC	1.29	1.10	-0.011
	Gas Heat with no AC	1.00	1.00	-0.011
	Electric Resistance Heat with AC	1.29	0.83	0
	Electric Resistance Heat with no AC	1.00	0.73	0
	Heat Pump	1.29	0.96	0
	Heating/Cooling Unknown[27]	1.25	0.97	-0.0063

Commercial Air Conditioned Space Interactive Effects

The Interactive Demand and Energy Savings Factors for Normal Temperatures (> 41°F) were chosen based on a review of interactive effects factors used in the CPUC DEER 2011 “Lighting HVAC Interactive Effects” Calculator.[28] The DEER analysis was one of the most recent and comprehensive studies available, with interactive effects based on field measurement, statistical analysis of utility bills, spreadsheet analysis, and building energy simulations. Additionally, of all the states with interactive effects factors available for analysis, California has the greatest climate zone similarity (comparing cooling and heating degree days) with Arkansas.

The calculator provides a range of interactive effects factors for existing commercial buildings. This analysis used California climate Zone 11,[29] based on similarity of cooling and heating degree days with Arkansas.[30] Table I4 and Table I5 show the range of interactive effects for commercial buildings in California climate Zone 11. Interactive effects factors for existing residential buildings were derived as part of a residential lighting logging study performed by Cadmus for Entergy Arkansas, Inc.

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[25] Residential light logging study performed by Cadmus for Entergy Arkansas, Inc. Cadmus EMV 2014.

[26] Electric heating penalties (if applicable) are incorporated into the interactive effects presented in this table.

[27] These values should be used for programs where heating or cooling type cannot be determined.

[28] “Lighting HVAC Interactive Effects 13Dec2011 Calculator.” California Public Utilities Commission Database for Energy Efficient Resources. DEER 2011 for 13-14: http://www.deeresources.com/DEER2011/download/LightingHVACInteractiveEffects_13DEC2011.xls.

[29] Average of four cities within CA climate zone 11. HDD: 3,149; CDD: 1,354. Source: “The Pacific Energy Center’s Guide to: California Climate Zones and Bioclimatic Design.” Pacific Energy Center. October 2006. http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf

[30] Average across weather zones: HDD = 3,317; CDD = 1,895. Source: Appendix C.

Table I4: DEER 2011 Conditioned Space Interactive Effects Factors for Commercial Buildings

Building Type	**IEF_D**			**IEF_E**		
	Min	**Max**	**Avg**	**Min**	**Max**	**Adj Avg**[31]
Assembly	1.14	1.17	1.16	1.01	1.04	1.04
Education – Primary School	1.00	1.00	1.00	1.03	1.08	1.08
Education – Sec. School	1.00	1.00	1.00	1.04	1.10	1.10
Education – Comm. College	1.27	1.37	1.31	1.09	1.12	1.15
Education – University	1.22	1.31	1.26	1.09	1.14	1.17
Education – Reloc. Classroom	1.00	1.00	1.00	1.03	1.11	1.07
Grocery	1.26	1.39	1.32	0.95	1.02	0.97
Health/Med – Hospital	1.19	1.24	1.22	1.07	1.10	1.13
Health/Med – Nursing Home	1.26	1.27	1.26	1.03	1.06	1.07
Lodging – Hotel	1.21	1.27	1.25	0.99	1.04	1.04
Lodging – Motel	1.22	1.26	1.24	1.01	1.06	1.06
Manf. – Bio/Tech	1.17	1.26	1.21	1.07	1.11	1.14
Manf. – Light Industrial	1.14	1.17	1.15	1.03	1.04	1.06
Office – Large	1.24	1.39	1.32	1.11	1.12	1.17
Office – Small	1.20	1.26	1.23	1.05	1.07	1.08
Restaurant – Sit-Down	1.15	1.23	1.18	1.00	1.05	1.04
Restaurant – Fast-Food	1.15	1.22	1.18	1.00	1.05	1.04
Retail – Multistory Large	1.16	1.22	1.19	1.04	1.06	1.07
Retail – Single-Story Large	1.17	1.29	1.22	1.04	1.08	1.08
Retail – Small	1.15	1.22	1.19	1.03	1.06	1.06
Storage – Conditioned	1.18	1.23	1.20	0.98	0.98	0.97
Warehouse – Refrigerated	1.22	1.24	1.23	1.26	1.43	1.49
All Buildings			**1.20**			**1.09**

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[31] Average adjusted by 40.0% due to higher CDD in Arkansas: (1,895-1,354) / 1,354 = 40.0%

Table I5: DEER 2011 Conditioned Space Heating Penalties for Commercial Buildings

Building Type	**IEF_G (Therms/kWh)**			**IEF_{ER} (kWh/kWh)**	**IEF_{HP} (kWh/kWh)**
	Min	**Max**	**Adj Avg**[32]	**Adj Avg**[33]	**Adj Avg**[34]
Assembly	-0.0088	-0.0093	-0.0096	-0.281	-0.091
Education – Primary School	-0.0096	-0.0111	-0.0105	-0.309	-0.100
Education – Sec. School	-0.0110	-0.0121	-0.0119	-0.349	-0.112
Education – Comm. College	-0.0087	-0.0113	-0.0108	-0.318	-0.103
Education – University	-0.0053	-0.0080	-0.0073	-0.213	-0.069
Education – Reloc. Classroom	-0.0098	-0.0110	-0.0110	-0.321	-0.104
Grocery	-0.0097	-0.0119	-0.0116	-0.339	-0.110
Health/Med – Hospital	-0.0057	-0.0068	-0.0067	-0.198	-0.064
Health/Med – Nursing Home	-0.0119	-0.0137	-0.0135	-0.395	-0.127
Lodging – Hotel	-0.0052	-0.0066	-0.0061	-0.179	-0.058
Lodging – Motel	-0.0051	-0.0066	-0.0062	-0.182	-0.059
Manf. – Bio/Tech	-0.0006	-0.0009	-0.0007	-0.022	-0.007
Manf. – Light Industrial	-0.0059	-0.0067	-0.0066	-0.194	-0.063
Office – Large	-0.0033	-0.0077	-0.0059	-0.173	-0.056
Office – Small	-0.0035	-0.0050	-0.0044	-0.130	-0.042
Restaurant – Sit-Down	-0.0064	-0.0087	-0.0080	-0.235	-0.076
Restaurant – Fast-Food	-0.0068	-0.0080	-0.0079	-0.231	-0.075
Retail – Multistory Large	-0.0060	-0.0074	-0.0072	-0.210	-0.068
Retail – Single-Story Large	-0.0066	-0.0071	-0.0073	-0.213	-0.069
Retail – Small	-0.0062	-0.0065	-0.0067	-0.198	-0.064
Storage – Conditioned	-0.0078	-0.0078	-0.0082	-0.241	-0.078
Warehouse – Refrigerated	-0.0000	-0.0001	-0.0001	-0.003	-0.001
All Buildings			**-0.008**	**-0.22**	**-0.07**

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[32] Average adjusted by 5.3% due to higher HDD in Arkansas: (3,317-3,149) / 3,149 = 5.3%

[33] Ibid.

[34] Ibid.

Residential Interactive Effects

The interactive effects specifically for Arkansas were determined by the evaluator during the 2013 program evaluation[35]. To determine interactive effects specific to Arkansas energy simulation models using BEopt™ Version 2.1[36] were developed. A total of five models were used to represent various heating and cooling combinations (see Table I6) and applied the weather from Little Rock[37] as the simulation location. Little Rock was chosen due to its central location and large population center as a proxy for the state because weather patterns in Arkansas are relatively consistent, so weather differences across the state would not result in a great deal of variation.

The lighting IEF is dependent on many influences, but the major defining factors are:

- The length of the respective heating and cooling seasons
- Electric heating saturation
- Cooling saturation
- Electric resistance versus heat-pump electric heating
- Gas heating saturation

Heating and cooling saturation indicates the percentage of houses for which interactive effects are relevant. The different efficiencies of electric resistance heating and heat pump heating affect the impact of lighting on heating load. In general, areas with long cooling seasons and low saturations of electric heating tend to have higher IEFE values. Table I6 shows Arkansas saturation data for different heating and cooling systems.

Table I6: Heating and Cooling Saturations

Type		**Saturation %**
Central Cooling [1]		85.6%
Electric Heating [1, 2]	Heat Pump	7.1%
	Electric Resistance	37.9%
Gas Heating [1]		41.5%

Sources:
[1] *American Community Survey*.2012.
[2] *Residential Energy Consumption Survey* (RECS). 2009.

The simulated homes were designed according to the parameters in the Arkansas TRM 3.0 Prototype Home A3. The heating and cooling setpoints on the thermostat were modified to conform to survey data from the 2009 RECS. Table I7 lists the simulation characteristics that were used.

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[35] EAI 2013 Annual EM&V report.

[36] BEopt is a residential energy simulation program developed by NREL. It uses either DOE 2.2 or EnergyPlus as the simulation engine, both of which are among the most advanced simulation engines available. The Team completed these simulations using EnergyPlus.

[37] Specifically, we used the Little Rock Air Force Base TMY3 weather.

Table I7: Simulation Characteristics

Parameter	Value
Size [1]	1,850 sq. ft.
Attic Insulation [1]	R-19
Wall Insulation [1]	R-11
Window Type [1]	Double-Pane Metal
Building Leakage [1]	10 ACH50
Heating Thermostat [2]	71°F w/68°F setback
Cooling Thermostat [2]	72°F w/74°F setback
Heat Pump [1]	7.2 HSPF 10.0 SEER
Gas Furnace [1]	78 AFUE
Air Conditioner [1]	10.0 SEER
Electric Furnace [1]	1.0 COP

Sources:

[1] Arkansas TRM 3.0 Prototype Home A3

[2] 2009 RECS for Arkansas, Louisiana, and Oklahoma

Using the BEopt model, lighting usage was simulated with load-shape information from the 2013 evaluation light logging study. A load shape represents the average hourly load for each hour of the day and for each day of the year. The load shape reflects real occupant behavior for lighting usage and is important for calculating lighting interaction during peak periods.

The simulation model assumes that all lighting energy from interior fixtures dissipates into the conditioned space of the home. While this is likely true for most interior fixtures, certain fixture types (such as recessed-can lighting) extend beyond the thermal boundary of the home. Cadmus conducted can lighting tests in their laboratory to quantify the lighting energy that dissipates through the attic and enters the home. The test showed that, on average, 60 percent of the lighting energy enters the home. By weighting socket studies with these results, it was determined that two percent of the lighting energy used in recessed lighting fixtures is dissipated outside. The factor was ten applied this to the model results.

The results for the upstream lighting value were weighted using socket survey data from the 2013 light logging study to account for lamps with no HVAC interaction. The study results showed that 84 percent of high-efficiency lighting was installed in conditioned spaces (living room, bedroom, etc.) and 16 percent was installed in unconditioned spaces (exterior, garage, etc.).

For each home two lighting scenarios were modeled: one with the baseline scenario of 34 percent fluorescent lighting (which consumed approximately 1,700 kWh/year) and one with 80 percent fluorescent lighting (which consumed 1,330 kWh/year). The latter model allowed the ability to calculate the proportion of heating and cooling energy changes associated with reduced lighting loads, which applies to any level of incandescent-to-CFL conversion.

The following equation was used to determine the IEFE for electrical energy.

$$\frac{\Delta\, Lighting\ kWh + \Delta Cooling\ kWh + \ \Delta Heating\ kWh}{\Delta\, Lighting\ kWh} = IEF_E$$

(2)

To determine the IEFD for electrical demand, the following equation was used. Peak period was defined as July and August weekdays from 3:00 p.m. to 6:00 p.m.

$$\frac{Average\,\Delta\, Lighting\ kW @\ Peak\ Period + Average\ \Delta Cooling\ kW\ @\ Peak\ Period}{Average\,\Delta\, Lighting\ kW\ @\ Peak\ Period} = IEF_D$$

(3)

The final equation used determines the IEFG for gas demand.

$$\frac{\Delta\, Heating\ Therms}{\Delta\, Lighting\ kW} = IEF_G$$

(4)

Applying all three equations to the hourly output of the simulations yields the results in Table I8.

Table I8: Interactive Effects by Equipment Type

HVAC Equipment	IEFE	IEFD	IEFG
Fuel Heat w/ CAC	1.12	1.35	-0.014
Fuel Heat w/o CAC	1.00	1.00	-0.014
Heat Pump	0.96	1.35	0
Electric Resistance w/ CAC	0.80	1.35	0
Electric Resistance w/o CAC	0.68	1.00	0

Weighting the values to statewide average heating and cooling system saturations and lamp locations resulted in an IEF_E of 0.97, an IEF_D of 1.25, and an IEF_G of -0.0063 (Table I9). These results show that on average, every 1 kWh of lighting energy saved results in 0.97 kWh of total electricity being saved and an additional 0.0063 therms of gas being burned; and 1 kW of lighting demand reduction results in a total 1.25 kW of net demand reduction.

Table I9: Weighted IEF Results

HVAC Equipment	IEFE	IEFD	IEFG	Weight
Fuel Heat w/ CAC	1.10	1.29	-0.011	47.1%
Fuel Heat w/o CAC	1.00	1.00	-0.011	7.9%
Heat Pump	0.96	1.29	0	7.1%
Electric Resistance w/ CAC	0.83	1.29	0	31.4%
Electric Resistance w/o CAC	0.73	1.00	0	6.5%
Weighted Average	0.97	1.25	-0.0063	

Method of Converting Gas Heating Penalty to Electric Heating Penalty

$$IEF_{ER,HP} = \frac{IEF_G \times 100{,}000}{3{,}412 \times COP_{ER,HP}} \tag{5}$$

Where:

IEF_G = Interactive effects factor for gas heating savings

IEF_{ER} = Interactive effects factor for electric resistance heating savings

IEF_{HP} = Interactive effects factor for heat pump heating savings

100,000 = Constant to convert from therms to BTU

3,412 = Constant to convert from BTU to kWh

COP = 1.0 (for Electric Resistance); 3.1 (for Commercial Heat Pump)[38]; 2.3 (for Residential Heat Pump)[39]

Refrigerated Space Interactive Effects

Refrigerated spaces refer to both building floor areas and equipment spaces cooled to temperatures lower than 41 degrees Fahrenheit. Examples of medium and low temperature spaces include, but are not limited to, low temperature warehouses, meat lockers, grocery store dairy storage and displays, and low temperature test areas. Examples of refrigerated equipment spaces include, but are not limited to, grocery and convenience store beverage, dairy, and frozen food open and closed cases.

Refrigerated spaces are typically illuminated using general fluorescent lighting technology. Recent emphasis on energy efficiency has promoted the practice of designing lighting systems with lower heat producing characteristics and/or designing lighting with the heat dissipating components outside the refrigerated area.

For medium and low temperature spaces, the demand and energy savings factors are equal because refrigeration is required 24 hours per day. Therefore, the refrigeration system is operating regardless of the time of peak coincidence. In developing the Interactive Savings Factors, it is assumed that the refrigerated area lighting is continuous and the refrigeration system cycles as required to

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[38] ASHRAE 90.1-2001-2007 minimum efficiency requirement for air cooled heat pumps

[39] COP = HSPF * 1055 J/BTU ÷ 3600 J/W-hr, using HSPF = 7.7 (based on current federal standard as of January 23, 2006). http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

maintain the refrigerated area’s set point.

Nine different sources were used to generate estimates of compressor kWh/kW savings per 1 kWh/1kW of lighting savings. Using these nine different sources, the most conservative savings ratios were chosen to be refrigerated spaces interactive effects factors.

Table I10 provides the resulting savings factors from each source.

Table I10: Refrigerated Interactive Effects Factors from Sources

1	LED Refrigerated Case Study	Low Temperature Factor (1): 0.45 Medium Temperature Factor (1): 0.31[40]
	David Bisbee, CEM (SMUD – July 2008)	
2	Energy-Efficient Lighting for Commercial Refrigeration	Low Temperature Factor (2): 0.35 Low Temperature Factor (3): 0.42[41]
	Narendran, Brons, Taylor (LRC – Nov 2006)	
3	LED Study, Fred Meyer Energy	Low Temperature Factor (4): 0.68[42]
	Schmidlkofer (Fred Meyer – June 2009)	
4	Fiber Optic Lighting in Low Temperature Reach-In Refrigerated Display Cases	Low Temperature Factor (5): 0.354 Low Temperature Factor (6): 0.340[43]
	Mitchell (So-Cal – 2007 ASHRAE)	
5	Niche Market Lighting Study	Low Temperature Factor (7): 0.333[44] Medium Temperature Factor (2): 0.250[45]
	Navigant (Oct 2008)	
6	DOE Gateway Demonstration	Low Temperature Factor (8): 0.327[46]
	PNNL (Albertsons Grocery, Oct 2009)	
7	LED Supermarket Case Lighting	Low Temperature Factor (9): 0.479[47]
	Theobald with EMCOR for PG&E (Jan 2006)	
8	LED Supermarket Case Lighting	Low Temperature Factor (10): 0.471[48]
	Theobald with EMCOR for PG&E (June 2008)	
9	LED Reach In Freezer Case Lighting	Low Temperature Factor (11): 0.500[49]
	Theobald with EMCOR for PG&E (Dec 2008)	

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[40] Savings cited on page 13

[41] Light and compressor kWh deltas between fluorescent and LEDs with 100% and 50% control voltage used to generate factors

[42] kWh (heat load) = 1 kWh (Lighting) * (3.412 Btu/Wh)/(5 Btu/Wh)

[43] Light and compressor kWh deltas between fluorescent and LED refrigerator case lighting at standard power and low power used to generate factors

[44] Factor calculated from the market potential for the currently installed base of LED refrigerator case lighting, mostly low temperature: 0.02 TWh/yr (compressor) / 0.06 TWh/yr (lighting)

[45] Factor calculated from the potential for the installation of all LED refrigerator case lighting in all commercial applications, mostly medium temperature: 0.4 TWh/yr (compressor) / 1.6 TWh/yr (lighting)

[46] Test case: 655 kWh/yr (compressor) / 2,004 kWh/yr (lighting with occupancy sensor reduction)

[47] Test case: 0.46 kW (load reduction on refrigeration system) / 0.96 kW (demand reduction from lighting system)

[48] Test case: 2.4 kW (load reduction on refrigeration system) / 5.1 kW (demand reduction from lighting system)

[49] Test case: 0.039 kW (load reduction on refrigeration system) / 0.078 kW (demand reduction from lighting system

The following sources were used in determining medium and low temperature factors in Table I10:

- Bisbee, Dave, CEM. "LED Freezer Case Lighting Systems." Sacramento Municipal Utility District (SMUD), Energy Efficiency, Customer Research & Development. July 2008.
- Narendran, Brons, Taylor (Rensselaer Polytechnic Institute Lighting Research Center). "Energy-Efficient Lighting Alternative for Commercial Refrigeration, Final Report." The New York State Energy Research and Development Authority. November 2006.
- Schmidlkofer, Daniel. LED Study. Fred Meyer Energy. June 2009.
- Watt Stopper/Legrand. "Case Study: Watt Stopper/Legrand Helps Wal-Mart Achieve Environmental Goals." Wal-Mart. July 2007.
- Southern California Edison, Design & Engineering Services Customer Service Business Unit. "Fiber Optic Lighting in Low Temperature Reach-In Refrigerated Display Cases." Southern California Edison. December 15, 2006.
- Navigant Consulting Inc. "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications." U.S. Department of Energy. October 2008.
- Pacific Northwest National Laboratory (PNNL), et al. "Demonstration Assessment of Light-Emitting Diode (LED) Freezer Case Lighting, Host Site: Albertson's Grocery in Eugene, OR." U.S. Department of Energy. October 2009.
- Theobald, Marc A., EMCOR Energy Services. "LED Supermarket Case Lighting Grocery Store, Northern California: Application Assessment Report #0608." Pacific Gas & Electric (PG&E), Emerging Technologies Program. January 2006.
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- Theobald, Marc A., EMCOR Energy Services. "LED Lighting in Reach In Freezer Cases: Retail Sector." Pacific Gas & Electric (PG&E), Emerging Technologies Program. January 2006.