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90.1 Energy Credits Analysis Documentation

90.1-2019 Addendum AP

January 2022

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U.S. DEPARTMENT OF ENERGY

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Executive Summary

The Standing Standards Project Committee (SSPC) for ASHRAE Standard 90.1 established a working group to develop an energy credits proposal. Energy credits provide for additional required prescriptive savings that are more flexible than base prescriptive requirements. The package of measures proposed for ASHRAE Standard 90.1-2022 includes 32 energy efficiency, renewable energy, and load management measures available. Building-type-specific targets were developed with a goal of 5% total building energy cost savings.

Energy credits have been adopted in other model building energy codes. For example, in the 2021 International Energy Conservation Code, energy credit measures were expanded from selecting 1 of 8 alternate options to 15 available energy saving measures that can be flexibly selected to achieve a 5% level of energy savings. The contribution of different measure types to a cost-effective package of measures is shown in Figure E-1.

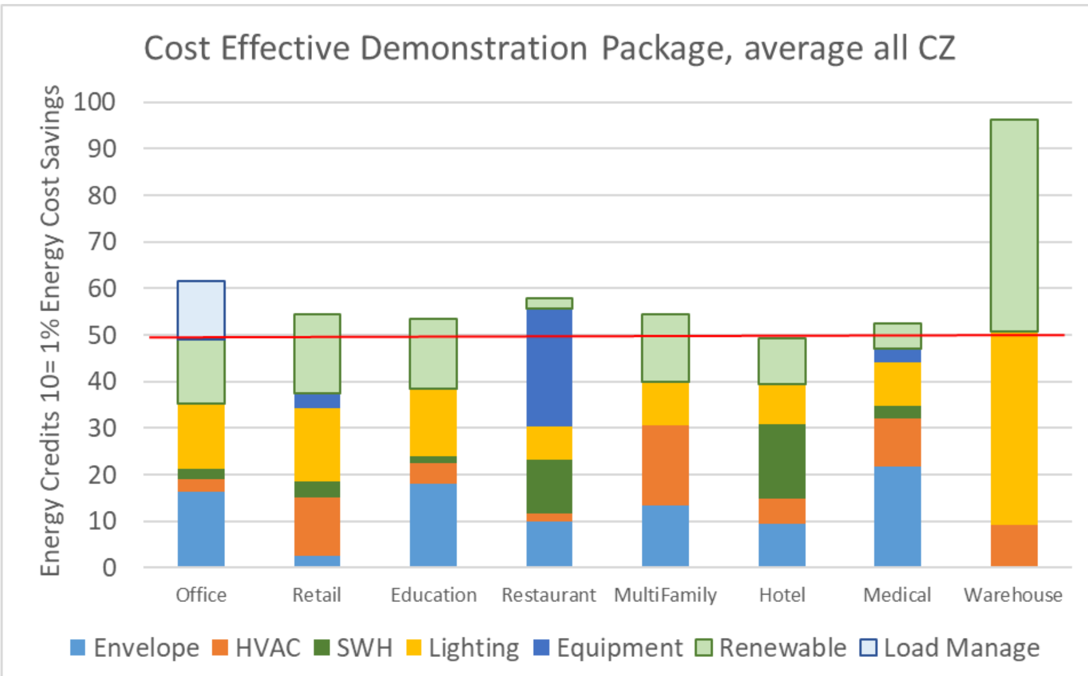

Figure E-1. Cost effective Demonstration Package Credits by Measure Type

This technical documentation includes 26 energy efficiency measures, 1 renewable measure, and 7 load management measures. Two of the energy efficiency measures are references to future measures not yet included in Addendum **ap**. It builds on the former energy credit approaches with a base goal of around 5% energy savings. The energy credits here are based on site energy cost and each credit represents 1/10 of 1% building energy use. Load management measures base cost savings on grid cost impact represented by a time-of-use electric price structure.

This technical document provides the general description of the proposed energy credit measures, the basis for calculation of potential energy credits, and the demonstration cost effective packages that justify the energy credit requirements by building type and climate zone. The actual code language, credit requirements, and available credits by measure can be found in addendum **ap** to 90.1-2019 and are not included here due to copyright issues.

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1.0 Energy Credit Concept

Energy codes have traditionally contained *mandatory* and *prescriptive* items. Mandatory measures must be complied with in all situations while prescriptive measures can be traded with other efficiency measures by following either a whole-building or discipline performance path. Recent editions of the International Energy Conservation Code (IECC) also include extra efficiency measures, and adequate measures must be selected to satisfy an “additional” efficiency requirement. The efficiency requirement is stated on a point scale, with each measure assigned points relative to the building efficiency improvement. Such a structure is currently employed in Section C406 of the 2021 IECC (ICC 2021); similar approaches are in several state building codes, and an energy credit proposal is currently undergoing public review for ASHRAE Standard 90.1 (ICC 2021, ASHRAE 2019a) through addendum **ap** to 90.1-2019. This approach has the advantage of providing increasing levels of performance, while maintaining flexibility in allowing designers to optimize the most appropriate technologies and efficiency measures based on the attributes of each particular project.

1.1 Overall Summary

We discuss the benefits of energy credits, outline the code approach, review the analysis approach, and review cost effectiveness considerations.

1.1.1 Benefits of Energy Credits

In the 2021 IECC, energy credit measures were expanded from 8 alternate options to 15 measures that can be flexibly selected to achieve a 2.5% level of building energy cost savings. This document supports a proposal for a similar package of measures proposed for ASHRAE Standard 90.1-2022 through addendum **ap**, with 32 energy efficiency, renewable energy, and load management measures available. Building-type-specific targets were developed with a goal of 5% total energy cost savings.

This technical brief includes 24 energy efficiency measures, 1 renewable measure, and 7 load management measures. It builds on the former energy credit approaches with a base goal of around 5% energy savings. The energy efficiency credits in the proposal are based on site energy cost and each credit represents 1/10 of 1% of total building energy cost savings. Load Management measures base cost savings on grid cost impact represented by a time-of-use electric price structure that has been adopted by SSPC 90.1 for evaluation of similar measures. The Code Approach is to add a prescriptive requirement for additional saving measures that can be selected by design teams to meet the requirements for each building use type and climate zone.

Energy codes include mandatory requirements that all buildings must fulfill prescriptive requirements that can be used without following a performance path, and discipline[1] or whole-building performance paths where equivalent energy performance to the prescriptive path is demonstrated. To fit into the existing code structure, additional energy credits constitute a new prescriptive requirement; however, instead of all measures being required, the building designer can select from various options to achieve a defined level of energy performance. To maintain

[1] An example of a discipline performance path is the Building Envelope Trade-Off Compliance Path in the envelope discipline of Standard 90.1 that is supported by Appendix C. There are current proposals under public review in Standard 90.1 for discipline performance paths for both lighting and HVAC disciplines.

equivalent energy impact, whole-building performance paths must be adjusted to reflect the impact of the required efficiency energy credits. These issues are addressed in the proposed code language through modifications to Section 11 and a process for modifying Building Performance Factors for Appendix G.

1.1.2 Energy Credit Development

Energy credits have been developed from typical measures used in green building programs, new construction utility incentive programs, and Advanced Energy Design Guidelines (ASHRAE 2019b). More detail is included in Section 1.4.

1.1.3 Cost Effectiveness Considerations

While baseline prescriptive requirements usually undergo individual review for cost effectiveness, the approach for energy credit measures is different. Each measure can be selected for a particular building; however, not all measures are required. Thus, the approach to establish cost effectiveness is to demonstrate that at least one package of measures is cost effective using the ASHRAE 90.1 scalar method. More detail is included in Section 2.2.

1.2 Energy Credit Adoption Principles

Energy credits have been used in numerous energy codes, especially the IECC for more than a decade.[1] A working group on energy credits was established reporting to ASHRAE's 90.1 SSPC in November 2019. Initially the working group was ad hoc, exploring the energy credit concept, and in April 2020, after presenting initial findings, a chartered working group was established, since this cross-discipline proposal could not be handled by one subcommittee. As the working group met, they moved toward agreement around several options in energy credit development. While the principles here reflect at least a majority opinion of the working group, it is acknowledged that there are sometimes contrary minority opinions. As for all addenda to 90.1, addendum **ap** went through public review, and based on helpful feedback from the process and members of the SSPC as a whole, modifications were made that are reflected in these principles. The agreed-to principles for selecting measures and determining credits are listed here, then discussed in detail:

- Energy credit measures provide energy cost savings related to prescriptive requirements and general practice
- Establish energy credits for different building types and climate zones based on prototype analysis and end-use proration; allow for non-simulated building types as well as additions and alterations
- Determine credits for measures that are based on approximate energy cost savings equivalency
- Use measure descriptions that are based on prescriptive descriptions and do not require performance analysis

[1] Originally Section C406 appeared in the 2012 IECC as a "select one of 3" options approach. It has evolved over the years to including 6 options in 2015, 8 options in 2018, and finally assigned points to multiple measures with a 10 point (2.5% cost savings) requirement in 2021. See Section 1.4 for a more complete history.

- Where possible, integrate energy credits with discipline trade-off or performance paths such as the envelope tradeoff, HVAC performance, or lighting performance methods.
- Establish energy credit requirements by building type and climate zone based on a cost effective demonstration package(s) of reasonably applicable measures
- Limit the share of credits from renewables and load management to ensure a balanced portion of credits from energy efficiency
- Ensure that required energy credits are accounted for in the performance paths
- Review future measures for addition to the measure energy credits based on these criteria

1.2.1 Energy Credit Measures Provide Incremental Annual Savings

The most important quality that energy credit measures have is that they provide incremental savings above the prescriptive path and standard practice in building construction. Although savings occur, measures in the energy credit category do not necessarily fit most building conditions, otherwise they would likely be incorporated in the prescriptive path. One wrinkle with this concept is that Standard 90.1 undergoes continuous maintenance. This has two considerations:

- It is desirable to update the energy credits for each edition based on changes to the prescriptive path. While there is no mandate to require this, it can be incorporated into the committee work plan and supported by DOE funding for analysis.
- It is not always possible to include every proposal in the baseline since they are moving on parallel public comment paths. Just as updating the Appendix G BPFs has a similar issue, the best that can be done is to estimate likely changes to the prescriptive path at the time any update to credits available and credit requirements is made.

Using percentage improvements in the credit language mitigates some of the issue related to parallel proposals.

- For example, the credits are based on a percentage improvement of cooling efficiency above the minimum efficiency, if the minimum efficiency changes for a particular edition, there is an automatic adjustment in the credits achieved for cooling equipment relative to code minimums. While this is not perfect, it goes a long way toward keeping the credits in line with actual savings related to changing prescriptive requirements.
- Similarly, there is a credit related to lighting power reduction as a percentage of the requirement. So, even when the base lighting power requirement is changed, the relative savings of the percentage reduction as a share of total building energy cost remains close.
- Incorporating discipline performance methods like the envelope tradeoff, HVAC Total System Performance Ratio (TSPR), and lighting performance provide similar adjustment, as these methods will be based on the prescriptive baselines or targets in their respective disciplines. Only the envelope tradeoff exists in 90.1-2019; the others are in the adoption process.

1.2.2 Credit Points Are Unique by Building Type and Climate Zone

A review of measure results for the 2021 IECC found that there was wide climate zone variation for many measures, as seen in Figure 3 and Figure 4. There were also perceived applicability issues to certain building types. For example, retail building service hot water loads are generally low and central water heating with recirculation is not typical. Since what are essentially “point of use” water heaters are typical in retail, savings for this measure is not allowed for energy credits in this building type. Other measures have very small savings results in some climate zones, so where the total building savings for heating falls below 0.05% in a climate zone, the measure is excluded.

Measure savings and credits are determined based primarily on prototype simulation. In addition end use results from one prototype can be prorated to other building types based on end use building type energy use. More information on the analytical method of establishing credits can be found in Section 2.1.

While Standard 90.1 does not have a set of clearly defined building types and does not refer to uniform building code use groups, there is a set of building type names that have been used for the building performance factors in Appendix G. The energy credits are aligned with the same building use types. There is also an “other building” category since all building use types are not covered. To accommodate these buildings, the credits achieved are averaged from the simulated building prototypes and requirements for the “other” buildings are also based on an average that is then reduced (currently by half) since the “other” buildings often have fewer energy saving options. In addition to establishing building use types, the energy credit code language accommodates the following:

- Mixed use buildings can be separated into their uses to establish a weighted energy credit requirement and then the individual building use type credits can be weighted to determine if requirements have been met.
- Minimum floor area thresholds can be established for new buildings, additions, and two types of alterations:
  - Substantial alterations involve the major remodel of a building rather than just completing some minor replacements. Two of three major systems—lighting, HVAC, or building envelope—must be substantially replaced.
  - Rules need to accommodate core and shell construction and later initial build out of tenant spaces and how the credits are shared together (or not in some cases).

1.2.3 Measure Credits Have Approximate Energy Savings Equivalency

The basic concept of the energy credits is to assign points to measures that reflect approximate relative savings for the measure in the building type and climate zone. After discussion, the working group arrived at the following guidelines:

- The credit points are based on a percentage of total building savings. Alternatives discussed included a flat energy savings quantity by building type.
- The credit points are based on energy cost savings using approved 90.1 annual average energy prices. Alternatives included site Btu’s, source Btu’s and emissions. Load

management credits are based on time of use energy cost savings using the approved 90.1 time of use pricing, and do not always save energy.

- The credit points are based on first year savings. Alternatives included adjusting points for either measure life or persistence. The working group overall thought that those adjustments would add too much complication to the development of credit points.

- Energy credits are set at 1 point equal to 0.1% total building savings.[1] This level was thought to be enough credits to notice, while fine enough to distinguish between measures, climate zones, and building types. The choice of 0.1% also allowed an easy gage of percent building savings for measures with a simple decimal point shift. Note that this is different from the 2021 IECC at 0.25% per point, although a proposal for the 2024 IECC suggests a shift to 0.10% per point.

- Where measures have proration adjustments, the points for each measure are rounded to the nearest whole number, or 0.1% annual savings.

- Since energy credit points are based on prototype building analysis rather than custom building analysis, results are necessarily somewhat approximate. The desire in establishing points is that there be rough energy equivalency between measures.

1.2.4 Measures Do Not Require Customized Performance Analysis

The basic idea behind energy credits is to keep it simple, allowing a designer to simply select measures from a list and add up the points to meet or exceed the requirement for that building. There are some cases where simple proration of measure points is used, but these are simple linear adjustments, not sophisticated regression-based approaches, although those approaches could be used for some measures in the future. One exception to this simplified approach is integration with discipline based simplified performance approaches that are discussed later. Overall, thinking about point development ran along these lines:

- Interaction between measures is not accounted for. For this initial roll out of energy credits in 90.1, the credit requirements are capped at 5% of building cost savings, so the impact of interaction is not expected to be high.

- The basis of savings is prototypical analysis. Measures are evaluated in the context of prototype building models established for the 90.1 progress indicator by PNNL. Most measures can be evaluated in this context; however, for some measures—especially service water heating—separate engineering calculations are more appropriate.

- In the prototype analysis process, sometimes measures may be evaluated in one particular prototype in a building group or generally. Then the savings is determined relative to the end uses for the analyzed building, and then those savings are prorated to the end uses of other prototypes. See Section 2.1 for more details.

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[1] The percentage of cost savings is based on total building energy use, not just regulated loads. This simplifies the analysis. This percentage approach results in credits being worth more in lower energy cost buildings and less in higher energy cost buildings. The background concept is that high energy use buildings should devote more attention to energy savings, whether the higher energy use is a result of building use type or climate zone.

1.2.5 Integrate Energy Credits with Discipline Performance Methods

While measures are generally prescriptive with prototypical non-interactive savings used to establish credits, in some cases a simplified discipline-centric trade off or performance method is established. Where these are available, it is helpful to integrate them into the energy credits.

- For envelope, the building envelope trade-off compliance path (Appendix C of 90.1) has been established for several code cycles. The results of this simplified analysis—that is integrated into COMcheck—can be easily converted to total building savings and energy credits. This allows full interactive savings analysis of envelope measures to be completed in one calculation and provides more accuracy than creating many envelope component measures. The Appendix C method has been recently updated to include air leakage impacts and wall reflectivity.

- For HVAC, there is a performance method based on total system performance ratio that is currently undergoing public review. Once adopted, this method can be added as an alternative performance approach for HVAC energy credits; however, it is not part of Addendum **ap**.

- For lighting, there is a performance method based on the interaction of lighting power and controls that is currently undergoing public review. Once adopted, this method can be added as an alternative performance approach for lighting energy credits, and possibly replace some of the initial lighting measures. Since it is not yet adopted, this method it is not part of Addendum **ap.**

1.2.6 Energy Credit Requirements Based on Cost Effective Demonstration

For each building type, energy credit requirements can be set based on cost effectiveness of a selected package of demonstration measures for the building as a whole. This selected package should include a reasonable selection of measures that can be broadly applied. In some cases, it may be appropriate to review multiple packages for building types that have different system approaches regionally, for example central hot water heating vs. one water heater per apartment. The working group agreed that there was not a requirement that individual measures be cost effective, as the 90.1 cost effectiveness approach is based solely on energy savings and does not consider non-energy benefits such as improved comfort, improved occupant control, or property management benefits of green marketing. Some measures provide these other benefits, even though the strict cost effectiveness analysis based only on energy savings may not find them to be cost effective using 90.1 methods. As long as requirements for energy credits are set based on a reasonable cost-effective package, then designers can choose other measures based on their own building development criteria.

One situation that is included in the initial proposal, is a renewable energy adjustment where needed. This is because it is reasonable to include renewable energy in the demonstration packages at a level that can be applied to most buildings, based on rooftop PV panels. However, some buildings are located in parts of the country where insolation is quite low or have limited roof space available. Where these conditions occur, provisions are made to reduce required credits based on the level of renewables included in the demonstration package relative to total credits. The approach to this reduction is as follows:

- Set up a table of renewable adjustment credits that would apply if the building met one of the exceptions in Section 10. Always allow a minimum adjustment based on half the renewable credits for 0.1 W/sq ft or 20 credits, whichever is less. Base those adjustment credits on the credits included for renewable in each building's cost effective package as follows:

$$EC_{RenAdj} = MAX\left(min\left[20, \frac{EC_{R0.1}}{2}\right], EC_{CAP} - \ (EC_{CE} - RP_{CE})\right)$$

Where:

$EC_{R0.1}$ = Renewable points for 0.1 W/sq ft installed in each building type

EC_{CAP} = The required credit cap that is currently 50 points

EC_{CE} = The total credits used in the cost effective package for the building type (this may be greater than EC_{CAP})

RP_{CE} = Renewable points included in the cost effective package

- The renewable adjustment points for each building type and climate zone are included in the adjustment table, with a formula to make adjustments based on available roof area as shown in the proposal.

In addition to demonstrating cost effectiveness of a reasonable package, credits were limited to 50 energy credit points or 5% of total building energy cost savings in the initial roll out of energy credits in addendum **ap** for 90.1.

1.2.7 Ensure a Portion of Credits Come from Energy Efficiency

As renewable energy has been added to the 90.1 standard, there have been limits placed on offsetting energy efficiency in the performance path with renewable energy. In addition, the energy credit options include load management measures that make sense for a building owner in a region that has peak use pricing. These measures do not always save energy directly, but they reduce the building owner's energy cost and provide for a more efficient grid.

As initially proposed, the energy credits would limit the credits achieved through load management and renewables to 60% of the required total, so that a substantial base of the credits promotes direct energy use reduction.

1.2.8 Required Energy Credits in the Performance Paths

There are two different performance paths in 90.1: Chapter 11 and Appendix G. Since the general approach of determining compliance is different, each path requires a different approach to incorporating savings for energy credits:

- In appendix G the inclusion of energy credit savings is pretty straightforward. The demonstrated savings for Appendix G is based on building performance factors (BPF) that have been traditionally updated every edition of 90.1 with comparison to a stable baseline that approximates the status of 90.1 in 2004. The process is slightly modified, where the performance indicator based simulations are used to model the prescriptive path requirements for each edition, and then the BPFs are adjusted to represent the additional savings by building type and climate zone required by the energy credits. In this process, the difference between regulated and unregulated loads needs to be considered, as that is part of the Appendix G performance target.

- In Chapter 11 the inclusion is also straightforward. The energy cost budget is based on a building that meets prescriptive requirements. There is already a formula that adjusts the energy cost budget for additions and alterations. Addendum **ap** proposes modification of this formula to include the added required savings from energy credits.

1.2.9 Review Future Energy Credit Measures Based on Criteria

Any future additions or adjustments to the energy credits allowed or their descriptions will go through the standard ASHRAE 90.1 process, either with an external CMP or an internally generated proposal. This maintains the integrity of the standards process. In evaluating future measure proposals, it is suggested that committee members rely on the following criteria.

- The measure description is clear, prescriptive, and moderately broadly applicable
- The measure broadly applies to multiple equipment types and is not a niche product from one manufacturer
- The measure provides savings compared to prescriptive requirements and standard practice for applicable building types
- Analysis is provided with documentation showing energy cost savings by applicable building type and climate zone, preferably using the PI prototypes
- Review measures for “free ridership” where many projects use the credit and the measure is really just standard practice.
    - One goal of energy credits is “market transformation”, making less used methods the norm. Oregon’s residential “options” led to early market transformation: 6” studs and R-21 insulation became the norm long before model codes required this for our climate zones.
    - Should a credit be moved to the mandatory or prescriptive sections if it has wide adoption.
    - Does overall EC scalar get re-reviewed if an item is moved to the body of the standard?

It is recommended that ongoing or edition cycle review of addenda to 90.1 for the impact on credits be established in the workplan. This could require several items:

- Include in standard work a check with the energy credits section and adjustment there if an addendum raises the base prescriptive requirements and dilutes the value of a particular credit.
- Either establish an ongoing working group or assign energy credit review to an existing subcommittee (ECB may be a candidate). At least once per 90.1 edition, review pending addenda to find:
    - Any addendum that could reduce (or increase) the effectiveness/number of points of a credit measure
    - An addendum could either be in conflict with a credit or make a credit moot
    - Impact of an addendum on the credit list would need to be reviewed

- If there are significant credit changes within an edition cycle, consider re-evaluating the demonstration packages for cost effectiveness.

1.3 Requirement Package

The energy credit requirement is a prescriptive requirement. To establish requirements for different building types, a demonstration package of energy credit measures is selected by building type and climate zone. The package is selected to demonstrate cost effectiveness. The base demonstration package is designed to be achievable across a broad range of building types and situations and is evaluated for cost effectiveness. An alternate package is also developed that does not use any efficiency upgrades for equipment covered by ECPA yet achieves at least the base credits using reasonable measures. The alternate package is not evaluated for cost effectiveness.

1.3.1 Base Demonstration Package

The base demonstration package is selected with a goal of 5% total building energy savings. For some buildings or climate zones, this goal is not always practical, and then the requirement is lower. For buildings with higher energy use, since the goal is a percentage of total building energy use, the result may be a smaller energy credit available for the same measure application and a similar absolute energy savings. Consequently, the credit requirement, based on percentage of building savings, may be smaller in high energy use buildings—typically those in hot and cold climates.

1.3.2 Demonstration Cost Effectiveness

The demonstration package has savings that vary from 3.8% to 12.4% of total building energy cost across building types and climate zones. The “other” building is excluded from this analysis, as they require only half of the average building credits from designated building use types and can be highly varied.

1.3.3 Requirements vs. Potential Savings

The requirements based on the demonstration package can be compared to the potential savings from identified measures. For this comparison, mutually exclusive and niche measures were not included. Figure 1 shows the credits that can be achieved with identified measures and illustrates the availability of a range of measure choices to meet a 5% building cost savings requirement. The figure also demonstrates that measures are available for a variety of end uses, so the energy credits do not rely on just one end use to achieve the required credits.

Figure 2 shows the same potential savings organized by climate, with a “Warm” group including Climate Zones 0 to 2, a “moderate” group including Climate Zones 3 to 5, and a “Cold” group including Climate Zones 6 to 8. This illustrates that adequate credits are available in all climates to meet the requirement.

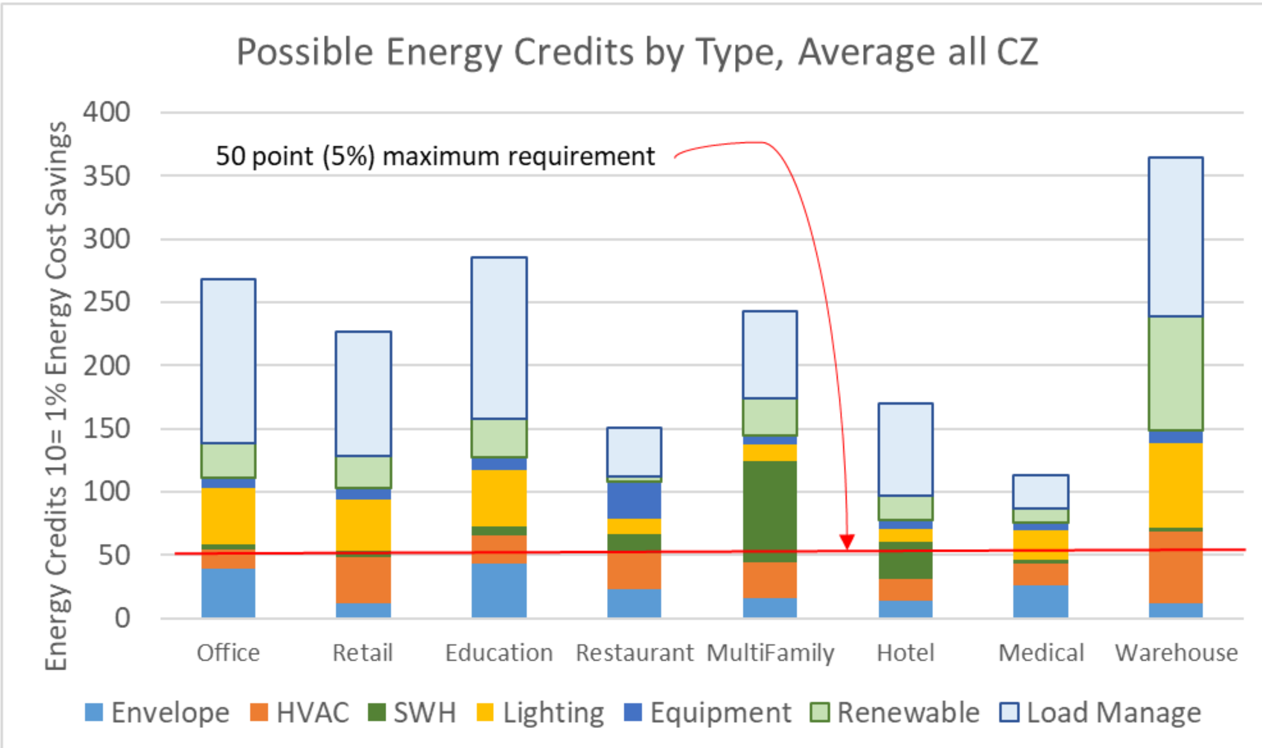

Figure 1. Potential Energy Credit Points by Building and Measure Type

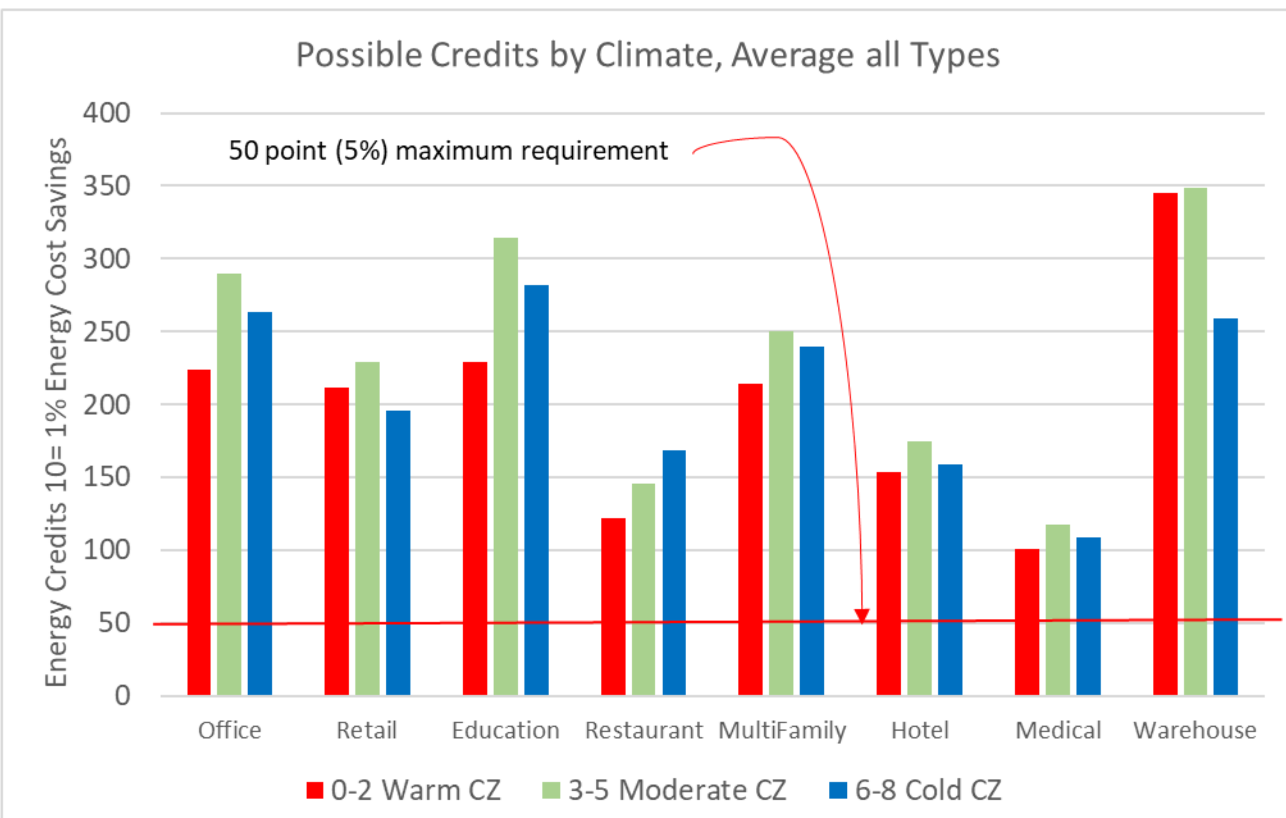

Figure 2. Potential Energy Credit Points by Climate and Building Type

1.3.4 Renewable Credit Adjustments

Renewable credits in the second public review were made more uniform at 0.1 W/ft2. In most cases this is easily achievable, and the portion of credits by building use group can be seen in Figure 1. In some cases, due to low insolation in a particular area of the country or for a high rise building, there is not the same potential for on-site renewable. In this case, there is a reduction in required credits allowed. This adjustment is based on the following factors:

1. Installed on-site renewable energy assumed in the requirement demonstration package, which was set at 0.1 W/ft^2 of total building conditioned area across the board.

2. The deduction is first established based on the total points in the demonstration cost-effective package—that may exceed the 50 credit cap—less the assumed on-site renewable amount. In some cases this deduction was zero where the possible demonstration credits less the renewable credits included was greater than the 50 credit cap.

3. Then, when greater than a renewable deduction estimated in step 2, at least half the demonstration on-site renewable is allowed as a deduction if renewables are not applicable for a particular building.

1.4 Technical Considerations

How does the proposed measure compare to what's required in current codes?

Currently 90.1 does not employ energy credit measures. In the 2021 IECC, points for the additional energy efficiency measures are assigned by building type and climate zone rather than all having the same requirements, as is done in the 2018 IECC (ICC 2018). Sufficient measures must be included in the building design until at least 10 points are achieved. This increases building savings by about 2.5% of total building energy cost compared with the base prescriptive path requirements.

Addendum **ap** adds energy credit measures to 90.1 in a similar manner to the 2021 IECC and distinguishes requirements based on building type and climate zone. The energy credit points attributed to individual measures are determined from building simulation prototype analysis. The assigned points for each measure are based on relatively equivalent energy savings. Here the measure credits are based on energy cost savings. Each efficiency measure credit equals 0.1% of total building energy cost based either on average national energy prices or a composite time of use electric price schedule. For example, a score of 10 credits represents a 1% energy cost reduction for the building as a whole and a score of 50 credits represents a 5% reduction.

Why is an energy efficiency credit assignment method superior to other approaches?

The extra efficiency credit approach provides compliance flexibility to designers and builders. The approach does require selecting multiple items and adding up points; however, in many cases, credit can be earned for measures that are often included in buildings but not previously accounted for in prescriptive compliance. Expanding the number of measures available for achieving credits makes it possible for buildings to save more, allowing the credit requirements to be set initially at about 5% savings.

In Figure 3, the credits for selected measures in an office building are plotted so the range of energy savings and resulting credit points for selected measures across climate zones can be seen. The credits in addendum **ap** are based on 1 energy credit point representing 0.1% savings of total building energy cost, so 10 credits equal 1.0% energy cost savings. Here the y-axis point values are based on site Btu energy savings, but the representation of measure spread and relation is close. The determination of credits is based on prototype building analysis in the specified climate zone as described in Section 2.0. Figure 4 shows similar results for a multifamily building.

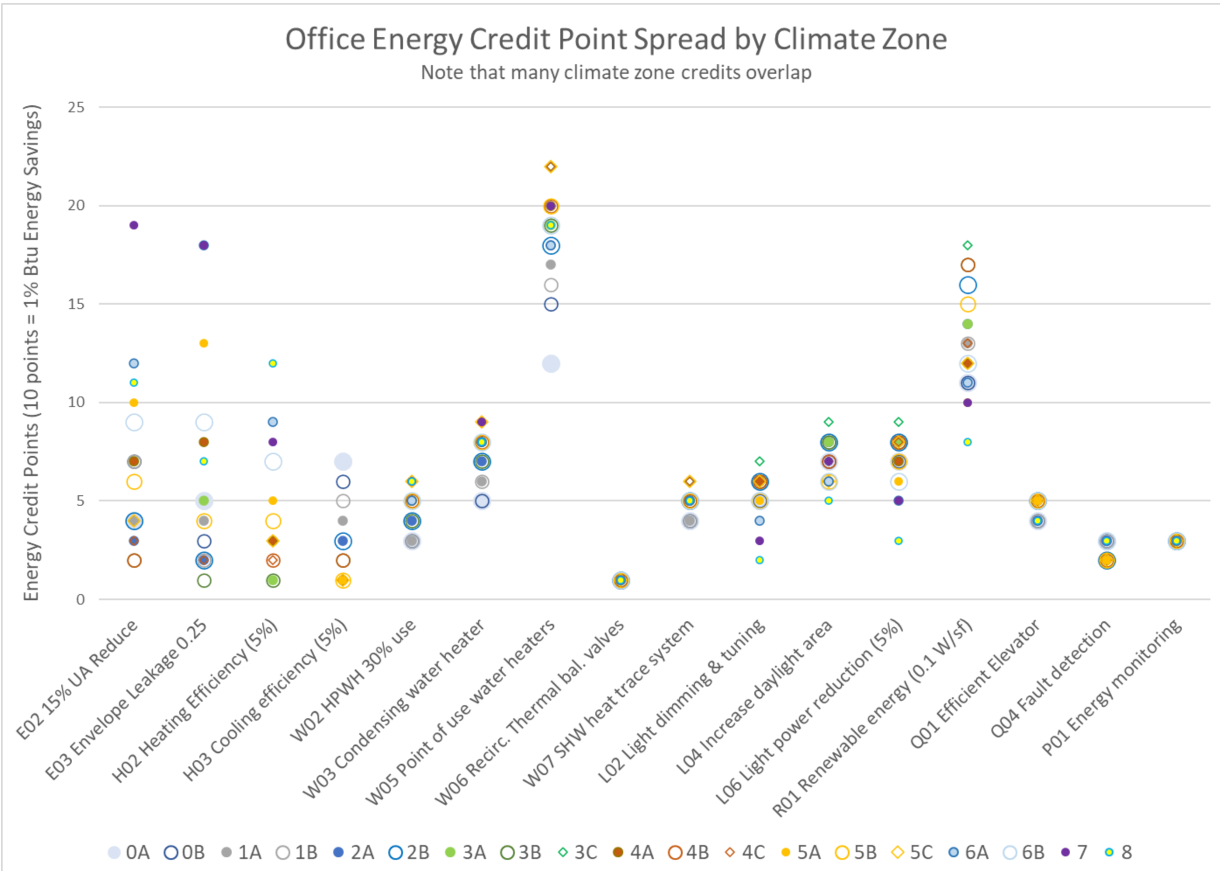

Figure 3. Range of Credit Points for a Sample of Measures for Office Buildings

The measure savings by climate zone has a wide range, especially for building envelope measures. The spread is also broad for lighting reduction, as the reduced lighting heat load must be made up by the heating system in colder climates, while in warmer climates there is added savings in the cooling system. Service hot water (SHW) measures are impacted by different average incoming cold water temperatures. For multifamily buildings, SHW measures provide significant energy credit opportunities. The spread by climate for other measures like service water heating system recirculation is small. Overall the wide spread for many measures indicates that separate credits by climate zone should be provided.

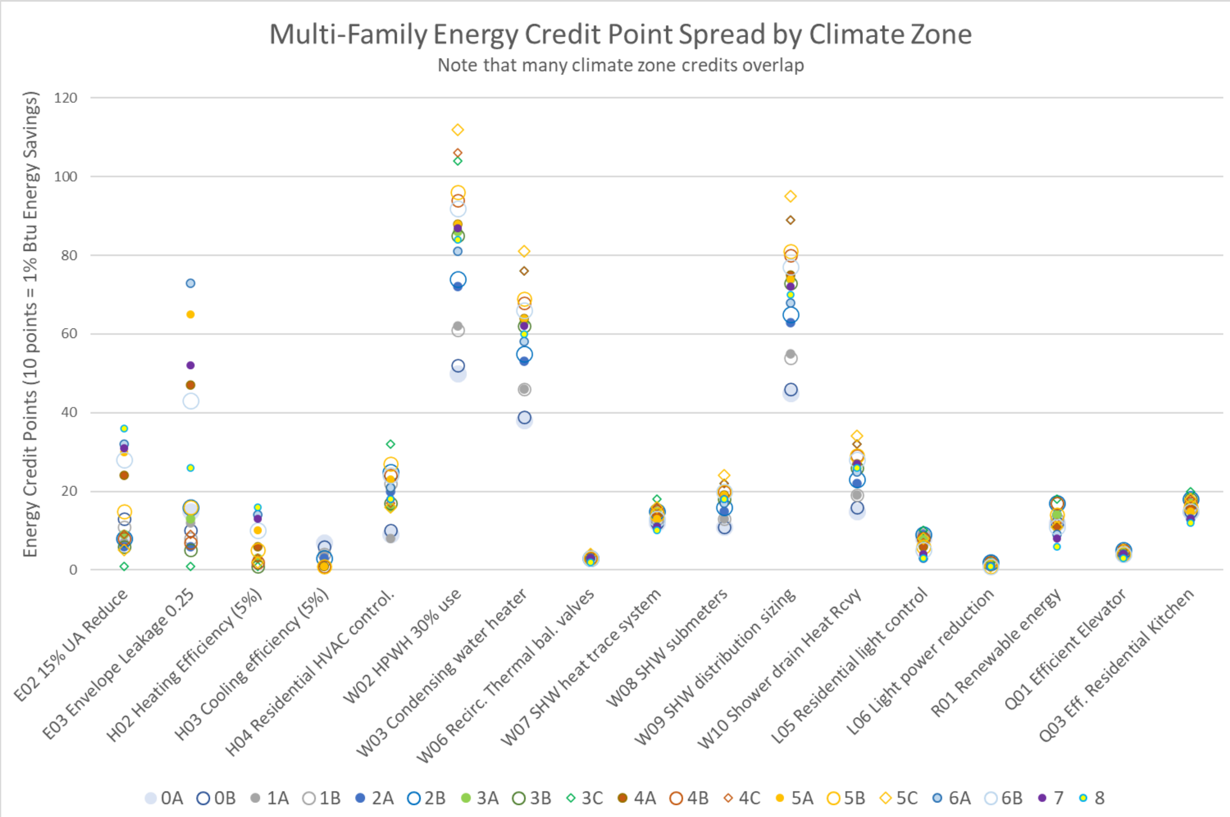

Figure 4. Range of Credit Points for a Sample of Measures for Multifamily Buildings

What strategies are considered to minimize compliance burdens?

To achieve deeper savings in response to energy and carbon reduction policy goals, energy credits provide a more expedient compliance path than the performance path, which requires developing a custom building model. By expanding the number and flexibility of options for achieving energy credits and differentiating credits by building type, additional savings can be achieved with a simplified approach. To streamline its implementation and review, the energy credit measures included in the COMcheck program for the 2021 IECC can be expanded to include the 90.1 measures introduced in Addendum **aq**. While there is some additional review required for the building official, it is less complex than the review typically required for a whole building model.

Are there existing codes and standards that take a similar approach?

The outlined approach is a simple expansion of the structure currently employed in the 2021 IECC for commercial buildings, which has been adopted by several states. The credits approach has been used in the Washington State Energy Code since the 2015 edition, with good results (WSBCC 2015). The approach is also similar to packages of measures used in both residential and commercial energy codes, particularly in the Pacific Northwest. The Washington State and Seattle energy codes have successfully used the approach to address and balance multiple project considerations, including energy performance, design flexibility, and evolving technologies.

1.5 Energy Credit Development

This technical documentation covers multiple measure types:

- Energy efficiency measures that directly reduce the energy use of a building through reduced loads, improved efficiency, improved system configuration, or improved controls.
- Renewable energy measures that reduce the energy impact of the building through local waste heat recovery or energy generation, such as photovoltaic electrical generation systems that offset local building energy use.
- Load management measures that shift building electrical loads and support the effective utilization of renewable and low carbon generation sources on the electric grid.

In the proposed requirements, renewable and load management credits are limited in their use to meet requirements to avoid diluting the impact of energy efficiency measures.

1.5.1 Energy Efficiency Measures

The credit energy efficiency measures considered in the analysis were identified from lists of energy saving measures recognized as being effective for new construction and major renovation projects. The big difference between baseline prescriptive requirements and energy credit measures is that baseline requirements must be applicable to almost all buildings. As a result, there is a limit on the level of energy efficiency that can be achieved. Because the selection of energy credit measures is flexible, the credit approach supports achieving deeper energy savings. For example, lower solar heat gain coefficient (SHGC) glass reduces solar heat gain in commercial buildings, saving cooling energy. At certain limits, low SHGC glazing products may have inventory or supply issues in some styles and locations. As a result, there is limit to how low SHGC requirements are set for the baseline prescriptive requirement. This helps meet the supply needs of the construction industry. Since there are lower SHGC products available, energy credits can account for their use; however, if a particular design includes the baseline prescriptive SHGC product, the designer can choose some other energy credit measure, like increased cooling efficiency or added insulation in exterior walls, to achieve similar savings.

Energy efficiency credits were sourced from Advanced building guidelines like the Advanced Energy Design Guidelines (ASHRAE 2019b), prescriptive energy code requirements in general, measures in utility new construction programs, green building programs, and other building industry documentation to arrive a list of potential measures. The measures build on existing measures that were previously developed (Hart et al. 2019) and include measures considered by other code development groups including the State of Washington technical review committee. Table 1 lists the energy efficiency measures included in this technical brief and shows how they relate to measures in the 2021 IECC Section C406.

Table 1. Energy Efficiency Credit Measures

ID	ap Section	Measure Name	IECC 2021	Proposed IECC 2024
E01	13.5.2.2.1	Envelope performance (90.1 Appendix C basis)		New
H01		HVAC performance (TSPR) [Future]		New
H02	13.5.2.2.2	Heating efficiency	C406.2.1-3	Expanded
H03	13.5.2.2.3	Cooling efficiency	C406.2.2-4	Expanded
H04	13.5.2.2.4	Residential HVAC control		New
H05	13.5.2.2.5	DOAS/fan control	C406.6	Modified
W01	13.5.2.2.6	SHW preheat recovery	C406.7.2	Same
W02	13.5.2.3.1 a	Heat pump water heater	C406.7.4	Modified
W03	13.5.2.3.1 b	Efficient gas water heater	C406.7.3	Same
W04	13.5.2.3.1 c	SHW pipe insulation		New
W05	13.5.2.3.2	Point of use water heaters		New
W06	13.5.2.3.3 a	Thermostatic balancing valves		New
W07	13.5.2.3.3 b	SHW submeters		New
W08	13.5.2.3.4	SHW distribution sizing		New
W09	13.5.2.3.5	SHW shower drain heat recovery		New
P01	13.5.2.3.6	Energy monitoring	C406.10	Same
L01		Lighting performance		*Future*
L02	13.5.2.5.2	Lighting dimming & tuning	C406.4	Expanded
L03	13.5.2.5.3	Increase occupancy sensor		New
L04	13.5.2.5.4	Increase daylight area		New
L05	13.5.2.5.5	Residential light control		New
L06	13.5.2.5.6	Lighting power reduction	C406.3.1-2-3	Expanded
Q01	13.5.2.7.1	Efficient elevators		New
Q02	13.5.2.7.2	Efficient commercial kitchen equipment	C406.12	Same
Q03	13.5.2.7.3	Fault detection and diagnosis (FDD)	C406.11	Same

1.5.2 Renewable and Load Management Credit Measures

There are several load management measures in this proposal, which are listed in Sections 3.8 and 3.9. For reference, in the IECC, the renewable measure was previously included with the 2021 IECC credit measures; however, the load management measures are a proposal for IECC 2024. Renewable and load management measures proposed for 90.1 include:

- R01: On-Site Renewable Energy (2021 IECC Section C406.5; 90.1 Section 13.5.2.6)
- G01: Lighting load management (90.1 Section 13.5.2.8.1)
- G02: HVAC load management (90.1 Section 13.5.2.8.2)
- G03: Automated shading (90.1 Section 13.5.2.8.3)
- G04: Electric energy storage (90.1 Section 13.5.2.8.4)
- G05: Cooling energy storage (90.1 Section 13.5.2.8.5)
- G06: SHW energy storage (90.1 Section 13.5.2.8.6)
- G07: Building thermal mass (90.1 Section 13.5.2.8.7)

1.6 Savings from Efficiency Measures

Energy credits can increase the energy savings beyond baseline prescriptive efficiency requirements. They provide a flexible array of energy saving options that do not have to work for all buildings. In general, savings from Addendum **ap** will be close to 5% energy cost.

1.6.1 Energy Credit Metric

There are several ways to evaluate energy savings in a building. Among them are:

- Energy cost savings, based on local or national average prices
- Site energy savings, based on delivered (metered) energy measured in a consistent conversion to a common metric such as British thermal units (Btu) or gigajoules (GJ)
- Source energy savings, which include adjustments to site energy savings to reflect the conversion efficiency of electrical generation and drilling and distribution losses for natural gas
- Emission savings, usually expressed as carbon equivalent (CO_2e), which may be based on a national conversion rate, regional electric conversion rates, or various streams of future emission impact resulting in a range of possible results

For the 90.1 addendum **ap** analysis, the energy credits are based on site energy cost.

2.0 Energy Savings and Cost Effectiveness

2.1 Energy Savings Analysis

To estimate energy savings for this project, PNNL used prototype buildings from the ASHRAE Standard 90.1 model code analysis process (PNNL 2020) to analyze savings for each measure. In some cases, other engineering calculation methods were used. The baseline used was ASHRAE Standard 90.1-2019. The following process was used:

1. The measure was reviewed to determine the differences in building and system configuration that would contribute to energy savings.
2. One or more prototypes were used to run the baseline and improved building cases to find the relative savings in 19 ASHRAE climate zones. Prototypes were selected based on the relevance of each individual measure.
3. The energy savings was characterized as a percentage cost reduction in the modeled building prototype end uses.
4. End-use breakdowns from the Standard 90.1-2019 performance indicator analysis were used as prototype group[1] basis and the group prototype savings was projected based on proration of end-use savings by the analyzed prototype percentage end-use savings (Nambiar et al. 2021).

2.2 Cost Effectiveness Considerations

To demonstrate cost effectiveness for a base demonstration package of energy credit measure requirements, appropriate measures are selected for the different building use types in different climate zones. Typical costs are compared to expected savings and evaluated using the ASHRAE 90.1 Scalar Method. While there are many combinations that building designers can choose, the approach here is to demonstrate that at least one reasonable cost effective path exists.

2.2.1 Methodology

DOE uses three possible scenarios when evaluating cost effectiveness: (1) publicly owned method, (2) privately owned method, (3) ASHRAE Scalar Method (Hart and Liu 2015).[2] For this analysis of commercial building measures, the ASHRAE Scalar Method was applied, since this is the method used to evaluate the commercial model code, Standard 90.1.

The Scalar Method was developed by ASHRAE Standing Standard Project Committee (SSPC) 90.1 to examine the cost effectiveness of evaluating a specific addendum to Standard 90.1 (McBride 1995). The Scalar Method is an alternative life-cycle cost approach for individual energy efficiency changes with a defined useful life, taking into account first costs, annual energy cost savings, annual maintenance, inflation, energy escalation, and financing impacts. The Scalar Method allows a discounted payback threshold (scalar ratio limit) to be calculated based on the measure life. A measure is considered cost effective if the simple payback (scalar

[1] Prototype groups reflect the building use types that designate separate tables of available energy credits. For example, the school building use type is a composite of the primary and secondary school prototype end uses.
[2] https://www.energycodes.gov/commercial-energy-and-cost-analysis-methodology

ratio) is less than the scalar limit. Limits for both heating (primarily gas, SRh) and cooling (primarily electricity, SRc) are shown in Figure 5.

Table 2 shows the economic parameters used for the ASHRAE Standard 90.1-2022 analysis that were also used for this study. These parameters were adopted by the ASHRAE 90.1 project committee.

Table 2. Scalar Ratio Method Economic Parameters and Scalar Ratio Limit

Input Economic Variables	Heating (gas) SRh	Cooling (electricity) SRc
Economic Life – Years (example)	40	40
Down Payment - $	0.00	0.00
Energy Escalation Rate - %[a]	2.90	2.25
Nominal Discount Rate - %[b]	8.1	8.1
Loan Interest Rate - %	5.0	5.0
Federal Tax Rate - %[b]	NA[b]	NA[b]
State Tax Rate - %[b]	NA[b]	NA[b]
Heating – Natural Gas Price, $/therm	0.983	
Cooling - Electricity Price $/kWh		0.1099
Scalar Ratio Limit (weight: 0.25/0.75)	**25.4**	**22.0**

(a) The energy escalation rate used in the scalar calculation for 90.1-2022 includes inflation, so it is a nominal rather than a real escalation rate.
(b) Beginning with addenda for 90.1-2016, SSPC 90.1 eliminated tax analysis from the Scalar Method by using a pre-tax discount rate.

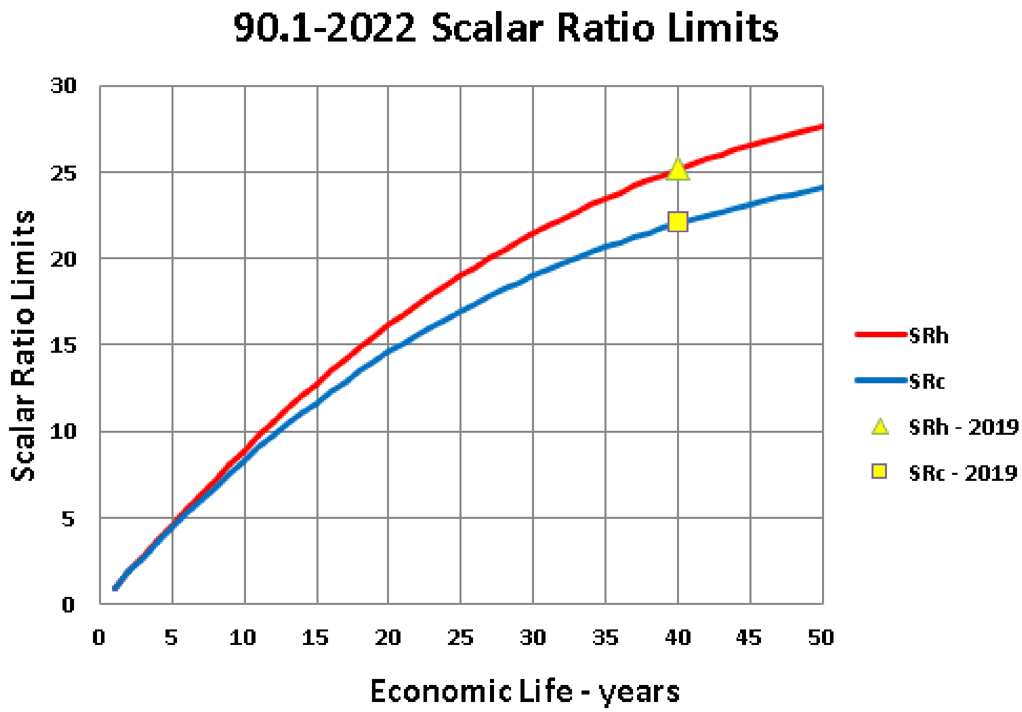

Figure 5. Scalar Ratio Limits Based on Measure Life

As the Scalar Method is designed to be used with a single measure with one value for useful life, it does not account for replacement costs. PNNL extended the Scalar Method to allow for the evaluation of multiple measures with different useful lives (Hart and Liu 2015). This extension is necessary to evaluate a package of measures. This extended method takes into account the variation in lives for different measures in the package. In some cases, the costs were negative, so the individual measure lives were weighted based on savings to determine a package weighted measure life. The scalar ratio limits ranged from 13.8 to 20.5 across all building types and climate zones with an average of 16.6. See Appendix E for detailed thresholds.

The measure costs and savings for the package are tallied and an overall payback is found. This result is compared to the scalar ratio limit for the savings weighted lives. Due to differing escalation rates for different energy types, the scalar threshold is determined separately for heating (primarily gas, SRh) and cooling (primarily electricity, SRc). To develop one scalar threshold that can be used across building types, the gas (SRh) and electric (SRc) scalar limits were weighted at 25% and 75%, respectively. The packages of changes for each combination of prototype and climate location were considered cost effective if the corresponding scalar ratio was less than the scalar ratio limit.

2.2.2 Cost Effective Energy Efficiency Demonstration Packages

The energy credit requirements are justified based on a selection of a package of measures that meet the requirement and are cost effective for each building use type and climate zone. About one quarter of the measures were selected for inclusion in the cost effectiveness analysis, based on their general applicability and reliable savings. Two demonstration packages were reviewed, one to evaluate cost effectiveness and one to show a reasonable package without using efficiency improvements for HVAC and SWH equipment subject to EPACT (42 USC 6833) minimum federal efficiencies:

- The base demonstration package included standard efficiency measures with a cap of 5% for required credits to allow for measure selection flexibility. While the energy credits are limited to 5% whole-building savings, in many cases the selected measures that were cost effective exceeded that savings level cap.
- The alternative demonstration package was selected by replacing HVAC and SWH equipment with alternative reasonable measures to achieve similar savings to the base demonstration package. Cost effectiveness was not determined for the alternate package.

2.2.2.1 Base Demonstration Package

Table 3 provides an overview of measures selected for inclusion in the base demonstration package. Measures are selected with the goal of 5% savings or 50 credits for this package. Measure selection may be climate zone specific. For example, cooling efficiency only makes sense in warm climate zones. The climate zones (CZ) or application of measures is shown along with individual measure lives used for determining cost effectiveness.
Based on this selection of measures, the scalar value or payback for each building type for the selected group of measures is given in Table 4. This represents the cost for all measures included in the package divided by the annual consumer energy cost savings. Note that for multifamily buildings and hotels, the SHW distribution redesign results in a significant cost reduction, so the overall package cost is less than the baseline and the “CE” indicates that the packages in those buildings are immediately cost effective. A scalar limit or threshold is developed for each combination of climate zone and building type based on the individual measure lives shown in Table 3, weighted by the measure cost savings. The measures included in the base package—and therefore credits required—are adjusted so that all building types in all climate zones have a consumer payback that is less than the scalar limit, indicating cost effectiveness of at least one combination of measures for the efficiency credit requirements. The office and warehouse building type paybacks were closest to the scalar limits, but even there, the payback was always less than the scalar limit. See Appendix E for detailed results.

Table 3. Matrix of Base Demonstration Package Efficiency Measures

ID	Energy Credit Abbreviated Title	Measure Life, yr	Multifamily /Dormitory	Health Care	Hotel/Motel	Office	Restaurant	Retail	School/ Education	Warehouse/ Semiheated
E01	Glazing U & SHGC reduction	40	all CZ	all CZ	all CZ	all CZ	all CZ	CZ 0,3A,3C-4C	all CZ	
H02	Heating efficiency	18	15%, CZ 5A-8	15%, CZ 5A-8	10%, CZ 5B,6-8			10%, CZ 4-8		5%, CZ 5A-8
H03	Cooling efficiency.	15	10%, CZ 0-2A	15%, CZ 0-3B	10%, CZ 0-2	10% CZ 0-1	5%, CZ 0-3B	5%, CZ 0-2	10% CZ 0-2	5% CZ 0-1
H04	Residential HVAC control.	15	all CZ							
W02	Heat pump water heater	13		all CZ (30%)	all CZ (30%)					
W03	Efficient gas water heater	13		all CZ (70%)	all CZ (70%)		all CZ			
W05	Point of use water heaters	15				CZ 0B-5A			CZ 0-4	
L03	Increase occupancy sensor	15		CZ 0-6A	all CZ	all CZ		CZ 0B, 5B, 5C	all CZ	
L04	Increase daylighting area	15						CZ 0-5		CZ 0-5A 10%; 5B-8 5%
L05	Residential Light Control	15	all CZ							
L06	Light power reduction	20	all CZ, 5%	all CZ, 5%	all CZ, 10%	all CZ, 5%	all CZ, 10%	all CZ, 5%	all CZ, 5%	all CZ, 5%
R01	On-site renewable (0.1 W/ft^2)	25	all CZ	all CZ	all CZ	all CZ	all CZ	all CZ	all CZ	all CZ
Q02	Efficient kitchen equipment	15					all CZ			
Q03	Fault detection	15		all CZ				all CZ		
G02	HVAC Load Management	15				all CZ				

[a] Dining areas and kitchens in dormitories, hotels, and schools treated as a separate area where efficient kitchen equipment credits apply

Table 4. Scalar Ratios for Base Demonstration Package Efficiency Measures by Climate Zone and Building Type

	Climate Zone																		
Building Use Type	**0A**	**0B**	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**
Multifamily/Dormitory	6.8	7.4	8.2	7.9	9.0	11.2	13.2	11.6	13.3	12.2	10.6	14.1	10.1	10.4	14.7	8.7	9.8	9.0	7.8
Health Care	2.6	2.9	3.0	3.0	3.0	3.8	3.6	3.9	3.8	3.9	4.0	3.6	3.6	3.8	2.8	3.3	2.8	2.4	2.2
Hotel/Motel	3.2	3.6	4.0	3.9	4.4	5.0	5.6	5.5	5.2	5.7	5.2	5.9	5.9	5.8	6.1	5.3	5.6	4.9	4.4
Office	6.3	4.4	5.0	4.6	5.7	5.3	5.3	5.2	5.7	5.3	4.9	5.8	5.5	7.5	9.2	8.3	7.6	7.9	8.4
Restaurant	3.2	3.4	3.9	3.8	3.9	4.3	4.3	4.4	5.1	4.5	4.6	4.8	4.5	4.4	4.5	4.3	4.3	3.9	3.7
Retail Buildings	5.9	6.1	7.3	7.0	8.7	9.2	11.5	11.3	12.2	10.5	11.2	12.4	8.5	9.2	11.0	7.2	8.5	8.6	7.5
School/Education	3.7	4.0	4.7	4.3	5.0	5.4	6.2	5.7	6.0	6.0	5.4	6.5	8.3	7.4	8.6	7.7	7.7	7.8	8.1
Warehouse	10.5	10.4	10.8	10.6	9.8	9.0	10.1	8.9	9.3	10.9	9.1	11.1	9.0	9.0	11.9	7.4	8.2	7.8	8.6

Figure 6 shows the contribution of different measure types in the demonstration package to achieving the required credits. The contribution of different types is based on a selection of reasonable measures to demonstrate cost effectiveness. Other measure mixes or selections could have been made, resulting in different weights of contribution. Two specific restrictions should be noted:

- The multifamily demonstration package would have been much more aligned with end uses in the building with the selection of central service water heating measures. Such a selection would have been more cost effective as well. The measures were selected to avoid service water heating to demonstrate that an effective package could be created for multifamily buildings that are designed with individual water heaters for each apartment.

- The warehouse building type includes almost double the required credits in the demonstration package. While the requirement is limited to 5% building cost savings like the other buildings, since a large portion of the credits come from renewable energy, it was important to demonstrate that a good share of credits could be achieved even in situations where renewable energy was restricted due to limited roof area or low insolation.

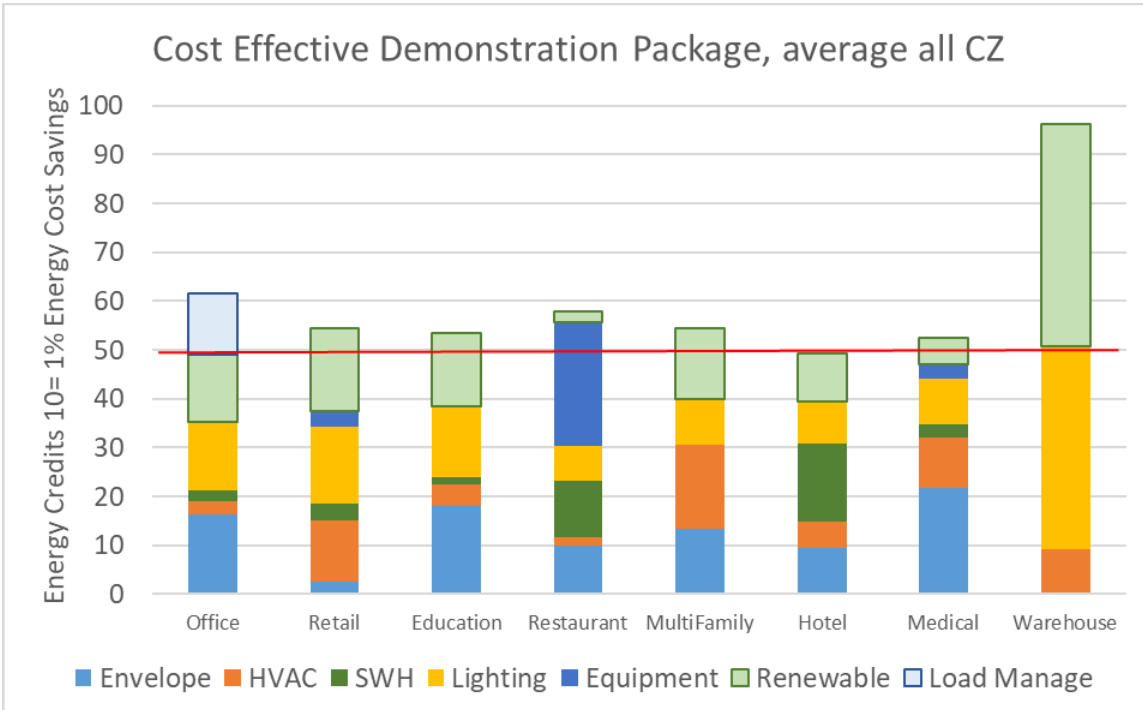

Figure 6. Cost effective Demonstration Package Credits by Measure Type

2.2.2.2 Alternate Demonstration Package

Table 5 provides an overview of energy efficiency measures selected for inclusion in an alternate package. The purpose of this package is to demonstrate that the energy credit requirements can be met using minimum efficiency HVAC and SWH equipment as defined by EPACT (42 USC 6833). Reasonable measures were selected with the same goal of 5% savings, or 50 credits; however, HVAC and service water heating efficiency measures (H02, H03, W02, W03) are not included in the alternate package. The climate zones or application of measures are shown. Cost effectiveness of this package was not estimated.

Table 5. Matrix of Alternate Demonstration Package Efficiency Measures

ID	Energy Credit Abbreviated Title	Measure Life, yr	Multifamily /Dormitory	Health Care	Hotel/Motel	Office	Restaurant	Retail	School/ Education	Warehouse/ Semiheated
E01	Glazing U & SHGC Reduction		Same	Same	Same	Same	Same	+CZ 5A-8	Same	
H04	Residential HVAC control.		Same							
H06	DOAS + fan control.			+CZ 0-2, 25% area				+CZ 4C-8, 80% area		
W01	Energy recovery preheat SHW			30% HR	30% HR					
W05	Point of use water heaters					Same			Same	
W08	SWH distribution sizing		all CZ		all CZ					
W09	SHW shower drain heat recovery				CZ 0, 4C, 5C, 7-8					
L03	Increase occupancy sensor				Same	CZ 0	CZ 3B, 4C-5C	+CZ 4C, 5C, 7-8	Same	+ all CZ
L04	Increase daylight area						CZ 3B, 4C-5C	CZ 1-5C, +8	+CZ 0-1	CZ 4C,5A, 5C,6A,7,8
L05	Res. Light Control (Ex. # b)		Same							
L06	Light power reduction 5%-> 10%		Same	most CZ	Same	CZ 0-2A	all CZ	all CZ	CZ 0, 4C, 5C	Same
R01	Renewable energy (ex. CZ 4C/5C)		CZ 0-3, 0.1 W/sf	0.2 W/sf All cz	0.2 W/sf +CZ 0B-3B	Same	0.2 W/sf +CZ 0-4B	0.2 W/sf +CZ 8	Same	Same
Q01	Efficient Elevators		CZ 0A, 6A		CZ 0B-2A, 3C-8					
Q02	Efficient Kitchen Equipment						Same			
Q03	Fault detection			Same	CZ 0-1			CZ 5C	CZ 0-2A	
G02	HVAC Load Management								CZ 0-3A	
G05	Cooling Stroage				CZ 0A	CZ 0A				
G06	SHW Stroage						CZ 0-3A, 4C, 5A, 6-8			
E01	Glazing U & SHGC Reduction		Same	Same	Same	Same	Same	+CZ 5A-8	Same	

[a] Dining areas and kitchens in dormitories, hotels, and schools treated as a separate area where efficient kitchen equipment credits apply

3.0 Energy Efficiency, Renewable Energy, and Load Management Credit Measures

Each of the energy credit measures included in the sample code language in Addendum **ap** is described with the following information:

- The modifications to the building required to achieve the credit
- In some cases, the limitations on the measure
- How the measure saves energy compared to the prescriptive baseline
- What the measure applicability is to different buildings
- How the measure relates to the measures included in C406 of the 2021 IECC

3.1 Measure Applicability

Several of the measures may not be applicable in certain building use types. This occurs where the measure may be common practice already, where there are concerns about measure persistence for the particular building use, or where the savings are quite low for that building type. Where measures are not applicable, they are noted with NA in Table 6. The reasons for non-applicability for an entire building use type are included with the measure discussions below. Some measures may have very low savings or even energy increases in certain climate zones. In this case the measure non-applicability in a certain climate zone is indicated by an “NA” or “x” in the measure available credits in addendum **ap**.

Table 6. Energy Credit Measure Applicability

ID	Energy Credit Abbreviated Title	Multifamily	Health Care	Hotel/ Motel	Office	Restau-rant	Retail	School/ Education	Ware-house	Other
E01	Envelope Performance (90.1 Appendix C)	YES	YES	YES	YES	YES	YES	YES	YES	YES
H02	Heating Efficiency	YES	YES	YES	YES	YES	YES	YES	YES	YES
H03	Cooling efficiency.	YES	YES	YES	YES	YES	YES	YES	YES	YES
H04	Residential HVAC control.	YES	NA	NA	NA	NA	NA	NA	NA	NA
H05	Ground source heat pump	YES	YES	YES	YES	YES	YES	YES	NA	YES
H06	DOAS/fan control.	NA	YES	NA	YES	NA	YES	YES	NA	YES
W01	SHW preheat recovery	YES	YES	YES	YES	YES	YES	YES	YES	YES
W02	Heat pump water heater	YES	YES	YES	YES	YES	YES	YES	YES	YES
W03	Efficient gas water heater	YES	YES	YES	YES	YES	YES	YES	YES	YES
W04	SHW pipe insulation	YES	YES	YES	YES	NA	NA	YES	NA	YES
W05	Point of use water heaters	NA	NA	NA	YES	NA	NA	YES	NA	YES
W06	Thermostatic balancing valves	YES	YES	YES	YES	YES	YES	YES	YES	YES
W07	SHW submeters	YES	NA	NA	NA	NA	NA	NA	NA	NA
W08	SHW distribution sizing	YES	NA	YES	NA	NA	NA	NA	NA	NA
W09	SHW shower drain heat recovery	YES	NA	YES	NA	NA	NA	YES	NA	NA
P01	Energy monitoring	YES	YES	YES	YES	YES	YES	YES	YES	YES
L02	Lighting dimming & tuning	YES	YES	YES	YES	YES	YES	YES	NA	YES
L03	Increase occupancy sensor	NA	YES	YES	YES	YES	YES	YES	YES	YES
L04	Increase daylight area	NA	NA	NA	YES	NA	YES	YES	YES	YES
L05	Residential light control	YES	NA	NA	NA	NA	NA	NA	NA	NA
L06	Light power reduction	YES	YES	YES	YES	YES	YES	YES	YES	YES

ID	Energy Credit Abbreviated Title	Multifamily	Health Care	Hotel/ Motel	Office	Restau- rant	Retail	School/ Education	Ware- house	Other
R01	Renewable energy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Q01	Efficient Elevator	YES	YES	YES	YES	YES	YES	YES	YES	YES
Q02	Efficient Kitchen Equipment	NA	NA	NA	NA	YES	NA	NA	NA	NA
Q03	Fault detection	YES	YES	YES	YES	YES	YES	YES	YES	YES
G01	Lighting load management	NA	NA	NA	YES	NA	YES	YES	YES	YES
G02	HVAC load management	NA	NA	NA	YES	NA	YES	YES	NA	YES
G03	Shading load management	YES	YES	YES	YES	YES	YES	YES	NA	YES
G04	Electric storage	YES	YES	YES	YES	YES	YES	YES	YES	YES
G05	Cooling storage	YES	YES	YES	YES	YES	YES	YES	YES	YES

3.2 Building Envelope

Improvements to the building envelope can achieve energy credits either through the envelope performance (E01).

3.2.1 E01: Envelope Performance (90.1 Appendix C)

Envelope performance captures savings from multiple improvements in the building envelope:

- Increased insulation reduces heat loss and gain, reducing heating, ventilation, and air conditioning (HVAC) energy use.
- Improved glazing reduces energy use through any of the following:
  - Lower U-factor results in less heat transfer, reducing HVAC energy.
  - Lower SHGC reduces heat gain, saving cooling.
  - Increased glazing visual transmittance allows more daylight, reducing lighting where there are daylight controls.
  - A reduced window area generally provides savings.
- Lower reflectivity reduces cooling loads in warm climates.
- Better air barriers reduce outdoor air leakage into the building, reducing HVAC energy.

While these general improvements usually save energy, in some cases they may not. All of these impacts can be modeled in the ASHRAE Standard 90.1 methodology that is accessible in COMcheck. The input to model these changes is the same as needed to verify compliance with the prescriptive requirements. There are two advantage to using that model for envelope changes:

- It accounts for the different internal loads of different occupancy types
- It is already used in COMcheck if there are envelope tradeoffs

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a new measure and an alternative to the UA reduction and air leakage reduction energy credits in the IECC.

3.3 HVAC

Improvements to the building HVAC system can achieve energy credits either through the HVAC performance measure (H01) or a combination of other HVAC measures (H02-H03 and H05). The residential HVAC control (H04) and dedicated outdoor air system (DOAS) (H05) measures can be completed independently or in conjunction with other HVAC measures.

3.3.1 H01: HVAC Performance (TSPR) (Reserved)

This is an alternative lighting performance path that is under development. It is currently out for public review consideration for Standard 90.1.

Measure H01 requires the installation of HVAC equipment efficiency improvements and distribution system design upgrades that match the inputs to the HVAC performance analysis. It is flexible and credits can be achieved when the proposed HVAC system total system performance ratio (TSPR) is greater than the TSPR of a target system. To be effective, the TSPR language covered in a separate technical brief would also have to be adopted into the energy code (Goel et al. 2021). Multiple HVAC system changes can be included, including the following:

- Improved heating or cooling equipment efficiency, including packaged units, chillers, heat rejection, and boilers
- Reduced fan energy due to better ductwork design, better fan selection or fan drive and motor efficiency, and improved fan controls
- Reduced pumping energy due to better piping design, better hydronic configuration, better pump selection or pump motor and drive efficiency, and improved pump controls
- Separate management of ventilation air including energy recovery, low dedicated outdoor air system (DOAS) fan power, demand controlled ventilation, energy recovery bypass, or improved delivery effectiveness
- Improved energy recovery opportunities, including ground loop systems and other energy recovery systems

Measure H01 saves energy by increasing the overall delivered heating and cooling relative to the total energy input to the HVAC system, when compared to a target HVAC system that is selected from available prescriptive systems.

This measure is applicable to all building use types. Compared to the 2021 IECC, this creates a new measure. It is an alternative to other HVAC energy credits. In the base code language in Section 3.0, this is considered a future measure with a reserved space. If a jurisdiction wishes to adopt this measure as an energy credit, then the instructions in Appendix B should be followed.

3.3.2 H02: Heating Efficiency

Measure H02 requires the installation of more efficient heating equipment than required by the minimum HVAC efficiency requirements. Examples of such improvements include:

- Replacing a standard furnace or boiler with a condensing furnace or boiler
- Including a heat pump with a higher heating seasonal performance factor or heating coefficient of performance than the minimum heat pump heating efficiency requirements

Measure H02 does not provide credit for system type or fuel switches, such as from a furnace to a heat pump or from electric resistance heat to a heat pump. For such system comparisons, when available H01 (TSPR) can be used instead. In H01, the proposed system is compared to a preset target system for the building type.

Measure H02 saves energy by increasing the overall delivered heating relative to the heating energy input to the HVAC system, when compared to the minimum heating efficiency required in the prescriptive energy code for the proposed heating equipment.

This measure is applicable to all building use types. Compared to the 2021 IECC, this matches existing measures with some modification. For H02, the credits are based on a minimum efficiency improvement of 5% and credits can be adjusted to reflect an efficiency improvement of up to 20%. This replaces both the 5% and 10% heating efficiency improvement measures in the 2021 IECC. H02 will be an alternative to the HVAC performance (H01) energy credits when available.

3.3.3 H03: Cooling Efficiency

Measure H03 requires the installation of more efficient cooling or heat rejection equipment than required by the minimum HVAC efficiency requirements. Examples of such improvements include:

- Replacing a standard AC unit, chiller, (including heat rejection equipment with water-cooled chillers) with a higher efficiency AC unit or chiller plus heat rejection equipment
- Including an evaporative assist device for air-cooled equipment where the efficiency improvement of the cooling equipment efficiency can be documented seasonally
- Measure H03 does not provide credit for system type switches, such as from an air-cooled chiller to a water-cooled chiller, or from packaged units to variable air volume hydronic units. For such system comparisons, when available H01 (TSPR) can be used instead. In H01, the proposed system is compared to a preset target system for the building type.

Measure H03 saves energy by increasing the overall delivered cooling relative to the cooling energy input to the HVAC system, when compared to the minimum cooling efficiency required in the prescriptive energy code for the proposed cooling equipment.

This measure is applicable to all building use types. Compared to the 2021 IECC, this matches existing measures with some modification. For H03, the credits are based on a minimum efficiency improvement of 5% and credits can be adjusted to reflect an efficiency improvement of up to 20%. This replaces both the 5% and 10% cooling efficiency improvement measures in the 2021 IECC. It will be an alternative to the HVAC performance (H01) energy credits when available.

3.3.4 H04: Residential HVAC Control

Measure H04 requires the installation of a centralized HVAC setback control in multifamily buildings. The controls will relax temperature setpoints when occupants are away from their apartments. Alternative approaches to such controls include:

- A main manual control by each dwelling unit main entrance that initiates setback and non-ventilation mode for all HVAC units serving the dwelling unit and is clearly identified as “Heating/Cooling Master Setback.”

- Occupancy sensors in each room of the dwelling unit combined with a door switch to initiate setback and non-ventilation mode for all HVAC units in the dwelling within 20 minutes of a door switch operation followed by all spaces being vacant. Where separate room HVAC units are used, individual occupancy sensors are adequate.
- An advanced learning thermostat that senses occupant presence and automatically creates a schedule for occupancy and provides a dynamic setback schedule based on when the spaces are generally unoccupied. Where ventilation is provided by a separate system, it shall also have occupancy sensor control.

Measure H04 saves energy by reducing the temperature difference between interior HVAC setpoint and outdoor conditions, resulting in reduced heating and cooling system operation. In addition, ventilation outdoor air is curtailed when the space is unoccupied, resulting is less heating and cooling of outdoor air.

This measure is applicable only to the multifamily building use type. Compared to the 2021 IECC, this is a new measure. It is allowed in conjunction with either the HVAC performance (H01) energy credits or other HVAC credits (H02, H03, H05).

3.3.5 H05: Ground Source Heat Pump

Measure H05 requires installation of a ground source loop or other water source loop to serve individual zone water-to-air heat pumps that provide heating and cooling. To match typical system design approaches, the simulated bore field is sized to handle the cooling load for about 90% of the operating hours that typically provides half the peak cooling load. When cooling loads are higher, a dry fluid cooler is used to reject heat.

Measure H06 saves energy primarily by using a moderately high efficiency zone cooling device that rejects heat to an earth ground sink. In addition, there are savings through reduced fan energy use with a distributed zone fan system that has relatively short duct runs.

This measure is applicable to all building use types except warehouse, as ground source heat pumps are rarely used in warehouses. Compared to the 2021 IECC, this is a new measure. It is allowed in conjunction with other HVAC credits (H02, H03, H06).

3.3.6 H06: DOAS/Fan Control

Measure H06 requires the installation of local zone or central DOAS sized to provide the minimum outdoor air ventilation requirements. The DOAS is equipped with an energy recovery device providing a 65% enthalpy recovery ratio. An energy recovery bypass is required for a DOAS serving multiple zones.

Measure H05 does not provide credit for zone heating and cooling system type switches, such as from a packaged terminal air conditioner to a fan coil or from packaged units to variable air volume hydronic units. For such system comparisons, use H01, TSPR, instead. In H01, the proposed system is compared to a preset target system for the building type.

Measure H05 saves energy primarily by reducing the fan energy use of the zone heating and cooling system, since it can be shut down in the deadband when neither heating nor cooling is required. In addition, there are savings through use of energy recovery to preheat or precool outside air.

This measure is applicable to health, office, retail, and education building use types. It is not applicable to multifamily as their fans are typically in cycling mode; not to lodging as guest room HVAC shutoff controls are already required; not to restaurant as the measure is superseded by transfer air used for exhaust; and not to warehouse as ventilation requirements are too low and fans are typically set in cycling mode.

Compared to the 2021 IECC, this is a modification of an existing measure. The modifications include a specified energy recovery specification in addition to zone unit fan control not required in the existing measure. It is an alternative to the HVAC performance (H01) energy credits.

3.4 Service Hot Water

SHW energy use can be reduced through a combination of measures. These include more efficient hot water generation, energy recovery, reducing hot water use, reducing the heat loss in hot water distribution systems, and metering multifamily hot water use. The energy credits allowed vary with the typical hot water use patterns of the different building types. The first three efficiency improvement credits (W01, W02, and W03) improve SHW generation efficiency. For systems with recirculation, there is a choice of W05 or W06. Other measures have specific building applications.

3.4.1 W01: SHW Preheat Recovery

Measure W01 requires the installation of SHW preheat recovery devices that recover heat from chiller system heat rejection, kitchen drain water, site-based renewable systems, refrigeration systems, or some other heat source. The system preheats entering cold water and reduces by between 30% and 80% the use of non-renewable energy sources for annual SHW heating.

Measure W01 saves energy primarily by reducing the electric or fossil fuel used to heat SHW by using waste or renewable heat to preheat the cold water entering the system.

This measure is applicable to all building use types, although usually practical only where a chiller is used. Compared to the 2021 IECC, this is a modification of an existing measure. It can be combined with other SHW efficiency (W02 or W03) energy credits. It can be combined with appropriate non-efficiency SHW (W04 through W09) energy credits.

3.4.2 W02: Heat Pump Water Heater

Measure W02 requires the installation of an air-source heat pump water heater sized to meet 50% of the design water-heating requirement. The system includes either an integrated or separate hot water storage tank with a pump. In recirculating hot water distribution systems, there is typically a separate gas or resistance electric heater to reheat the circulated water for temperature maintenance in periods of low demand.

Measure W02 saves energy primarily by using a more efficient heat pump system rather than electric resistance or combustion heating. The system heats entering cold water and reduces by between 30% and 80% the use of non-renewable energy sources for annual SHW heating.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a modification of an existing measure. It can be combined with other SHW efficiency (W01 or W03) energy credits. It can be combined with appropriate non-efficiency SHW (W04 through W09) energy credits.

3.4.3 W03: Efficient Gas Water Heater

Measure W03 requires the installation of a gas water heater with higher efficiency than the minimum prescriptively required. A condensing water heater is required to meet the efficiency increase to 95%.

Measure W03 saves energy primarily by reducing the gas energy used to provide the same water heating. Through use of a condensing water-heating coil, the exhaust gas temperature is lower than a conventional gas water heater, transferring that additional heat to the heated water.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a modification of an existing measure. It can be combined with other SHW efficiency (W01 or W02) energy credits. It can be combined with appropriate non-efficiency SHW (W04 through W09) energy credits.

3.4.4 W04: SHW Pipe Insulation

Measure W01 requires the installation of additional pipe insulation beyond the minimum required prescriptively.

Measure W01 saves energy primarily by reducing the heat loss from piping delivering the SHW or recirculating the SHW for temperature maintenance.

This measure is applicable to office, health, multifamily, lodging, and education building use types that typically have extensive hot water distribution systems. The other building types typically do not have recirculation systems and savings are quite limited. Compared to the 2021 IECC, this is a new measure. It is allowed in combination with other SHW efficiency (W02 and W03) energy credits.

3.4.5 W05: Point of Use Water Heaters

Measure W05 requires the installation of point of use water heaters with reduced piping lengths in buildings that typically use recirculation systems and a central water heater. Good application of a point of use water heater is a small electric water heater that serves a cluster of restrooms. Exceptions are provided for showers and kitchens that have local water heaters that require recirculation for temperature maintenance.

Measure W05 saves energy primarily by reducing the heat lost from SHW piping in two ways:

- Recirculation piping for temperature maintenance along with its heat loss is eliminated.
- Supply piping length is reduced, along with a reduction in heat loss.

This measure is only applicable to office and education building use types where hot water use is relatively low and there are extensive distribution systems to deliver hot water to remote restrooms. Compared to the 2021 IECC, this is a new measure. It is one option that can be selected from the SHW distribution temperature maintenance energy credits (W05 and W06).

3.4.6 W06: Thermostatic Balancing Valves

Measure W06 requires the installation of thermostatic balancing valves for a recirculation system rather than manually adjusted or fixed-flow balancing valves. The valves are required to minimize the return water flow when the branch return temperature is greater than 120°F. These valves reduce the balancing labor compared with manual valves as they are self-balancing.

Measure W06 saves energy primarily by reducing the recirculation pipe temperature and associated heat loss. This is because actual temperature is measured rather than a constant flow delivered regardless of primary supply temperature or an estimate of flow required to maintain the desired temperature.

This measure is applicable to all building use types where there are recirculation systems. Compared to the 2021 IECC, this is a new measure. It is one option that can be selected from the SHW distribution temperature maintenance energy credits (W05, W06, and W07).

3.4.7 W07: SHW Submeters

Measure W07 requires the installation of separate dwelling unit SHW meters in multifamily buildings served by a central water-heating system. A data collection and reporting system is also required.

Measure W08 saves energy primarily by allowing centrally heated SHW to be reported or billed to individual tenants, providing an incentive to reduce hot water use.

This measure is only applicable to multifamily building use types where there is some possibility of affecting hot water use behavior. Compared to the 2021 IECC, this is a new measure. It is allowed in combination with any other SHW efficiency energy credits.

3.4.8 W08: SHW Distribution Sizing

Measure W08 requires the installation of reduced flow sink, lavatory, and showerhead fixtures in buildings with residential occupancies. The hot water distribution system must also be sized in accordance with IAPMO/ANSI, *WE●Stand – 2017 Water Efficiency and Sanitation Standard for the Built Environment* (IAPMO 2017) Appendix C. This standard is an alternative path for sizing multifamily SHW systems and is recognized in some plumbing codes. Using this method for hotel guest room hot water piping would require a plumbing variance.

Measure W08 saves energy primarily by reducing the SHW end use and by reducing the piping size, and therefore heat loss, of the SHW distribution piping.

This measure is applicable to multifamily and lodging building use types that have a large number of dwelling units or sleeping units. Compared to the 2021 IECC, this is a new measure. It is allowed in combination with any other SHW efficiency energy credits.

3.4.9 W09: SHW Shower Drain Heat Recovery

Measure W09 requires the installation of shower drain heat recovery devices used to preheat the cold water serving showers.

Measure W09 saves energy primarily by reducing volume of hot water used for showering, since the cold water is warmer and less hot water is required to achieve the same mixed shower water temperature.

This measure is applicable to multifamily, lodging, and schools. Other buildings do not have enough shower use to provide adequate savings. Compared to the 2021 IECC, this is a new measure. It is allowed in combination with any other SHW efficiency energy credits.

3.5 Power

The power energy credit measure acknowledges the potential for improved operation for energy monitoring where not required prescriptively.

3.5.1 P01: Energy Monitoring

Section C405.12 of the IECC requires energy monitoring in non-residential buildings 25,000 square feet and larger. Measure P01 provides an energy credit where similar electrical monitoring is installed in smaller buildings. This equipment is much less expensive to install in new construction than to retrofit into existing buildings.

Measure P01 potentially saves energy by providing detailed energy use information to tenants and operating staff of buildings so they can note excess energy use at times when the building is unoccupied and should have low energy use or where there is increased energy use over time due to degradation of energy system controls or equipment.

This measure is applicable to all building use types where it is not already required by Standard 90.1. Compared to the 2021 IECC, this is essentially the same as an existing measure.

3.6 Lighting

Lighting energy credit measures either reduce lighting power installed or improve the controls compared to prescriptive requirements.

3.6.1 L01: Lighting Performance (Reserved)

This is an alternative lighting performance path that is under development. It is currently out for public review consideration for Standard 90.1. The method combines lighting power reduction and lighting controls into a comprehensive interior lighting approach that considers interaction of all possibilities. When available it would provide a comprehensive alternative to L02, L03, L04, and L06.

L01 is not included as a measure in Addendum **ap** and will require a future addendum to be included with energy credits.

3.6.2 L02: Lighting Dimming & Tuning

Measure L02 requires the installation of dimming lighting systems with central and zonal controls and an intentional high-end trim adjustment commissioning process for at least half the building floor area or lighting power.

Measure L02 saves energy by tuning the light levels in different spaces more specifically to the needed task. This reduces the initial maximum light output to best match the space task visual need. Additionally, lighting is often designed for higher initial lighting levels to compensate for luminaire output depreciation over time. The capability to manually or automatically tune lighting output overtime to maintain task level illumination, allows the added depreciation compensation power to be saved.

This measure is applicable to all building types except warehouses that are unlikely to have dimming systems. Compared to the 2021 IECC, this is a modification of an existing measure. It can be applied in conjunction with other lighting energy credits, excluding L03 and possibly the future lighting performance credit (L01), depending on how the final implementation of the lighting performance measure related to zonal tuning is established. This measure is more stringent than the current measure through the addition of tuning that provides reliable energy savings.

3.6.3 L03: Increase Occupancy Sensor Control Area

Measure L03 requires the installation of full off occupancy sensor controls where time controls are allowed by the prescriptive path. This allows the lighting system to respond to actual occupancy rather than time control that is often set for the most expansive scheduled use of the space. Time controls require manual intervention to turn lighting on outside of scheduled times or to schedule special events, and eventually evolve to the worst case situation, with extended “on” periods of time.

Measure L03 saves energy by reducing lighting operation when lighting is not required, since the spaces are unoccupied. A prime example of this is custodial work performed after hours, where often the entire building or multiple floors are lit up via the time scheduled controls, even though the work is occurring in a small area. A time control, or even a bypass switch, lights up large areas of the building, whereas occupancy sensors control a small area where the work is actually occurring.

This measure is applicable to all building types except multifamily that have very few areas where occupancy sensors are suitable and not already required. Compared to the 2021 IECC, this replaces and expands the enhanced digital lighting control measure. It can be applied in conjunction with some other lighting energy credits, including L04, L05, and L06.

3.6.4 L04: Increase Daylight Area

Measure L04 requires the installation of daylight responsive controls in space types beyond where they are typically required by current energy codes. So, if the building is arranged to provide more daylight area than typical, or controls are added to areas where the low wattage would otherwise exempt the area from daylight responsive controls, then credit is provided for increased daylight area.

Measure L04 saves energy by increasing the area where electrical lighting reductions can be achieved with daylight availability at satisfactory levels of illuminance required to perform visual tasks. This reduces the energy used for lighting and also reduces the energy used for cooling.

This measure is applicable to office, retail, warehouse and education building use types. It is not applicable to multifamily and lodging buildings as it is not suitable for apartments or guest rooms. Health and restaurants are not suitable for additional daylighting areas.

Compared to the 2021 IECC, this is a new measure. It can be applied in conjunction with other lighting energy credits, excluding the future lighting performance credit (L01).

3.6.5 L05: Lighting Control for Multifamily Buildings

Measure L05 requires the installation of a centralized master switch near apartment (dwelling unit) exits that can turn off the entire lighting in the unit with one or two switch operations. This can be achieved by wiring the lighting circuits through a central switch at the unit entrance. There is an additional requirement that there be two clearly identified switched receptacles in each room connected to the unit exit control. It is anticipated these receptacles would be used for floor lamps or other task lighting. As a master switch, this does not require three-way or four-way switching. The measure can be implemented with traditional wiring or with wireless remote-control methods.

Measure L05 saves energy by making it easy for apartment occupants to turn off all lighting in an apartment when exiting the unit. This reduces lighting operation and also reduces cooling energy use, although it may increase heating energy use in colder climates.

This measure is applicable to multifamily building use types only. Transient lodging already has requirements for guest room lighting controls. Compared to the 2021 IECC, this is a new measure. It can be applied in conjunction with other lighting energy credits, possibly excluding the future lighting performance credit (L01).

3.6.6 L06: Lighting Power Reduction

Measure L06 requires that the installed lighting system be at least 5% lower LPD than the prescriptive lighting power allowance. This can be achieved through selection of higher efficacy luminaires or a better match of design fixture layout to space lighting requirements.

Measure L06 saves energy by reducing the lighting power required to meet minimum lighting levels.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a modification of two existing measures. Rather than listing separate 10% and 20% reductions, L06 is based on a 5% LPD reduction and can be adjusted up to a 15% LPD reduction (limited to three times the L06 base credit).. It will be an alternative to the future lighting performance (L01) energy credits and may be replaced by that performance approach.

There has been some question whether 5% to 15% savings in lighting power is obtainable. Figure 7 shows results for a Pacific Northwest field study[1] of new construction characteristics. The field verified installed lighting power densities are shown for three building types: retail, office, and education. These buildings are for new construction in the State of Washington and while the sample sizes are small, they represent a range of installed LPDs. For each building type a range of values is shown:

- The code LPD values for 90.1-2022 as a range from the building area method to a higher value representing the space by space method estimated at approximately 10% higher. Additional decorative or display lighting is not included.

[1] Preliminary results from *Washington 2015 Commercial Construction Code Evaluation Study*. 2022. Cadmus for Northwest energy Efficiency Alliance.

- The range of actual LPD values found in the study. Additional lighting is included.
- The range of lighting required to get the energy credits from 5% below the higher 90.1-2022 space-by-space value to 15% below the lower building area value.

As can be seen in Figure 7, there are several buildings in the sample that could have achieved all or part of the LO6 LPD reduction credit. It should be noted that all of these buildings met code in Washington state, even though they might be higher than what is shown for the 90.1 limits, even though generally Washington has more stringent LPD limits. One thing not accounted for is the additional decorative or display lighting included in the actual LPDs found in the field when the space-by-space method is used. That could be the explanation for the higher actual building case. So the L06 energy credit may not be appropriate for all buildings, in which case a different credit could be pursued; however this actual field data indicates it can be applied to actual buildings in the field. In all cases the maximum 15% reduction is above the median building installed LPD.

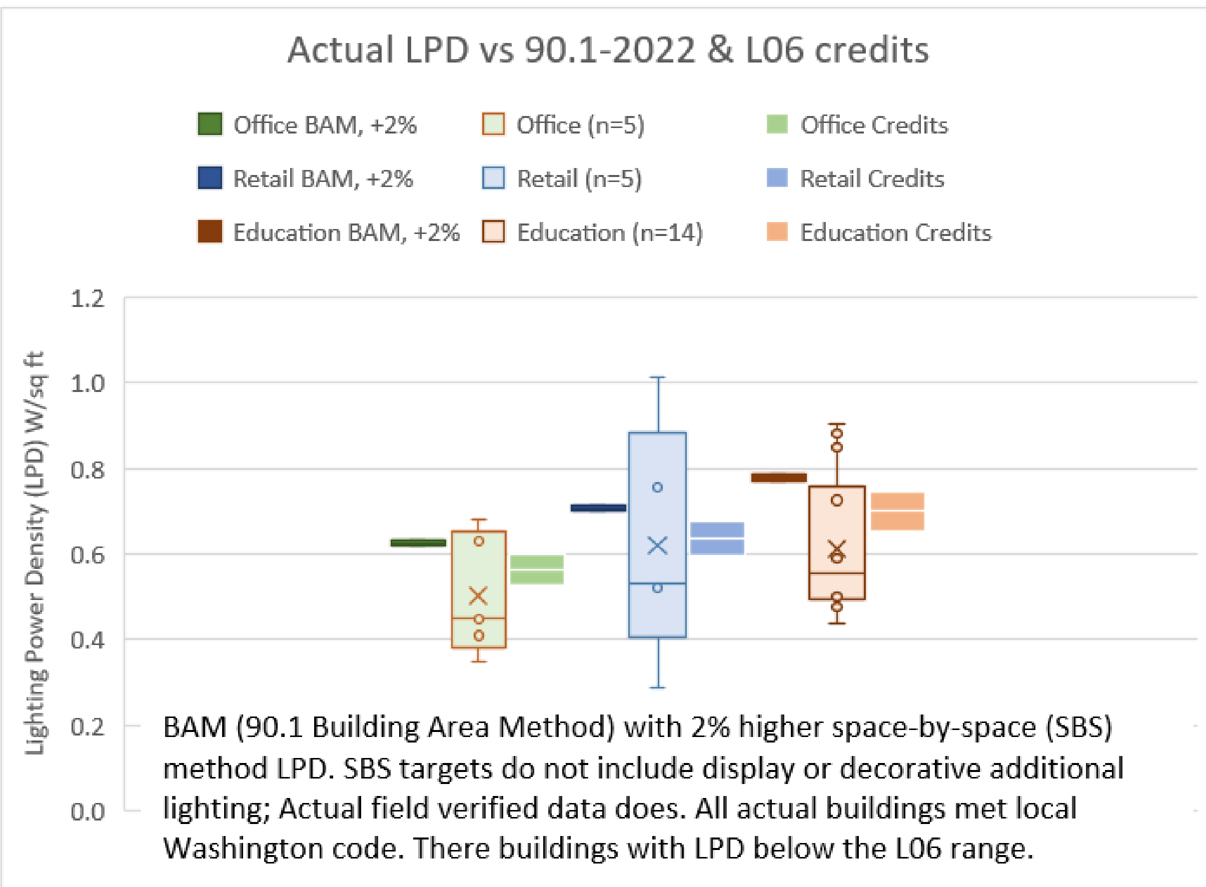

Figure 7. LPD: 90.1 BAM vs. Field Study in Washington State vs. L06 Credits

3.7 Renewable Energy

Site-based renewable energy is usually incorporated into a building with photovoltaic panels that produce electrical energy that is used by the building. In the few hours when more electrical energy is produced than can be used in the building, it is typically transferred to the electrical grid through a net-metering arrangement or stored in batteries. The credit can also be achieved by installing other renewable measures, such as solar water-heating panels that provide SHW or space heating. Wind power or geothermal sources that capture high-temperature telluric thermal energy can also be used.

3.7.1 R01: Renewable Energy

Measure R01 requires the installation of site-based renewable systems—typically photovoltaic panels—that use site-available solar energy sources to offset imported metered energy into the building.

Measure R01 saves energy by using renewable energy to offset purchased energy.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a minor modification of an existing measure. Rather than being fixed at an installation requirement of 0.25 W/ft^2 of building area and having a separate measure to accommodate larger renewable installations, this measure starts at a minimum of 0.10 W/ft^2 of building area and allows linear expansion if a larger system is installed. The alternative annual savings method that is an option in the current IECC—which required a detailed analysis and review by the building official—is abandoned to reduce complexity.

3.8 Equipment

More efficient equipment installed in buildings can save energy.

3.8.1 Q01: Efficient Elevator

Measure Q01 requires the installation of higher efficiency elevator equipment than is typical. The requirement is for class A elevators based on ISO 25745-2. The level of efficiency according to this standard is required to be documented in ASHRAE Standard 90.1-2019, although there are no IECC requirements.

Measure Q01 saves energy by providing an increase in elevator energy efficiency, based on an international standard. The savings come through improved motor and traction efficiency, along with regeneration in some cases.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is a new measure. It can be applied in conjunction with other energy credits.

3.8.2 Q02: Efficient Commercial Kitchen Equipment

Measure Q02 requires the installation of higher efficiency fryers and ovens that meet Energy Star specifications in commercial kitchens. In addition, other kitchen equipment installed before the occupancy permit is required to be more efficient in line with Energy Star specifications. When claiming this credit, other measures are required to be high efficiency.

Measure Q02 saves energy by reducing the energy used by kitchen equipment, primarily by reducing standby losses.

This measure is applicable to restaurants. Other buildings with commercial kitchens like schools or dormitories can receive credits for this measure by treating the dining and kitchen area separately and using a weighted average of the separate building use credits. Compared to the 2021 IECC, this is an existing measure. It can be applied in conjunction with other energy credits.

3.8.3 Q03: Fault Detection

Measure Q03 requires the installation of a fault detection and diagnosis (FDD) system. This system detects failures in HVAC system equipment and controls and reports them automatically to building operators.

Measure Q03 saves energy by noting where controls have failed and alerting building maintenance staff to the problem.

This measure is applicable to all building use types. Compared to the 2021 IECC, this is an existing measure. It can be applied in conjunction with other energy credits.

3.9 Load Management Measures

Load management measures work in conjunction with an energy-efficient building to support grid modernization, building owner cost savings, and occupant needs and preferences.

The electric grid is transitioning from being centralized, fossil fuel based, and relatively predictable to being more distributed and dynamic due to increasing levels of generation being contributed by variable, non-controllable distributed renewable energy resources. Load management measures provide behind-the-meter demand flexibility in support of a clean, reliant grid. Automated load management controls can be activated in response to an input signal based on demand response, dynamic price, TOU price, or building peak demand monitoring to reduce or shift electric demand and decrease electricity costs. Typically, such communication interfaces also support value-add cloud-based services that provide improved building operation through smart analytics, occupant comfort, room scheduling, and optimized space utilization.

Load management measures apply to building equipment and systems capable of storing energy or shifting building loads. These measures reduce building electric load during periods of high electric demand and high peak demand prices. They also help maximize the utilization of on-site renewable energy generation. Load management credit requirements address capabilities for load flexibility, controls, and operation sequences.

3.9.1 G01: Lighting Load Management

Measure G01 reduces electrical charges by directly reducing lighting levels and power by 20% using dimming during peak price or demand periods. It has been shown that occupants rarely notice light reduction levels up to 20% as long as they are dimmed gradually. Also, circadian rhythm impacts from lighting are not significant when this reduction occurs later in the afternoon when price signals and building demand are generally high. LED technology has made dimming much less costly than it was for fluorescent fixtures. The lighting dimming control sequence requires integration with automated controls that interface with utility signals or local building demand monitoring software.

This measure is applicable to office, retail, warehouse and education building use types. It is not applicable to multifamily and lodging buildings as it is not suitable for apartments or guest rooms. Health and restaurants are not suitable for lighting adjustment in most areas.

3.9.2 G02: HVAC Load Management

Measure G02 requires that building-wide thermostats be reset during peak price periods, with heating reset during winter peak periods and cooling reset during summer peak periods. Preheating is engaged for the winter peaks that occur in the early morning, but cooling does not use pre-cooling. The thermostat setpoints are reset gradually by 3 °F (5 °C) over the peak period. Research has shown that rather than a fixed full step up in temperature, better peak reduction can be achieved with a gradual increase of about 2/3 of the setpoint shift over the first 1/3 of the peak period, with the remaining increase gradually over the last 2/3 of the peak period (Lee and Braun 2008). The HVAC setpoint adjustment control sequence requires integration with automated controls that interface with utility signals or local building demand monitoring software.

For systems serving multiple zones that also have an outdoor air ventilation requirement less than 70% of supply air, additional savings can be achieved by over ventilating just before the summer peak period and then reducing ventilation during that peak period. This type of average ventilation is allowed under Standard 62.1. This ventilation shaving is not required for single zone packaged units or DOASs, and the controls cannot readily handle such a sequence.

This measure is applicable to office, retail, and education building use types. It is not applicable to multifamily and lodging buildings as it is not suitable to apartments or guest rooms. Health and restaurants are not suitable for temperature adjustment. Warehouses typically already have thermostat setpoints at the limit of the acceptable range.

3.9.3 G03: Automated Shading Load Management

Measure G03 provides automated external shades to reduce solar gain through fenestration during peak price hours. This credit can be met by exterior roller, movable blind, or movable shutter shading devices; however, fixed overhang, screen, or shutter shading will not meet the requirement. Roller shades that reject solar gain but still allow a view are allowed as long as they provide an effective 50% reduction in net solar gain. Interior shading devices will not meet the requirement. In addition to automated shading devices, electrochromatic windows that achieve 50% of SHGC would qualify. This reduced the solar gain into the enclosed space, consequently reducing cooling loads and cooling equipment energy use during peak price periods. The automated shading devices require integration with automated controls that interface with utility signals or local building demand monitoring software.

This measure is applicable to all building use types except warehouses that typically have a small window area and would not receive much benefit.

3.9.4 G04: Electric Energy Storage

Measure G04 requires installation of batteries, flywheels, or other electric storage devices. The storage devices require integration with automated controls that interface with utility signals or local building demand monitoring software. Electricity sourced either from renewable generation or from the grid during off-peak times is stored for release during the on-peak pricing periods.

This measure is applicable to all building use types.

3.9.5 G05: Cooling Energy Storage

Measure G05 requires either ice or chilled water cooling energy storage to be installed. Such storage allows generation of stored cooling medium at night when chilled water or ice is more efficiently produced. In addition, during peak price periods, stored cooling can be used rather than electrical cooling systems, reducing building electrical demand. An additional benefit of a cooling storage system is that the cooling plant size can be reduced, resulting in lower cost. The cooling storage system requires integration with automated controls that interface with utility signals or local building demand monitoring software.

This measure is applicable to all building use types, although it is more suited for larger buildings with chillers and chilled water systems.

3.9.6 G06: SWH Energy Storage

Measure G06 can be achieved with two alternate approaches:

- Provide additional hot water storage so that peak service water-heating requirements can be met without loading electrical hot water generation equipment.
- Preheat SHW above the required temperature and then shut off SHW electric generation equipment during peak price periods. This approach requires reliable automatic temperature mixing valves to assure that water delivered to building fixtures is at a safe temperature.

The SHW storage system requires integration with automated controls that interface with utility signals or local building demand monitoring software.

This measure is applicable to all building use types.

3.9.7 G07: Building Thermal Mass

Measure G07 requires two complimentary components:

- Provide additional building mass exposed to the interior space so that peak cooling requirements can be met with less reliance on electrical cooling generation equipment.
- Include night flush logic to pre-cool the building at night when unoccupied. Such logic needs to avoid overcooling the building resulting in morning heating, only operate fans when the outside air is cold enough to provide a net benefit, and operate at a lower fan speed to reduce fan energy use.

This measure saves energy more passively by extracting heat from the building at night during the unoccupied period using mass storage, and then removing heat from the building during the day when there are internal and solar heat loads. There is no actual OpenADR protocol required because the cooling loads are naturally reduced during peak price hours.

This measure is applicable to office, restaurant, retail, education, and warehouse building use types. It is not applicable to multifamily and lodging buildings as it is not adaptable to apartments or guest rooms. Health buildings typically do not have unoccupied hours.

4.0 References

42 USC 6833. *Energy Conservation and Policy Act*, Public Law 94-385, as amended. http://www.gpo.gov/fdsys/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf. Also see https://www.energycodes.gov/about/statutory-requirements.

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Appendix A – Basis of Savings

This appendix describes the basis for analysis and modeling methodology used for analyzing the energy efficiency credits. The analysis was primarily conducted by applying measures to the U.S. Department of Energy (DOE) Commercial Prototype Building Models for ASHRAE Standard 90.1-2019. These models were then simulated using EnergyPlus. Some credits were analyzed using methods other than hourly simulation, such as engineering calculations, where appropriate.

A.1 General Approach to Savings Analysis

To estimate energy savings for this project, Pacific Northwest National Laboratory (PNNL) used one or more prototype buildings from the ASHRAE Standard 90.1 model code analysis process (PNNL 2020). The baseline used was ASHRAE Standard 90.1-2019. This baseline is somewhat equivalent to the 2021 IECC. The following process was used:

1. The measure was reviewed to determine the differences in building and system configuration that would contribute to energy savings.
2. One or more prototypes were used to run a baseline and improved building to find the relative savings in 19 ASHRAE climate zones.
3. The energy savings were characterized as a percentage reduction in various building prototype end uses for each climate zone.
4. End-use breakdowns from the 90.1-2019 performance indicator analysis (Nambiar et al. 2019) were used as prototype basis and adjusted based on related analyzed end-use savings.

A.1.1 General Analysis Method Applied

For each measure, various measures are used to arrive at general savings, as noted in Table A-1. These include the following:

- “Eng” indicates a standard handbook or engineering method, usually involving spreadsheet calculations. For these calculations, meta data results from the prototype simulations, such as end use data, are often used.

- “Sim” indicates direct simulation using EnergyPlus in the 90.1 prototype models PNNL maintains for Standard 90.1 savings progress reporting.

- “End” indicates using measure results from a 90.1 prototype simulation with EnergPlus for one building use type and prorating savings based on end-use savings share to the end-use data for another building use type to determine savings. Note that for H02 and H03, heating and cooling efficiency, savings is taken as a percentage reduction of modeled end use for all prototypes as it better reflects the annualized energy savings.

- “Avg” Indicates results for the credits in the calculated building types were averaged for application to other buildings.

Table A-1: Measure Savings Analysis Method Used

ID	Energy Credit Abbreviated Title/ Building	Multi-family	Health	Lodging	Office	Food	Retail	Educa-tion	Ware-house	Other
E01	Envelope Performance (90.1 Appendix C)	Appendix C used for Envelope								
H02	Heating Efficiency	End	End	End	End	End	End	End	End	Avg
H03	Cooling efficiency.	End	End	End	End	End	End	End	End	Avg
H04	Residential HVAC control.	Sim	NA	NA	NA	NA	NA	NA	NA	NA
H05	Ground source heat pump	End	End	End	**Sim**	End	End	End	NA	Avg
H06	DOAS/fan control.	NA	End	NA	**Sim**	NA	End	End	NA	Avg
W01	SHW preheat recovery	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
W02	Heat pump water heater	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
W03	Efficient gas water heater	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
W04	SHW pipe insulation	Eng	Eng	Eng	Eng	NA	NA	Eng	NA	Avg
W05	Point of use water heaters	NA	NA	NA	Eng	NA	NA	Eng	NA	Avg
W06	Thermostatic balancing valves	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
W07	SHW submeters	Eng	NA	NA	NA	NA	NA	NA	NA	NA
W08	SHW distribution sizing	Eng	NA	Eng	NA	NA	NA	NA	NA	NA
W09	SHW shower drain heat recovery	Eng	NA	Eng	NA	NA	NA	NA	NA	NA
P01	Energy monitoring	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
L02	Lighting dimming & tuning	Sim	End	End	**Sim**	End	End	End	End	Avg
L03	Increase occupancy sensor	NA	End	End	**Sim**	End	End	End	End	Avg
L04	Increase daylight area	NA	NA	NA	**Sim**	NA	End	End	End	Avg
L05	Residential light control	**Sim**	NA	NA	NA	NA	NA	NA	NA	NA
L06	Light power reduction	**Sim**	End	End	**Sim**	End	End	End	End	Avg
R01	Renewable energy	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	Avg
Q01	Efficient Elevator	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
Q02	Efficient Kitchen Equipment	NA	NA	NA	NA	Eng	NA	NA	NA	NA
Q03	Fault detection	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Eng	Avg
G01	Lighting load management	NA	**Sim**	NA	**Sim**	NA	NA	**Sim**	**Sim**	Avg
G02	HVAC load management	NA	NA	NA	**Sim**	NA	**Sim**	**Sim**	NA	Avg
G03	Shading load management	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	NA	Avg
G04	Electric storage	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	Avg
G05	Cooling storage	End	End	End	**Sim**	End	End	End	End	Avg
G06	SHW storage	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	**Sim**	Avg
G07	Building mass / night flush	NA	NA	NA	**Sim**	End	End	End	End	Avg

A.2 Energy Credit Measure Basis of Savings

A.2.1 Building Envelope Measures

A.2.1.1 E01 Envelope Performance (90.1 Appendix C)

The envelope performance measure is calculated using an overall 10% reduction in Envelope Performance Factor based on the ASHRAE 90.1 Appendix C methodology. The measure savings was calculated using a 10% reduction in energy cost index savings for the energy end uses regulated in Appendix C. The baseline value is the total of both the non-regulated and regulated uses without any reduction applied.

For purposes of the demonstration package cost effectiveness analysis, a window upgrade including a double silver coating is included and analyzed using the appendix C process. This results in a lower SHGC and a lower U-factor as follows:

Climate Zone	Proposed			Baseline 90.1-2019			Improvement		
	U	SHGC	VT	U	SHGC	VT	U	SHGC	VT
6a	0.24	0.29	0.5	0.34	0.38	0.42	29.4%	23.7%	16.0%
4B	0.248	0.21	0.29	0.36	0.36	0.4	31.1%	41.7%	-37.9%
2A	0.248	0.21	0.29	0.45	0.25	0.28	44.9%	16.0%	3.4%

A.2.2 HVAC Measures

A.2.2.1 H01 HVAC Performance (TSPR)

Savings from the HVAC performance measure (total system performance ratio, TSPR) were estimated by reducing the overall HVAC energy use from the 90.1-2019 end-use analysis (Nambiar et al. 2019) by 5% for each building type and all climate zones.

A.2.2.2 H02 Heating Efficiency

This measure was analyzed by using the energy simulation results for the progress indicator of the prototypes using EnergyPlus. Then a 5% savings was applied to the end use heating costs and weighted by building construction for the multiple prototypes in each building use type group and climate zone.

A.2.2.3 H03 Cooling Efficiency

This measure was analyzed by using the energy simulation results for the progress indicator of the prototypes using EnergyPlus. Then a 5% savings was applied to the end use cooling and heat rejection costs for the prototypes and weighted by building construction for the multiple prototypes in each building use type group and climate zone. This approach better reflects annualized savings reflected by integrated part load value (IPLV) or integrated energy efficiency ratio (IEER) as compared with a 5% improvement of full load COP for cooling.

A.2.2.4 H04 Residential HVAC Control

This measure was analyzed by comparing energy simulation results of a baseline case to a measure case in EnergyPlus. The measure case was modeled with a heating and cooling temperature setback of 5°F for a total of 9 hours (4 hours during the day and 5 hours at night).

A.2.2.5 H05 Ground Source Heat Pump

This measure was modeled using the medium office prototype that has a packaged VAV system for the baseline. This measure was analyzed by comparing energy simulation results of a baseline case to a measure case in EnergyPlus. The systems were modeled using the medium office prototype. The baseline was modeled as a packaged VAV system with electric zone reheat. The ground source heat pump heating and cooling efficiency was based on minimum efficiency requirements from the standard for both the baseline VAV system and measure ground source heat pump systems. For the ground source system, minimum efficiencies were based on brine-to-air, ground loop heat pumps. The cooling EER was converted to coefficient of performance (COP), which was used in EnergyPlus. This was done to address the input requirements of EnergyPlus, which requires COP as the cooling efficiency metric and needs the fan portion of the testing metric to be removed.

Based on discussion with industry experts, the ground loop bore field was sized based on the following parameters:

- The simulated bore field is sized to handle the cooling load for about 90% of the operating hours that typically provides half the peak cooling load.
- When cooling loads are higher than can be met by the ground loop field, a dry fluid cooler is used to reject heat, based on 90.1 efficiency requirements for a propeller or axial fan dry cooler (air-cooled fluid coolers) The fluid cooler is located downstream of the ground bore field.
- Dry cooler was modeled to maintain a maximum loop temperature of 100°F (37.8°C)
- Borehole ("one-way") length: 200 ft of bore hole per ton of load (400 ft bore pipe/ton), for full capacity, adjusted to match cooling load for about 90% of operating hours or 100% of heating hours, whichever is highest.
- Bore hole radius: 3 in (6 in diameter)
- Grout thermal conductivity: 0.8 Btu/h·ft·R
- Ground thermal conductivity: 1.68 Btu/h·ft·R
- Pipe outside diameter: 1.61 in
- Pipe thickness: 0.151 in
- U-tube distance: 2.75 in
- Flow through ground heat exchanger: 3 gpm/ton
- Distance between bore holes, 20 ft.

Results for the measure were applied to other prototypes by prorating end use impacts for the simulated Medium office to the end use profiles of other building types.

The borehole length was adjusted by the multipliers shown in Table A-2 so the simulated bore fields alone are able to handle the cooling load for about 90% of the operating hours.

Table A-2. Bore Hole Length Multiplier by Climate Zone

Climate Zone	Bore Hole Length Multiplier
0A	1
0B	0.75
1A	0.5
1B	0.75
2A	0.5
2B	0.75
3A	0.25
3B	0.5
3C	0.25
4A	0.25
4B	0.5
4C	0.25
5A	0.25
5B	0.5
5C	0.25
6A	0.5
6B	0.5
7	0.5
8	0.5

While the base system configuration was based on a typical installation of a ground exchange bore length to serve 90% of the cooling operating hours, the system efficiency can be increased by either increasing the ground exchange bore length or using an evaporative fluid cooler for peak heat rejection. These options were simulated, with the results shown in Figure A-1 and the resulting consolidated savings and credit multipliers shown in Table A-3.

Table A-3 –GSHP Heat Rejection Adjustments

	HR_{adj} by field source capacity		
Climate Zones	Full sized bore field with no heat rejection	90% hours source size; dry cooler heat rejection	90% hours source size; evaporative heat rejection
0A, 1B, 2B, 3A, 3B, 4A, 4B	3.3		2.6
0B, 1A, 2A, 3C	7.6		5.3
4C, 5A, 5B, 5C	2.3		1.5
6A, 6B, 7, 8	1.4		1.1
All climate Zones		1.0	

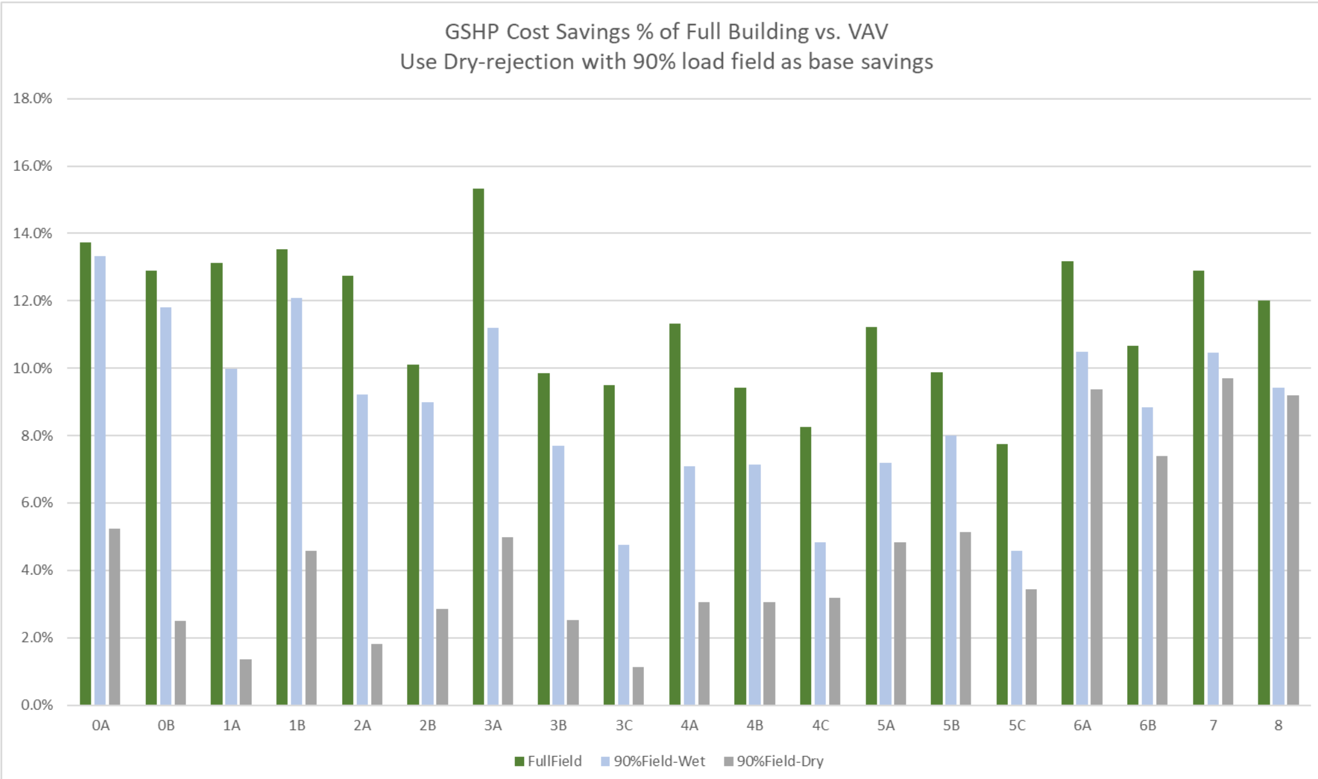


Figure A-1 –GSHP Heat Rejection Adjustments

A.2.2.6 H06 DOAS/Fan Control.

This measure was modeled using the results from the DOE TSPR analysis tool to model the impact of dedicated outdoor air system (DOAS) with fan control. The baseline system is a constant volume fan system that must operate continually at full speed to provide ventilation during occupied hours. A separate DOAS system was included for the measure, and zonal heating and cooling unit fans were cycled off during deadband indoor temperatures when neither heating nor cooling was required. The energy savings for heating, cooling, and fan energy end use were prorated based on the respective end uses for other climate zones for applicable prototypes. Note that heating savings is negative due to replacing fan heat due to reduced fan use. Energy savings based on TSPR analysis with adjustments based on engineering review was as follows:

End Use	Savings
Fan	21.27%
Heat	-11.79%
Cool	6.76%

A.2.3 Service Hot Water Measures

For energy credits related to heating service hot water (SHW), the base parameters used for water usage, pipe and tank losses, and generation efficiency are those documented in the 90.1 progress indicator enhancements (Goel et al. 2014). In many cases, a building type group is represented by two distinct building prototypes (PNNL 2020). For example, school buildings are represented by both primary and secondary school prototypes. The SHW measures were analyzed by post-processing of prototype model results. For each prototype, annual SHW energy was itemized into categories of water-heating energy use, pipe loss, dump or warmup loss, and tank loss. These values were then adjusted for the individual SHW measures according to the measure technologies under consideration.

A.2.3.1 W01 SHW Preheat Recovery

This measure assumes the use of heat recovery from a water-cooled chiller or water source heat pump, and accounts for 30% savings in water-heating energy (including losses). The measure also accounts for increased pumping energy in the central plant required by the energy recovery equipment.

A.2.3.2 W02 Heat Pump Water Heater

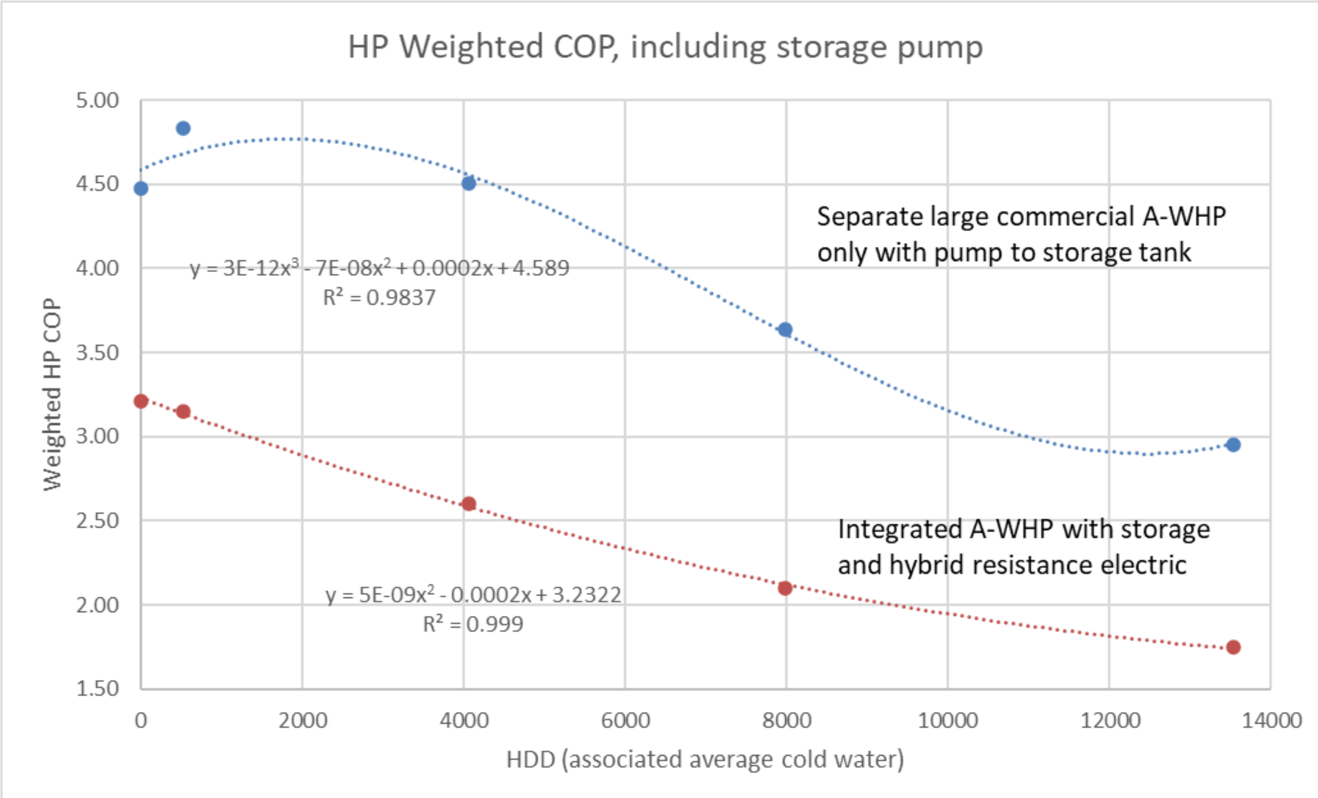
This measure is based on a multi-fuel baseline SHW system in which 20% of the water-heating load is handled by electric resistance and 80% is handled by a gas storage water heater. For the measure, it is estimated that the entire water-heating load is met by an air-source heat pump water heater (HPWH) system, and that the average COP is as discussed below, including the effects of any supplemental electric resistance heat.

The air-source HPWH COP is a function of entering water temperature (EWT) and entering air temperature (EAT). For a stand-alone HPWH for use with a preheat system, typical manufacturer’s data was regressed to find a formula for COP:

$$COP = 6.53587 + EAT \times 0.04045 + EWT \times -0.0662 + EWT^2 \times 0.00013$$

For a hybrid tank, COP was interpolated based on EAT
from 1.0 @ 30°F, to 2.0 @ 40°F, to 3.0 @ 70°F, to 4.0 @ 100°F

These COP’s were plotted against average expected EWT for different climate zones, based on multiple passes at a point about 1/3 between ground temperature and a 125°F target temperature. The COP formulas were used to arrive at a bin temperature weighted COP for different climate zones. The heating degree days for each climate zone was used as a proxy independent variable to develop weighted COP curves as follows:



The energy credits for heat pump water heating require a minimum of 30% end-use water heating be served by the heat pump without supplemental heat. If more is served, up to 80% of the credits are increased. To avoid operating the heat pump at a high delivery temperature, an arrangement like that shown in Figure D.1 allows storage of preheated water that is finished to final temperature with a gas or electric resistance final heater. This configuration is appropriate for larger systems, while smaller systems may use a single hybrid tank that has a finishing heater at the top.

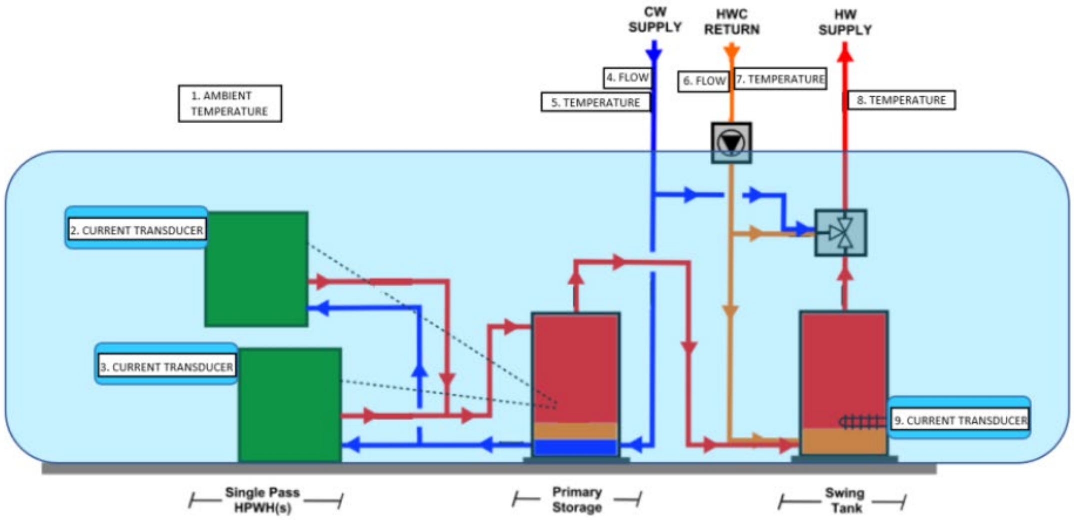


Figure D.1. Example Heat Pump Water Heater Configuration

A.2.3.3 W03 Efficient Gas Water Heater

This measure was analyzed by post-processing of prototype model results. The baseline is modeled as a gas storage water heater with a thermal efficiency of 80.3% and the measure assumes a condensing system with an efficiency of 95%. The result is an overall energy savings of 15.47%.

For buildings subject to Section 7.5.3 the baseline Et is 90%, so the credits are multiplied by 29.6% to represent the reduced increase in efficiency, based on the following:

Et	Gas input		Case	Normal	7.5.3
80	1.250		Base	80%	90%
90	1.111		Improved	95%	95%
95	1.053		Savings	0.197	0.058
			7.5.3 Share		0.296

For smaller gas water installations, the baseline storage water heater UEF may be around 60, so an upgrade to an instantaneous gas water heater with a UEF of at least 82% receives 25% of full condensing water heater credits.

A.2.3.4 W04 SHW Pipe Insulation

The SHW pipe insulation measure was evaluated by developing a representative pipe run for a typical multifamily building using the standard Hunter's Curve method. Baseline pipe insulation was set based on ASHRAE 90.1-2019 Table 6.8.3-1 (1 inch thick insulation for nominal pipe sizes less than 1.5 inch and 1.5 inch thick insulation for larger pipes). For the measure, the insulation thickness was increased by 1 inch for all pipe sizes. Overall thermal resistance for each pipe size was determined using the energy calculator for horizontal piping on the Whole

Building Design Guide website.[1] The overall reduction in pipe heat loss was thus estimated to be 24.7% of the baseline pipe heat loss.

A.2.3.5 W05 Point of Use Water Heaters

Measure W05 is based on a multi-fuel baseline SHW heating system in which 20% of the water-heating load is handled by an electric resistance heater and 80% of the load is handled by a gas storage water heater. The measure reduces pipe loss by converting from central water-heating system with recirculation piping to distributed point of use systems. The conversion is estimated to reduce overall piping loss by about 80%. For the school system, the showers and kitchen remain on gas water systems with local recirculation, while hot water for remote restrooms is provided by small local electric water heaters that do not have recirculation piping.

A.2.3.6 W06 Thermostatic Balancing Valves

Measure W06 savings is based on the installation of dynamic thermostatic balancing valves that decrease the temperature of water in the recirculation piping from an average of 130°F to 120°F. There is also a reduction in recirculation flow when there is active flow in the building hot water system.

A.2.3.7 W07 SHW Submeters

Measure W07 savings is based on reducing water use and the energy to heat it by 5%. There is no impact on piping or tank losses. Several studies showing an actual 15% savings impact from individual apartment electric meters support this estimate.

A.2.3.8 W08 SHW Distribution Sizing

Measure W08 uses a baseline piping layout established for a typical building using the standard Hunter's Curve method, and an alternative layout for the same building developed using the Appendix M method of the 2018 Uniform Plumbing Code. This results in the use of smaller diameter piping, with a corresponding 26.2% overall reduction in pipe heat loss. There is also a reduction in actual water use from requiring water wise low flow residential fixtures.

A.2.3.9 W09 SHW Shower Drain Heat Recovery

Measure W09 was evaluated based on a 54% recovery effectiveness for a heat exchanger device that recovers heat from drainwater and preheats the incoming cold water. The resulting increase in cold water supply temperature into the shower results in a 7.2% savings in hot water energy use, with no impact on pipe or tank loss.

A.2.4 Power Measure

A.2.4.1 P01 Energy Monitoring

Energy monitoring of electrical end uses is required for buildings greater than 25,000 square feet. This credit applies to smaller buildings that install similar monitoring. The monitoring equipment is much less expensive when installed in a new building rather than retrofit.

[1] https://www.wbdg.org/guides-specifications/mechanical-insulation-design-guide/design-objectives/energy-calculator-horizontal-piping

Monitored information can be used by building operating staff and managers to identify high energy use at unexpected times and improve lighting and HVAC controls or to provide feedback to occupants who can reduce energy use.

A.2.5 Lighting Measures

Lighting measures are evaluated in the prototype models.

A.2.5.1 L01 Lighting Performance (Reserved)

A lighting performance method is under development that would form an alternative to L03, L04, and L06. It uses a spreadsheet method to

A.2.5.2 L02 Lighting Dimming & Tuning

Measure L02 was analyzed by comparing energy simulation results of a baseline case to a measure case in EnergyPlus. The measure case lighting power density is set by reducing 75% of the space lighting by 7.5% compared to the baseline. This reflects a 15% reduction in initial tuned light power that is then slowly increased until lamps are replaced. The space types and modeled lighting power densities for the baseline and measure case for each prototype analyzed are shown in the table below:

Prototype	Space Type	Baseline (W/ft^2)	Measure (W/ft^2)
ApartmentMidRise	Corridor	0.49	0.46
	Office	0.74	0.70
Hospital	Basement	0.64	0.60
	Corridor	0.71	0.67
	Dining	0.40	0.38
	Exam Room	1.40	1.32
	Nurse Station	1.04	0.98
	ICU	1.25	1.18
	Kitchen	1.09	1.03
	Lab	1.33	1.26
	Lobby	0.82	0.77
	Operating Room	2.26	2.13
	Office	0.64	0.60
	Patient Room	0.68	0.64
	Physical Therapy	0.91	0.86
HotelSmall	Corridor	0.49	0.46
	Lounge	0.42	0.40
	Gym	1.08	1.02
	Office	0.74	0.70
	Stairs	0.49	0.46
	Storage	0.38	0.36
	Laundry	0.53	0.50
	Mechanical Room	0.95	0.90
	Conference Room	0.97	0.92
	Restroom	0.63	0.59
OfficeSmall	Office	0.64	0.60
RestaurantSitDown	Dining	0.60	0.57
	Kitchen	1.09	1.03
SchoolPrimary	Bath	0.63	0.59
	Café	0.40	0.38
	Computer Room	0.71	0.67
	Classroom	0.71	0.67
	Gym	0.90	0.85
	Kitchen	1.09	1.03
	Library	0.83	0.78
	Lobby	0.84	0.79
	Mechanical Room	0.95	0.90
	Office	0.74	0.70
Warehouse	Bulk Storage	0.33	0.31
	FineStorage	0.69	0.65
	Office	0.64	0.60

A.2.5.3 L03 Increase Occupancy Sensor

This measure was analyzed by comparing energy simulation results of a baseline case to a measure case in EnergyPlus. The measure cases are modeled by adjusting the lighting schedules in spaces that do not contain occupancy sensors in the baseline.

The space types in individual prototypes where this measure was applied, and the corresponding lighting schedule adjustment rates, are as given in table below:

Prototype	Space Type	% Floor Area with Occupancy Sensor in Measure Case	% Lighting Schedule Reduction in Measure Case
Small Office	Open Office	18%	24%
Primary School	Kitchen	100%	24%
	Library - Stacks	100%	24%
Hospital	Laboratory	100%	10%
	Kitchen	100%	24%

A.2.5.4 L04 Increase Daylight Area

This measure was analyzed in EnergyPlus using the prototype models by increasing the fraction of electric lights that can be dimmed when daylight is available at or above illuminance levels required to perform visual tasks. For this measure, the fraction of floor area capable of being daylight controlled was increased by 5% compared to the baseline as shown in the table below. This was accomplished by increasing the fraction of the zone controlled by daylight control reference point objects in EnergyPlus. Additionally, visible transmittance property of the windows was increased by a fraction of 1.5 times the minimum solar heat gain coefficient (SHGC) requirements for non-residential windows per 90.1-2019.

Prototype	Baseline	Measure
Medium Office	21%	26%
Primary School	42%	47%
Retail Stand-alone	35%	40%
Warehouse	49%	54%

A.2.5.5 L05 Residential Light Control

This measure was analyzed in EnergyPlus using the prototype models by reducing the lighting schedule fraction by 10% for residential spaces and 15% for corridor spaces compared to the baseline. This measure was only applied to the Midrise Apartment prototype.

A.2.5.6 L06 Lighting Power Reduction

This measure was analyzed in EnergyPlus using the prototype models by reducing the lighting power density (LPD) in non-residential space types by 10% compared to the baseline.

For non-residential spaces specialized light types including task and display lighting were omitted from the LPD reduction. This applies to the Retail Stripmall prototype.

Prototype	Space Type	Baseline (W/ft^2)	Measure (W/ft^2)
ApartmentMidRise	Corridor	0.49	0.44
	Office	0.74	0.67
Hospital	Basement	0.64	0.58
	Corridor	0.71	0.64
	Dining	0.40	0.36
	Exam Room	1.40	1.26
	Nurse Station	1.04	0.93
	ICU	1.25	1.13
	Kitchen	1.09	0.98
	Lab	1.33	1.20
	Lobby	0.82	0.74
	Operating Room	2.26	2.03
	Office	0.64	0.58
	Patient Room	0.68	0.61
	Physical Therapy	0.91	0.82
HotelSmall	Corridor	0.49	0.44
	Lounge	0.42	0.38
	Gym	1.08	0.97
	Office	0.74	0.67
	Stairs	0.49	0.44
	Storage	0.38	0.34
	Laundry	0.53	0.48
	Mechanical Room	0.95	0.86
	Conference Room	0.97	0.87
	Restroom	0.63	0.57
OfficeSmall	Office	0.64	0.58
RestaurantSitDown	Dining	0.60	0.54
	Kitchen	1.09	0.98
SchoolPrimary	Bath	0.63	0.57
	Café	0.40	0.36
	Computer Room	0.71	0.64
	Classroom	0.71	0.64
	Gym	0.90	0.81
	Kitchen	1.09	0.98
	Library	0.83	0.75
	Lobby	0.84	0.76
	Mechanical Room	0.95	0.86
	Office	0.74	0.67
Warehouse	Bulk Storage	0.33	0.30
	FineStorage	0.69	0.62
	Office	0.64	0.58

A.2.6 Equipment Measures

A.2.6.1 Q01 Efficient Elevator

The efficient elevator measure is modeled as a reduction in the total electricity consumption of 0.05 kW/ft^2. This is based on an analysis of PNNL prototypes with an upgrade of elevators from standard to premium VDI grade A.

A.2.6.2 Q02 Efficient Commercial Kitchen Equipment

The efficient commercial kitchen measure is calculated based on a more efficient fryer replacing a standard fryer. The high efficiency fryer is estimated to reduce the total cooking energy end use by 5.4%. No credit is taken for either lighting or HVAC energy reduction for this measure.

A.2.6.3 Q03 Fault Detection

The fault detection measure is modeled by based on an HVAC energy savings of 0.75% by reducing the system operation faults. This measure is only applied to HVAC energy and lighting energy reduction is not applied for this measure.

A.2.7 Renewable Measure

A.2.7.1 R01 Renewable Energy

Measure R01 is modeled as 0.1 W rated power of installed photovoltaics per square foot of building gross floor area. Total system rated power is calculated by multiplying the prototype gross square footage by 0.1 W. The total array size is estimated using an assumption of 250 W and 17.6 ft^2 per module.

Module insolation is determined for each prototype and climate zone using a calculator that computes the annual insolation from collector azimuth and tilt for each climate zone. AC power is calculated from insolation, module efficiency, and system efficiency. The calculator is based on the EnergyPlus photovoltaic model.

Model assumptions are:

- Tilt: Same as latitude
- Azimuth: South
- Inverter efficiency: 96%
- System losses: 14%

The electricity savings is calculated by subtracting the generated AC power from the baseline electricity consumption for each prototype and climate zone. The credits for renewable energy systems are based on the % of building cost reduction achieved through electric generation that is used in the building, without credit for net metering.

A.2.8 Load Management Measures

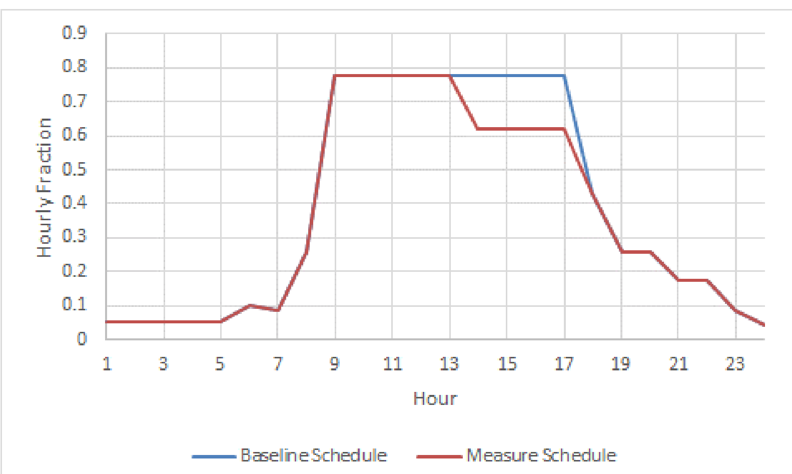
Dissimilar to the energy efficiency credits that are based on energy use savings, the load management credits are based on energy cost savings. The credit values are determined using a representative electricity time-of-use (TOU) rate. The rate includes a summer high price period based on electric demand that occurs during weekday afternoon hours. The rate also includes a winter high price period based on electric energy use that occurs during early morning and early evening weekday hours. More information about the TOU rate and its development are presented in Appendix E.

Establishing load management value through the energy credit code mechanism ensures a standardized, consistent assessment of impact is applied for compliance purposes. Invariably, actual building load management operation will be influenced by the building actual electric rate pricing, building load shape, self-utilization of on-site renewable energy, and other factors. Nonetheless, the approach credits indicate the relative ability to save electricity costs by reducing or shifting loads based on a representative rate.

A.2.8.1 G01 Lighting Load Management

Measure G01 was analyzed by comparing energy simulation results of the baseline case to the measure case in EnergyPlus using the energy code prototype building simulation models. The lighting load management measure sheds load during the high-cost electric demand periods. For the representative TOU rate, this period occurs June through September from 1 PM to 9 PM on weekdays.

The lighting load management measure decreases ambient lighting levels by 20% compared to their baseline operating capacity during the representative TOU rate summer peak demand period that is coincident with normal building operating hours. The measure is modeled by adjusting the interior lighting operating schedule profiles for the general lighting. The figure below provides an example of this adjustment applied to the medium office building. It indicates the baseline design lighting power fraction and the adjusted lighting power fraction for the measure. The lighting power in the analysis is determined for each simulation timestep by multiplying the total installed lighting power by the hourly fraction indicated in the schedule. Since this measure aims to decrease lighting and coincident cooling loads, the modified measure schedule occurs during the hour interval in which the TOU summer peak demand period coincides with normal building operating hours. For the medium office building, this results in a lighting schedule modification for hours 1 PM to 5 PM for June through September.

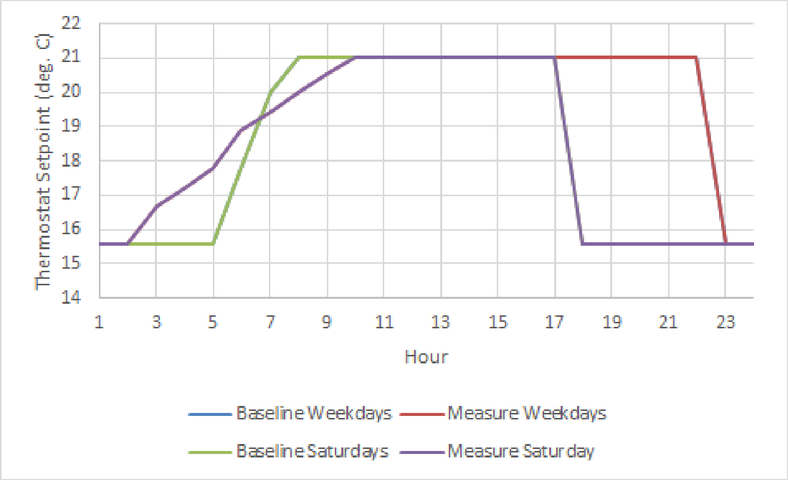


A.2.8.2 G02 HVAC Load Management

The G02 measure was analyzed by comparing energy simulation results of the baseline case to the measure case in EnergyPlus using the energy code prototype building simulation models. The measure sheds cooling loads during the high-cost electric demand hours. It also ramps electric preheat during high electricity energy use periods. For the representative TOU rate, the high-cost electric demand period occurs June through September from 1 PM to 9 PM on weekdays. The high-cost electric use period impacting morning warm up occurs from 6 AM to 10 AM during non-summer months

The shedding of cooling load is initiated on weekdays during the months of June through September. In the analysis, the baseline cooling setpoint temperature increases by 3 F starting at 3 PM. The setup schedule continues until the night-time temperature schedule commences. Implementing the measure later in the day after the start of the peak demand period helps to maintain comfort conditions through the end of the workday while still providing energy cost benefit resulting from reduced building electric demand.

To reduce energy costs associated with electric heating, a ramped preheat is initiated 2-hours early compared to the baseline case during the months of October through May. The strategy reduces the amount of electric energy used for preheating for hours after 6 AM during non-summer months. To implement the measure, the heating setpoints during the "winter period" (October to May) were modified to incorporate a longer ramped setpoint morning warm up. The figure below provides an example of this adjustment applied to the medium office building.



A.2.8.3 G03 Automated Shading Load Management

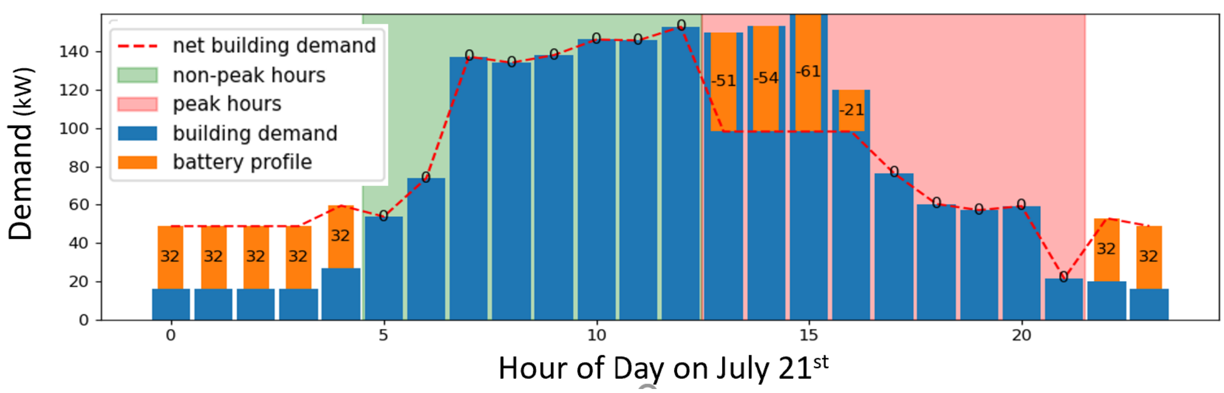
For the representative TOU rate, the high-cost electric demand period occurs June through September from 1 PM to 9 PM on weekdays. The high-cost electric use period impacting morning warm up occurs from 6 AM to 10 AM during non-summer months

To estimate the impact of automated shading during peak TOU pricing periods, the modeled solar heat gain coefficient (SHGC) of window assemblies was reduced during these periods by 50%. The same adjustment was made for all building types and climate zones.

A.2.8.4 G04 Electric Energy Storage

For measure G04, electric energy storage is used to shift energy use out of the high-cost electric demand price period. For the representative TOU rate, the high-cost electric demand period occurs June through September from 1 PM to 9 PM on weekdays. The battery storage analysis is implemented as Python scripts that post-process annual hourly demand time-series data from EnergyPlus simulation output for the code prototype building models. The analysis determines the annual hourly battery charge/discharge time-series profile and the hourly building electric demand and energy consumption. The energy costs savings are determined by applying the representative TOU rate to the building electricity consumption profiles and comparing the results of the baseline case to the measure case. For the representative TOU rate, the high-cost electric demand period occurs June through September from 1 PM to 9 PM on weekdays.

The applied strategy is referred to as the semi-optimized TOU strategy. The strategy discharges the battery during the “daytime” hours, from 5 AM – 10 PM, and the battery recharge occurs evenly across each hour during “night-time” from 10 PM to 5 AM. The figure below depicts the effect of applying the battery operation strategy to the medium office building in climate zone 2A on July 21st.



The analysis relies on anticipating each day’s demand load profile in the electric billing cycle month. The semi-optimized TOU strategy is designed to minimize monthly demand costs. It provides a customized battery operation strategy based on the building load profile and the representative TOU rate peak demand period. The procedure is outlined below.

1. Specify the “night-time” period in which the building’s electricity demand is at its minimal and the TOU rate has the lowest demand charge. The period is 10 PM to 5 AM in this analysis. The battery is charged evenly each hour over this period to achieve full capacity.

2. Based on the building’s historic (e.g., baseline) hourly electricity time-series data, identify the “worst” demand day for each month.

a. For each month, denote the period with the peak demand rate as period $P_{m,max}$.

b. If the month’s TOU rate includes a peak demand period, identify its “worst” day as the day that contains the highest hourly demand, $HD_{m,max}$, in period $P_{m,max}$ after applying the battery’s full discharge potential across the hours with the highest demand in period $P_{m,max}$.

c. If the month's TOU rate does not contain a peak demand period, consider all non "night-time" hours as the peak period $P_{m,max}$ and identify the "worst" day and $HD_{m,max}$ the same way as above.

During the building's real-time operation, the battery is discharged for each month during its $P_{m,max}$ hours if that hour's instantaneous demand, P_i, is higher than the month's $HD_{m,max}$. The discharge power for that hour is ($HD_{m,max}$ - P_i) or based on the available battery discharging power at that time, whichever is less. In short, the battery operation strategy aims to maintain the monthly building peak demand during $P_{m,max}$ to be no larger than $HD_{m,max}$. The battery operating strategy is intended to level out demand across the hours in the month that have the highest demand without the battery applied. The approach reduces the cost associated with the maximum peak demand while minimizing the discharge of the battery during hours when there is no cost benefit.

A.2.8.5 G05 Cooling Energy Storage

The G05 measure was analyzed by comparing energy simulation results of the baseline case to the measure case in EnergyPlus using the large office prototype building simulation model. The measure reduces cooling electric demand during high-cost electricity demand price periods. For the representative TOU rate, this period occurs June through September from 1 PM to 9 PM on weekdays.

An EnergyPlus model was developed for an ice storage system serving the large office prototype building. The large data center zone was removed from the large office model to make the baseline energy use profile more representative of a typical commercial building. Simulations were performed for all ASHRAE climate zones at a storage tank capacity of 1.0 ton-hours per ton of design day cooling load. Additional simulations were performed for three climate zones and sizing configurations ranging from 0.5 to 3.0 ton-hours/ton to establish a relationship between overall performance and system capacity. Energy savings were evaluated based on the ASHRAE TOU rate. The large office energy results were prorated to other prototypes based on ratio of peak cooling tons to building floor area.

A.2.8.6 G06 SHW Energy Storage

The G06 measure was analyzed by comparing the SHW energy use and costs for the baseline and the measure case for each code prototype building. The measure shifts electric SHW load from high-cost electricity demand price periods to base-cost periods. For the representative TOU rate, the high cost demand period occurs June through September from 1 PM to 9 PM on weekdays.

Evaluation of SWH storage was done using spreadsheet calculations based on the PNNL prototype equipment sizing and hourly hot water use schedules. The storage capacity was based on the tank size in the prototype, and an assumption that water in the tank could be heated to a temperature 40 °F above the normal storage setpoint. It was then assumed that the stored energy would be discharged at a constant rate during the TOU peak period, effectively giving a peak period demand reduction equal to one fourth of the stored energy. If the SWH load during the peak period was less than the stored energy, then the peak period reduction was limited by the load.

A.2.8.7 G07 Building Thermal Mass / Night Flush

The G07 measure was analyzed by comparing energy simulation results of the baseline case to the measure case in EnergyPlus using the energy code prototype building simulation models. These measure was analyzed for each code prototype building model and climate zone locations. The measure reduces cooling load and supports shifting cooling loads from the high-cost electric demand period to the base-cost period.

Thermal mass was added to the prototype building models to provide 10 pounds/ft^2 (50 kg/m^2) of project conditioned floor area of interior-facing exposed thermal mass. Along with thermal mass, a “night flush” ventilation strategy was modeled.

Night flush is activated when the building is unoccupied and “summer mode” is activated. Summer mode is activated when the outdoor air temperature exceeds 70 deg. F and is deactivated when outdoor air temperature falls below 45 deg. F. During night flush, the system outdoor air damper is open and the fan is running at its minimum speed (assumed to be 66%), then the outdoor air is then effectively pre-cooling the building. Night flush is stopped if the indoor average zone temperature is less than morning occupied setpoint, the outdoor air temperature is less than 5 deg. F below indoor average zone temperature, and in climate zone 0A through 3A if the outdoor dewpoint is below 50 deg F.

Appendix B – Development of the Representative Time-of-Use Rate

The introduction of a time-of-use (TOU) rate into the code development process allows demand flexibility and distributed energy resource measures, which may not provide an overall reduction in energy use, to be justified based on cost effectiveness. The representative TOU rate was specifically developed because of this issue. The rate represents a typical U.S. TOU rate. The rate values and TOU structure were developed from published utility rate data and information gathered from an investor-owned utility (IOU) survey. More details about the rate, its development approach, and data sources are provided below.

The representative TOU rate was developed by the ASHRAE 90.1 SSPC Economics Working Group (EWG) in the summer of 2019 as part of their regular duties to update economic parameters utilized in the code development process. The update occurs at the beginning of each new code cycle. Their recommendations are incorporated into the ASHRAE 90.1 2022 Work Plan, which is drafted to direct the development of the new code. The Work Plan is voted on by the full ASHRAE 90.1 SSPC during the ASHRAE Winter Conference Meeting. For the ASHRAE 90.1-2022 code cycle, the committee voted on February 3, 2020 and approved including the representative TOU rate as an optional alternative for evaluating code change proposals. The rate, as stated in the ASHRAE 90.1-2022 Work Plan, is defined as follows.

Winter (October through May)

$0.0946 per kWh, peak hours

$0.0571 per kWh, off-peak hours

$5.59 per kW, base

No peak kW charges

Peak: Monday–Friday, 6 AM to 10 AM and 5 PM to 9 PM

Summer (June – September)

$0.1104 per kWh, peak

$0.0586 per kWh, off-peak

$ 5.59 per kW, base

$10.99 per kW, peak

As mentioned, the rate was developed from published and survey data. The utility rate data source is the OpenEI database[1], which includes over 15,000 published commercial and industrial rates offered by municipalities, cooperatives, and IOUs. A dataset was created from the OpenEI data that includes nearly 8,000 rates, after excluding industrial and unique commercial rates (such as agricultural pumping). The dataset encompasses 2,400 utilities representing 70% of the electric load across the lower 48 U.S. states (NREL 2017).[2] Based on an analysis of the dataset, the approximately 6,200 rates listed without demand charges have

[1] For more information about database, refer to Utility Rate Database: https://openei.org/wiki/Utility_Rate_Database

[2] The NREL dataset was developed to support a market potential study for battery energy storage. It is available for download at https://data.nrel.gov/submissions/74.

an average maximum allowable customer demand of 52 kW. This implies that rates without demand charges are available generally for smaller buildings. Nearly 1,700 of the listed rates include demand charges and have an average maximum allowable demand of 700 kW, with minimum demand to qualify ranging from 50 to 3000 kW. For those rates including a demand charge, the average cost is $10.18/kW (the standard deviation is $7.35/kW and the maximum listed is $90/kW). This average demand charge was used as the starting point for establishing the demand charge in the representative rate.

The representative TOU rate includes electricity kWh and kW charges that vary by hour of day and season. The on-peak off-peak rate schedule and kWh values were established based on survey data. The survey was developed by the Edison Electric Institute (EEI) and provided to member IOUs.[1] The survey respondents represent ~ 13% of U.S. IOU commercial customers.[2] A summary of key survey results that informed the ASHRAE TOU rate are provided below.

- About 80% of TOU rate customers have kW demand charges.
- Many customers have two demand charges and two season – a peak and non-peak season with a peak demand charge and a monthly base demand charge. The difference between the peak and base demand charge ranged from ~ $4.00 to $5.50 per kW.
- The average energy rate for summer on-peak and off-peak charges are $0.096/kWh and $0.066/kWh. The average difference between on-peak and off-peak charges is $0.030/kWh.
- The average energy rate for Winter on-peak and off-peak charges are $0.092/kWh and $0.064/kWh. The average difference between on-peak and off-peak charges is $0.028/kWh. The average difference between Winter on-peak and off-peak energy charges is $0.028 per kWh.
- The number of on-peak hours per week averaged 39 for summer and 33 for winter.
- The average summer weekday schedule started/ended at 12:45 PM and 8:00 PM.
- The average Winter weekday schedule started/ended at 7:50 AM and 1:30 PM and 5:00 PM and 9:15 PM.

Based on the data outlined above, as well as professional judgment and some additional data not reported herein (including the most common responses for peak period start and end times), the values underlying the ASHRAE TOU rate are as follows.

Winter (October through May)

$0.0876 per kWh, peak hours

$0.0528 per kWh, off-peak hours

$5.18 per kW, base

No peak kW charges

Peak: Monday–Friday, 6 AM to 10 AM and 5 PM to 9 PM

Summer (June – September)

[1] Organized in 1933, EEI provides public policy leadership, strategic business intelligence, and essential conferences and forums to all U.S. investor-owned electric companies.

[2] ASHRAE TOU rate presentation made by Stephen Rosenstock to the ASHRAE 90.1 EWG on September 19, 2019.

$0.1023 per kWh, peak

$0.0543 per kWh, off-peak

$ 5.18 per kW, base

$10.18 per kW, peak

Peak: Monday–Friday, 1 PM to 9 PM

This initial rate was then adjusted based on simulation analysis results for the code medium office prototype building, which was modeled in climate zones 2A, 4A, and 6A. Specifically, each initial rate TOU price component (kWh and kW price during winter and summer) was scaled by a factor of 1.08 in order for the average of the annual energy costs determined for the three climate zones would to be equal to that determined for the Blended Rate established in the ASHARE 90.1-2022 Work Plan, which equals $0.1099/kWh .

Appendix C – Cost Effectiveness Detail

Five tables related to the cost effectiveness of the base demonstration package (See Section 2.2 for a detailed description of the cost effectiveness approach) are included here:

- Table E-1 shows the annual energy cost savings in $/1000 square feet based on U.S. average annual energy prices for the measures in the base demonstration package.
- Table E-2 shows the incremental measure cost in $/1000 square feet for the measures in the base demonstration package.
- Table E-3 shows the scalar payback for the measures in the base demonstration package.
- Table E-4 shows the scalar threshold for the measures in the base demonstration package.
- Table E-5 shows the ratio of the scalar threshold to the scalar payback. Where this ratio is greater than 1.0, the base demonstration package is cost effective for that building and climate zone.
- Tables E-6 through E-13 show the incremental costs in $/square feet by building type, climate zone, and measure. Some costs are negative, indicating a cost reduction—W05 for example reduces reduces the cost of piping with a decentralized point of use service water heating system.
- Table E-14 shows the incremental costs in $/square feet by building type and measure.
- Table E-15 shows the summary of sources used in measure cost development.
- Table E-16 shows a high-level summary of measure cost development.

Table E-1. Base Demonstration Package Cost Savings, $/thousand ft^2

Building Use Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily/Dormitory	97	89	80	83	73	54	46	52	46	50	57	43	65	64	45	76	67	74	85
Healthcare	271	241	232	228	229	181	193	176	127	124	123	135	151	144	192	165	171	201	219
Hotel/Motel	169	152	135	137	122	107	72	73	78	71	77	68	68	69	59	75	72	82	92
Office Buildings	105	110	97	105	61	65	65	67	61	65	70	60	63	69	57	63	68	66	62
Restaurant Buildings	621	577	492	514	492	446	454	443	364	413	406	392	418	423	412	439	436	478	502
Retail Buildings	118	120	96	100	81	76	58	56	52	64	60	54	59	58	49	66	55	55	63
School/Education Buildings	123	112	96	104	90	82	51	55	52	52	58	48	47	53	46	51	51	51	49
Warehouse and Semiheated	37	37	36	36	33	35	32	36	34	29	35	29	36	32	24	39	35	37	34

Table E-2. Base Demonstration Package Incremental Cost, \$/thousand ft^2

Building Use Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily/Dormitory	660	660	660	660	660	605	605	605	605	605	605	605	661	661	661	661	661	661	661
Healthcare	694	694	694	694	694	694	694	694	490	490	490	490	546	546	546	546	482	482	482
Hotel/Motel	546	546	546	546	546	546	409	409	409	409	409	409	409	408	371	408	408	408	408
Office Buildings	663	489	489	489	353	353	353	353	353	353	353	353	353	527	527	527	527	527	527
Restaurant Buildings	1972	1972	1935	1935	1935	1935	1935	1935	1867	1867	1867	1867	1867	1867	1867	1867	1867	1867	1867
Retail Buildings	701	733	701	701	701	701	665	633	633	670	670	670	506	538	538	471	471	471	471
School/Education Buildings	449	449	449	449	449	449	313	313	313	313	313	313	394	394	394	394	394	394	394
Warehouse and Semiheated	387	387	387	387	319	319	319	319	319	319	319	319	322	287	287	288	288	289	289

Table E-3. Base Demonstration Package Scalar Payback

Building Use Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily/Dormitory	6.8	7.4	8.2	7.9	9.0	11.2	13.2	11.6	13.3	12.2	10.6	14.1	10.1	10.4	14.7	8.7	9.8	9.0	7.8
Healthcare	2.6	2.9	3.0	3.1	3.0	3.8	3.6	4.0	3.8	4.0	4.0	3.6	3.6	3.8	2.8	3.3	2.8	2.4	2.2
Hotel/Motel	3.2	3.6	4.0	4.0	4.5	5.1	5.7	5.6	5.3	5.8	5.3	6.0	6.0	5.9	6.2	5.4	5.7	5.0	4.4
Office Buildings	6.3	4.5	5.0	4.6	5.8	5.4	5.4	5.3	5.8	5.4	5.0	5.9	5.6	7.6	9.3	8.4	7.7	8.0	8.5
Restaurant Buildings	3.2	3.4	3.9	3.8	3.9	4.3	4.3	4.4	5.1	4.5	4.6	4.8	4.5	4.4	4.5	4.3	4.3	3.9	3.7
Retail Buildings	5.9	6.1	7.3	7.0	8.7	9.2	11.5	11.3	12.2	10.5	11.2	12.4	8.5	9.2	11.0	7.2	8.5	8.6	7.5
School/Education Buildings	3.7	4.0	4.7	4.3	5.0	5.4	6.2	5.7	6.0	6.0	5.4	6.5	8.3	7.4	8.6	7.7	7.7	7.8	8.1
Warehouse and Semiheated	10.5	10.4	10.8	10.6	9.8	9.0	10.1	8.9	9.3	10.9	9.1	11.1	9.0	9.0	11.9	7.4	8.2	7.8	8.6

Table E-4. Base Demonstration Package Scalar Limit or Threshold

Building Use Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily/Dormitory	14.4	14.4	15.0	14.8	15.4	16.8	17.6	17.6	16.4	18.2	17.9	18.0	17.3	17.7	17.9	17.5	17.7	17.8	17.6
Healthcare	14.3	14.4	15.1	15.0	15.7	16.0	17.0	17.2	20.1	20.2	20.0	20.5	18.9	19.3	20.0	18.6	19.0	18.7	18.4
Hotel/Motel	13.9	13.9	14.5	14.4	15.0	15.1	17.0	17.0	17.2	17.2	17.1	16.6	16.6	15.6	15.2	15.1	15.2	15.2	15.1
Office Buildings	14.7	14.5	15.1	14.9	17.1	16.9	17.3	17.5	17.6	17.9	17.9	17.8	18.1	18.1	18.2	18.7	18.2	18.4	18.9
Restaurant Buildings	14.4	14.3	13.7	13.7	14.0	13.8	14.4	14.2	13.8	15.1	14.8	14.7	15.2	15.2	15.2	15.6	15.5	16.3	16.8
Retail Buildings	14.5	14.3	14.9	14.9	15.2	15.4	16.2	16.6	16.5	16.3	16.6	16.4	14.4	14.6	14.4	14.5	14.8	14.6	14.3
School/Education Buildings	14.3	14.5	15.2	15.0	15.6	16.0	18.5	18.5	18.3	19.0	18.9	19.0	19.6	19.4	19.4	19.8	19.6	19.9	20.1
Warehouse and Semiheated	15.0	14.9	15.2	15.1	15.4	15.6	15.4	15.7	15.6	15.3	15.7	15.3	14.8	15.8	15.7	15.1	15.4	15.1	15.0

Table E-5. Ratio of Scalar Limit or Threshold to Scalar Payback

Building Use Type	Climate Zone																		
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily/Dormitory	2.1	2.0	1.8	1.9	1.7	1.5	1.3	1.5	1.2	1.5	1.7	1.3	1.7	1.7	1.2	2.0	1.8	2.0	2.3
Healthcare	5.6	5.0	5.0	4.9	5.2	4.2	4.7	4.3	5.2	5.1	5.0	5.7	5.3	5.1	7.0	5.6	6.7	7.8	8.4
Hotel/Motel	4.3	3.9	3.6	3.6	3.3	3.0	3.0	3.0	3.3	3.0	3.2	2.7	2.7	2.7	2.4	2.8	2.7	3.1	3.4
Office Buildings	2.3	3.3	3.0	3.2	2.9	3.1	3.2	3.3	3.0	3.3	3.6	3.0	3.2	2.4	2.0	2.2	2.4	2.3	2.2
Restaurant Buildings	4.6	4.2	3.5	3.6	3.6	3.2	3.4	3.3	2.7	3.3	3.2	3.1	3.4	3.4	3.4	3.7	3.6	4.2	4.5
Retail Buildings	2.4	2.3	2.0	2.1	1.7	1.7	1.4	1.5	1.4	1.6	1.5	1.3	1.7	1.6	1.3	2.0	1.7	1.7	1.9
School/Education Buildings	3.9	3.6	3.3	3.5	3.1	2.9	3.0	3.2	3.1	3.2	3.5	2.9	2.4	2.6	2.2	2.6	2.5	2.5	2.5
Warehouse and Semiheated	1.4	1.4	1.4	1.4	1.6	1.7	1.5	1.8	1.7	1.4	1.7	1.4	1.7	1.8	1.3	2.1	1.9	1.9	1.7

Table E-6. Incremental Measure Costs for Multifamily/Dormitory, $/ft²

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070
H02	Heating Efficiency													$0.056	$0.056	$0.056	$0.056	$0.056	$0.056	$0.056
H03	Cooling efficiency.	$0.055	$0.055	$0.055	$0.055	$0.055														
H04	Residential HVAC control.	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153	$0.153
L05	Residential light control	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133	$0.133
L06	Light power reduction	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231

Table E-7. Incremental Measure Costs for Healthcare, $/ft²

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027
H02	Heating Efficiency													$0.056	$0.056	$0.056	$0.056	$0.056	$0.056	$0.056
H03	Cooling efficiency.	$0.205	$0.205	$0.205	$0.205	$0.205	$0.205	$0.205	$0.205											
W02	Heat pump water heater	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012
W03	Efficient gas water heater	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013	$0.013
L03	Increase occupancy sensor	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064	$0.064			
L06	Light power reduction	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231
Q03	Fault detection	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057	$0.057

Table E-8. Incremental Measure Costs for Hotel/Motel, $/ft^2

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.077	$0.039	$0.039	$0.039	$0.039	$0.039	$0.039
H02	Heating Efficiency														$0.037		$0.037	$0.037	$0.037	$0.037
H03	Cooling efficiency.	$0.136	$0.136	$0.136	$0.136	$0.136	$0.136													
W02	Heat pump water heater	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027	$0.027
W03	Efficient gas water heater	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006	$0.006
L03	Increase occupancy sensor	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032	$0.032
L06	Light power reduction	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231

Table E-9. Incremental Measure Costs for Office, $/ft^2

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047	$0.047
H03	Cooling efficiency.	$0.136	$0.136	$0.136	$0.136															
W05	Point of use water heaters		($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)	($0.173)						
L06	Light power reduction	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229	$0.229
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231
G02	HVAC load management	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020	$0.020

Table E-10. Incremental Measure Costs for Restaurant, $/ft²

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.074	$0.074	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037
H03	Cooling efficiency.	$0.068	$0.068	$0.068	$0.068	$0.068	$0.068	$0.068	$0.068											
W03	Efficient gas water heater	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225	$0.225
L06	Light power reduction	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174	$0.174
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231
Q02	Efficient Kitchen Equipment	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201	$1.201

Table E-11. Incremental Measure Costs for Retail, $/ft²

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01b	Retail Glazing U & SHGC Reduction	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164	$0.164							
H02	Heating Efficiency										$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037
H03	Cooling efficiency.	$0.068	$0.068	$0.068	$0.068	$0.068	$0.068													
L03	Increase occupancy sensor		$0.032					$0.032							$0.032	$0.032				
L04	Increase daylight area	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035				
L06	Light power reduction	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087	$0.087
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231
Q03	Fault detection	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117	$0.117

Table E-12. Incremental Measure Costs for School/Education, $/ft²

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
E01a	Glazing U & SHGC Reduction	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041	$0.041
H03	Cooling efficiency.	$0.136	$0.136	$0.136	$0.136	$0.136	$0.136													
W05	Point of use water heaters	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)	($0.081)							
L06	Light power reduction	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231

Table E-13. Incremental Measure Costs for Warehouse, $\$/ft^2$

ID	Energy Credit Abbreviated Title	Climate Zone																		
		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
H02	Heating Efficiency													$0.003	$0.003	$0.003	$0.004	$0.004	$0.005	$0.005
H03	Cooling efficiency.	$0.068	$0.068	$0.068	$0.068															
L04	Increase daylight area	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035
L06	Light power reduction	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018
R01	Renewable energy	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231	$0.231

Table E-14. Incremental Measure Costs, $/ft^2

ID	Energy Credit Abbreviated Title	Measure Life, yr	Multifamily /Dormitory	Healthcare	Hotel/Motel	Office	Restaurant	Retail	School/ Education	Warehouse/ Semiheated
E01a/b	Glazing U & SHGC Reduction	40	$0.070	$0.027	$0.077	$0.094	$0.074	$0.16	$0.082	
H02	Heating Efficiency	18	$0.019	$0.019	$0.019			$0.019		$0.005
H03	Cooling efficiency.	15	$0.027	$0.068	$0.068	$0.068	$0.068		$0.068	$0.068
H04	Residential HVAC control.	15	$0.15							
W02	Heat pump water heater	13	$0.035	$0.012	$0.027	$0.024	$0.102	$0.020	$0.018	$0.010
W03	Efficient gas water heater	13	$0.013	$0.022	$0.010	$0.020	$0.22		$0.045	
W05	Point of use water heaters	15				($0.17)			($0.081)	
L03	Increase occupancy sensor	15		$0.064	$0.032			$0.032		$0.013
L04	Increase daylight area	15						$0.035		$0.035
L05	Residential light control	15	$0.16							
L06	Light power reduction	20	$0.018	$0.087	$0.018	$0.23	$0.087	$0.087	$0.12	$0.018
R01	Renewable (x 4C/5C,7/8)	25	$0.23	$0.23	$0.23	$0.23	$0.23	$0.23	$0.23	$0.23
Q02	Efficient Kitchen Equipment	15					$1.20			
Q03	Fault detection	15		$0.057		$0.005				
G02	HVAC load management	15				$0.020				

Table E-15. Summary of Sources Used in Measure Cost Development

ID	Energy Credit Abbreviated Title	Cost Source	Cost Source Website if Applicable
E01	Glazing U & SHGC Reduction	ESC cost analysis: added double silver coating is $0.72 per sq.ft. (window) based on the 90.1 2016/2019 fenestration cost data Tom Culp; Retail from ESC database	NA
H02	Heating Efficiency	DEER workpapers ID SWHC031-01	http://deeresources.net/workpapers ID SWHC031-01
H03	Cooling efficiency.	DEER workpapers ID SWHC027	http://deeresources.net/workpapers ID SWHC027
H04	Residential HVAC control.	$163 incremental cost increase for smart vs. normal thermostat ($249-$86). Normal t-stat cost is average of 4 common models (Home Depot)	NA
W02	Heat pump water heater	HPWH prorated to 30% load on HPWH. Various models from 40 to 80 gallons at Home Depot	NA
W03	Efficient gas water heater	Title 24 - 2022, Final CASE Report, Aug 2020, Table 49, page 92	https://title24stakeholders.com/wp-content/uploads/2020/08/NR-Boilers-and-Water-Heating_Final-CASE-Report.pdf
W05	Point of use water heaters	RSMeans. This is a cost reduction due to less piping (no recirc loop).	https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf
L03	Increase occupancy sensor	Total incremental cost from 90.1-2016 national CE workbook - Lighting Controls Proto, which is from RS Means	https://www.energycodes.gov/national-and-state-analysis
L04	Increase daylight area	From 90.1-2016 cost effectiveness analysis	https://www.energycodes.gov/national-and-state-analysis
L05	Residential light control	RSMeans. Add 2 Master switches for fixed lights and light controlled outlets per apartment.	NA
L06	Light power reduction	Incremental cost increase is 2% of 90.1-2019 material costs from cost effectiveness analysis	https://www.energycodes.gov/national-and-state-analysis
R01	Renewable (x 4C/5C,7/8)	SSPC 90.1 renewable analysis; 0.1 W/sf basis, may be adjusted by building type	NA
Q02	Efficient Kitchen Equipment	"Characterizing the Energy Efficiency Potential of Gas-fired Commercial Foodservice Equipment" report (CEC-500-2014-095) from October 2014.	http://www.energy.ca.gov/2014publications/CEC-500-2014-095/CEC-500-2014-095.pdf
Q03	Fault detection	Title 24 - 2019, Health: Final CASE Report, Aug 2017, Table 25, page 48; Title 24 - 2013, CASE Report, Light Commercial HVAC, Sept 2011, page 52	https://title24stakeholders.com/wp-content/uploads/2016/11/203A5B1.pdf
G02	HVAC load management	RS Means	NA

Table E-16. Summary of Measure Cost Development

ID	Energy Credit Abbreviated Title	Incremental cost per unit	Multifamily /Dormitory	Healthcare	Hotel/Motel	Office	Restaurant	Retail	School/ Education	Warehouse/ Semiheated
E01	Glazing U & SHGC Reduction	$0.72 per sf glazing area	3304 sf	9130 sf	13,071 sf	7027 sf			23,931 sf	
H02	Heating Efficiency	$6.94 /MBH	33,740 sf	40,950 sf	43,210 sf			24,690 sf		52,050 sf
H03	Cooling efficiency.	$29.66 /ton for 5% improvement	33,740 sf	40,950 sf	43,210 sf	5,500 sf	2,500 sf		73,970 sf	52,050 sf
H04	Residential HVAC control.	$163 per dwelling unit	79 units							
W02	Heat pump water heater	30% of total water heating load		60/180 Mbtu/h, outpatient/hospital	32/61 Mbtu/h, small/large hotel	12/121 Mbtu/h, med/large office				
W03	Efficient gas water heater	$5.88 incremental cost per Mbtu/h		140/420 Mbtu/h, outpatient/hospital	76/142 Mbtu/h, small/large hotel		70/140 Mbtu/h, quick/full		280/1478 Mbtu/h, primary/secondar	
W05	Point of use water heaters	($15) per ft of pipe				pipe length: 148/308/632 ft, sm/med/lg			pipe length: 544/670 ft, k-12/secondary	
L03	Increase occupancy sensor	$637 per sensor each 1000 sq ft		2.5 sensors /ksf	2.2 sensors /ksf					
L04	Increase daylight area	$0.70 per sq.ft.						24,690 sf		52,050 sf
L05	Residential light control	$146 per apartment	31 units mid-rise apt							
L06	Light power reduction	incr costs are 2% of 90.1-2019 material cos	33,740 sf	40,950 sf	43,210 sf	5,500/500,500 sf, small/large	2,500 sf	24,690 sf	73,970 sf	52,050 sf
R01	Renewable (x 4C/5C,7/8)	$2.25 per Watt	33,740 sf	40,950 sf	43,210 sf	5,500/500,500 sf, small/large	2,500 sf	24,690 sf	73,970 sf	52,050 sf
Q02	Efficient Kitchen Equipment	$6,608 /kitchen for fryer & oven					1 kitchen			
Q03	Fault detection	$2730 /AHU Health $722 /RTU light com.		5 AHUs						
G02	HVAC load management	$300 Labor incl O&P, 2020$, total				2 hrs controls contractor labor				

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