PNNL- 28503

Pacific Northwest
NATIONAL LABORATORY

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R Hart
M Rosenberg
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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The U.S. Department of Energy (DOE) has developed two commercial energy code compliance methodologies:

- To support the *American Recovery and Reinvestment Act of 2009*, a checklist approach was applied to predetermined samples of buildings, with the results based on the percentage of measures in compliance.
- More recently, a pilot methodology was developed to quantify an estimate of lost savings and applied to a small, 9-building sample of office buildings with simple heating, ventilation, and air-conditioning (HVAC) systems.

This work enhances the second method, with the goal of answering the questions: What is the potential value of increasing compliance with the energy code and which code requirements should be emphasized during these studies? Ultimately, these are the questions that policy makers, funders, and program implementers care about. To answer them, a far more sophisticated approach is needed, one that addresses not only the question of value, but also the resource requirements to determine that value.

Determining Lost Energy Cost Savings

With the above in mind, the current research set out to expand a methodology capable of determining, for a sample of buildings, how much energy cost savings could potentially be gained through better compliance with the code. To estimate this, it is necessary to be able to assign a lost energy cost value to any condition likely to be encountered in such an assessment. The current research expanded from a pilot that considered only office buildings with simple HVAC systems in one climate zone (4C) to include the following:

- A retail prototype was added so two building types could be included, office and retail.
- Analysis was expanded to include climate zones 2A, 3B, and 5A.
- The measure list was expanded from 63 to 100 measures per building type, primarily due to the inclusion of more complex hydronic and variable air volume (VAV) HVAC systems in the office.

To accomplish the current work, several steps were undertaken:

- A feedback process was established to determine reasonable worst case conditions and field data collection protocols based on expert opinion.
- A sensitivity analysis of code measures was conducted using EnergyPlus[1] to determine the worst possible lost energy savings, so that the number of measures evaluated in the field could be reduced by including only those with high potential lost energy savings impact.
- An expanded spreadsheet tool was created to capture field parameters that would drive estimates for lost energy savings when buildings did not meet requirements.

[1] EnergyPlus Energy Simulation Software, Version 8.0, http://apps1.eere.energy.gov/buildings/EnergyPlus/.

- A DOE funding opportunity announcement was brought forward to find a contractor to use the revised methodology and complete a broader field investigation in multiple climate zones.
- Working with the field study contractor, the spreadsheet tool and methodology were refined to ensure accurate data collection.
- The results from the field evaluation will be entered into a data collection spreadsheet tool and the estimated lost savings extracted for analysis of overall building sample energy code compliance impacts.

Based on the sensitivity analysis results, the project team selected measures for inclusion in the field study. Generally, measures with a present value lost savings potential greater than $200 per thousand square feet were selected. In some cases, a higher cutoff was used where verification was thought to be difficult. In other cases, a lower cutoff was used where there were similar measures that were being inspected or verification was thought to be easier. The count of selected measures by climate zone and building type is shown in Table ES.1.

Table ES.1. Measures Identified and Selected for Field Study

Building Type	Office			Retail		
Climate Zone	2A	3B	5A	2A	3B	5A
Applicable Measures	86	87	90	67	68	71
Selected Measures	55	55	58	46	46	47
Percentage Selected	64%	63%	64%	69%	68%	66%

Reducing the Cost of Compliance Verification

Verifying that buildings adhere to the requirements in the commercial code is complicated and expensive, whether performed by a building official or a third-party verifier. It is unlikely that there will ever be enough resources available to fully judge compliance for all code measures in every building.

One goal of this research is to further test a methodology to identify measures that have the highest potential lost savings for the effort required to find their compliance condition. Focusing on the high impact measures, this next round of field data collection is intended to provide important data that can further focus on the important measures in a wide range of buildings. The high-impact measures cannot be positively recognized by sensitivity analysis alone. The field data needs to be collected to fulfil the vision of a full focused method. In this phase of field data collection, researchers want to make sure that any large contributor to lost savings is captured. The purpose of the field study is to further reduce the number of measures that need verification by gathering actual data in four areas:

- What is the actual worst case for each measure discovered in the field? In many cases, it may not be as bad as the theoretical worst case that was modeled and that would limit the impact of the measure on lost energy cost savings.
- What is the applicability of each measure in an actual sample of buildings? Measures that rarely occur will have a lesser impact on the total lost savings related to energy codes.

- What is the typical condition for each measure found in the field? Understanding the typical distribution of as-found conditions can allow an expected value of lost savings to be assigned to each measure.
- What is the effort involved in verifying each measure? It may be more beneficial to focus on verifying measures that have a high lost savings per hour of inspection time.

Once that additional information is gathered for a valid sample of instances for each measure, then the expected lost savings relative to the verification cost can be identified. This is discussed further in the pilot study.[1] Once measures are ranked in this way with more field data, then a much smaller set of measures can be included in the measure list for verification in future evaluations.

The results from the sensitivity analysis and field verification will be analyzed to develop a method for ranking the measures considering both their energy cost impact and the resources required to verify adherence with the code. This type of ranking can identify truly high-impact measures, which can inform the focus of evaluation efforts or energy code training in the future.

If future studies confirm this relationship holds true and a small fraction of the measures have a high impact on the lost energy savings, the following prioritized approach is proposed:

- Determine a set of high-impact lost energy savings measures that should always be verified in every building. These will likely vary by building type and climate zone. The number of measures could vary depending on the purpose of the verification and the complexity of the building type.
- Verify the remainder of the measures on a rotating or randomized basis to ensure all energy code requirements are met.

This approach will lead designers and contractors to pay the most attention to the most impactful requirements, while ignoring none. Such an approach has a significant efficiency advantage in that high-energy-impact measures are fully investigated, while less effort is applied to less impactful measures.

[1] Rosenberg, M, R Hart, R Athalye, J Zhang, W Wang, and B Liu. 2016. *An Approach to Assessing Potential Energy Cost Savings from Increased Energy Code Compliance in Commercial Buildings*. PNNL 24979, Pacific Northwest National Laboratory, Richland, WA.

Table ES.2 shows the top 20 measures based on including the top 10 ranked measures (bolded) from each case of building type and climate zone combination. They are then ranked by the average of case rankings. This ranking is highly preliminary, as it does not include the important information that will come from the field studies: actual worst case in the field, actual field applicability, typical as found field condition, and effort required to verify each measure's installed condition.

Table ES.2. Top 20 Measures Based on Worst Case Analysis*

Measure ID	Measure Name	Present Value of Lost Energy Cost Savings per 1,000 ft^2						
		Office			Retail			Average Impact
		2A	3B	5A	2A	3B	5A	
5012	Roofs insulated per CZ requirements	**$2,873**	**$3,330**	**$4,342**	**$9,526**	**$11,003**	**$15,114**	$7,698
9037	Interior lighting power allowance	**$3,637**	**$3,615**	**$3,022**	**$6,588**	**$6,686**	**$5,447**	$4,832
9009	Automatic time switch control	**$2,974**	**$2,887**	**$2,470**	**$6,295**	**$6,103**	**$5,413**	$4,357
9047	Additional retail lighting power allowance	NA	NA	NA	**$3,629**	**$3,609**	**$2,996**	$3,411
5034	Window-to-wall ratio shall meet maximum limits	**$1,689**	**$1,807**	**$1,809**	**$2,594**	**$2,838**	**$3,005**	$2,290
6019C	Night fan control	**$2,065**	**$2,228**	**$1,814**	**$1,868**	**$2,033**	**$2,244**	$2,042
5018A	Frame walls insulated per CZ req'mt	$1,149	**$1,259**	**$1,664**	**$2,729**	**$3,209**	**$3,929**	$2,323
6070	Multi-zone systems shall be VAV with VSD motors where required	**$1,405**	**$1,519**	**$1,150**	NA	NA	NA	$1,358
6109pAS	Parking garage fan controls	$1,225	$1,228	$1,150	**$2,002**	**$2,006**	$1,879	$1,582
5018B	Above grade mass walls insulated per CZ and density requirements	$606	$690	**$2,618**	$1,417	**$1,588**	**$3,731**	$1,775
6035	Exterior duct leakage requirement	$1,204	$929	**$1,845**	$1,552	$1,334	**$2,609**	$1,579
6042B	Hydronic piping insulation	**$1,407**	$1,143	$774	NA	NA	NA	$1,108
5036	Daylighting control when required	$1,214	$1,212	$1,031	**$1,629**	$1,353	$1,444	$1,314
6046A	Fan power limit for unitary AC	$1,223	**$1,376**	$1,075	$1,306	$1,448	$1,045	$1,245
6005E	WSHP efficiency	**$1,364**	$1,132	$800	NA	NA	NA	$1,099
5042B	Windows meet SHGC requirements	**$1,275**	**$1,388**	$714	$1,330	$1,479	$783	$1,162
6033p	Exterior duct insulation requirement	$905	$770	$258	**$2,714**	**$2,310**	$773	$1,288
6026p	Snow and ice-melting system control	NA	$216	$529	NA	$929	**$2,271**	$986
9003	Manual lighting control	**$1,499**	**$1,452**	**$1,242**	$195	$189	$164	$790
6019A	Thermostat setback, heating	$350	$312	$327	$944	$924	$1,491	$725

* Equipment sizing measures were eliminated from the field study, as discussed in Section 4.1.3.
CZ = climate zone; SHGC = solar gain heat coefficient; VSD = variable speed drive; WSHP = water source heat pump.

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Pacific Northwest National Laboratory

Acronyms and Abbreviations

AFUE	annual fuel utilization efficiency
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ARRA	American Recovery and Reinvestment Act of 2009
BECP	Building Energy Codes Program
CBECS	Commercial Buildings Energy Consumption Survey
CHW	chilled water
COP	coefficient of performance
CZ	climate zone
DCV	demand controlled ventilation
DL	daylighting
DOE	U.S. Department of Energy
ECR	energy cost rating
EER	energy efficiency ratio
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air-conditioning
HW	heated water
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
LCC	life-cycle cost
LPD	lighting power density
MBH	thousands of British thermal units per hour
PNNL	Pacific Northwest National Laboratory
PV	present value
R-value	thermal resistance in h·ft2·°F/Btu
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SWH	service water heating
U-factor	thermal resistance in Btu/h·ft2·°F
UPV	uniform present value
VAV	variable air volume
VSD	variable speed drive
WSHP	water source heat pump
WWR	window-to-wall ratio

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1.0 Background

The U.S. Department of Energy (DOE) Building Energy Codes Program (BECP) supports the development and implementation of building energy codes and standards (DOE 2018). This includes providing technical assistance to states to implement building energy codes, including identifying and quantifying opportunities to ensure consumer benefits. One key area in which BECP has worked over the past several years is providing resources and tools to assist states in evaluating compliance with building energy codes. The work described in this report expands on previous work in this area.

1.1 DOE's Commercial Compliance Work

DOE has explored different approaches to rating energy code compliance, beginning with binary pass/fail metrics evolving into the current lost opportunities approach described in this report.

1.1.1 Initial Checklist Approach

In 2010, DOE developed a commercial methodology and associated tools focused on determining a percent compliance rating for states (DOE 2010) to support the *American Recovery and Reinvestment Act of 2009* (ARRA 2009). Section 410 of ARRA requires states to develop "a plan for the jurisdiction achieving compliance with the building energy code or codes described in subparagraphs (A) and (B) within 8 years of the date of enactment of this Act in at least 90 percent of new and renovated residential and commercial building space."

The tools that were developed and made available as part of DOE's work include 1) the State Sample Generator, an online tool that generates a representative sample set distributed across building size and climate zone for each state; 2) compliance checklists; and 3) Score+Store, an online tool that collects checklist data, determines individual building scores, and calculates an average compliance score for the sample set. In the commercial compliance checklist, for each code requirement that was applicable to a particular building and observable, a binary decision was made regarding whether or not the requirement was met. The percentage of requirements that were met established the score for each individual building. Note that this approach does not distinguish between varying levels of non-compliance for individual requirements.

DOE worked with five Regional Energy Efficiency Organizations[1] to select states in which to conduct pilot studies using this DOE methodology and tools. Ultimately, eight studies covering nine states[2] were conducted. Details of this previous work are summarized in the report *90% Compliance Pilot Studies* (DOE 2013). While effective in collecting information about the condition of recently constructed buildings, with its binary approach to compliance determination, the initial checklist approach failed to answer a critical question: What is the value of increasing compliance with the energy code?

[1] Northeast Energy Efficiency Partnerships, the Southeast Energy Efficiency Alliance, the Midwest Energy Efficiency Alliance, the Southwest Energy Efficiency Project, and the Northwest Energy Efficiency Alliance.
[2] Studies were completed for Georgia, Iowa, Massachusetts, Montana, Utah, Wisconsin, Northwest Commercial Lighting Study (Washington, Oregon, Idaho, Montana), and Northwest Jurisdictional Survey.

1.1.2 Pilot Lost Savings Methodology

To move past a binary assessment of compliance, DOE worked with Pacific Northwest National Laboratory (PNNL) to develop a pilot methodology with a goal of determining lost energy savings due to non-compliance in commercial buildings (Rosenberg et al. 2016). This research developed a new methodology capable of determining how much energy cost savings could potentially be gained through better adherence to the requirements in the energy code and included a pilot covering the lost savings impact for nine commercial buildings. It also compared the level of effort required to evaluate compliance with the potential cost savings for different code measures.[1] The method was based on a combination of analysis and field investigation. The analysis used prototype building energy simulation to establish the range of energy impact that could result from different building parameters. The field investigation determined the installed condition of energy impactful measures and the time required to verify the installed condition. The pilot project focused on office buildings with simple unitary heating, ventilation, and air-conditioning (HVAC) systems and evaluated 63 measures related to energy codes. The PNNL small office building prototype was used to estimate the lost savings impact. Overall conclusions were as follows:

- For a sample of nine buildings, the present value of lost savings was $1,710 per thousand square feet.
- There was a wide range in savings for different measures, with 81% of the lost savings related to 14% of the measures.
- The field time required to verify measures relative to lost savings over the life of the buildings also had a wide range. Viewed as life-cycle cost (LCC) lost savings found per hour of investigation, it ranged from less than $1 per hour of investigation to as much $6,700 per hour.
- The sample was too small to get a good estimate of the worst case installation for each measure or the expected level of compliance for measures that were found to not meet code, but the methodology was validated as a reasonable approach for future research.

Based on the sensitivity analysis of a prototypical office building using simulation in the pilot study, the annual energy cost impact of the worst case for each measure was determined and a present value of lost savings calculated per thousand square feet of building area. In Figure 1.1, the frequency of these lost savings is organized into bins that double in value, from the highest potential lost savings to the lowest. The dashed line shows that less than 30% of the measures cover all individual measure’s worst-case impacts greater than $800 in life-cycle lost savings and more than 70% of the cumulative worst-case lost savings. This reinforces the Pareto principle concept of focusing on a limited number of high-impact measures to verify the majority of lost savings.

[1] A code measure is a group of related code requirements, and they are described in more detail in Section 2.2.1.

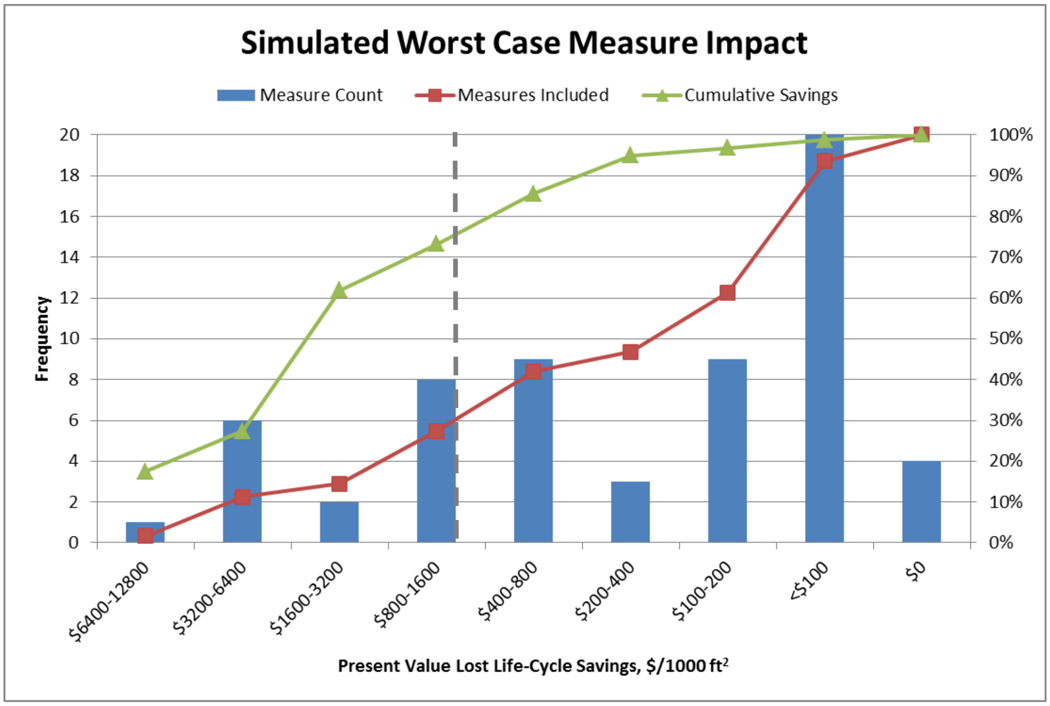

Figure 1.1. Distribution of Worst-Case Measure Impact

1.1.3 Expanded Lost Savings Methodology

With the goal of further developing a method to determine the value of increasing adherence to the energy code, it was important to further define what measures were most impactful and what their impact is on energy use and cost. With that goal, the prototype simulation-based approach used in the pilot methodology test (Rosenberg et al. 2016) was expanded as follows:

- A retail prototype was added so two building types could be included, office and retail.
- Analysis was expanded to include climate zones 2A, 3B, and 5A.
- The measure list was expanded from 63 to 100 measures per building type, primarily due to the inclusion of more complex hydronic HVAC systems in the office.
- The office prototype used was switched from the small office to the medium office, and systems were modified to capture measure impacts for unitary systems, variable air volume (VAV) systems, air- and water-cooled chillers, and boilers.
- Potential measures were evaluated using EnergyPlus[1] analysis to determine the worst possible lost energy savings, so that the number of measures evaluated in the field could be reduced by including only the most impactful.
- A DOE funding opportunity announcement was brought forward to find a contractor to use the revised methodology and complete a broader field investigation in multiple climate zones.

[1] EnergyPlus Energy Simulation Software, Version 8.0; http://apps1.eere.energy.gov/buildings/EnergyPlus/.

- A feedback process was established to determine reasonable worst-case conditions and field data collection protocols based on expert opinion.
- An expanded spreadsheet tool was created to capture field parameters that would drive estimates for lost energy savings when buildings did not meet requirements.
- The results from the field evaluation will be entered into a data collection spreadsheet tool and the estimated lost savings extracted for analysis of overall building sample energy code impacts.

1.2 Long-Term Compliance Evaluation Direction

It should be emphasized that the sensitivity analysis that is documented here is only the first step in the development of a prioritization of measures for code compliance verification. There are several questions not answered by a simple analysis of theoretical lost savings. Further work is needed to get a true picture of the most important measures to evaluate. That will require field studies to gather more information. The purpose of those studies is to further reduce the number of measures that need verification by gathering actual data in four areas:

- What is the actual worst case for each measure discovered in the field? In many cases it may not be as bad as the theoretical worst case that was modeled and that would limit the impact of the measure on lost energy cost savings.
- What is the applicability of each measure in an actual sample of buildings? Measures that rarely occur will have a lesser impact on the total lost savings related to energy codes.
- What is the typical condition for each measure found in the field? Understanding the typical distribution of as-found conditions can allow an expected value of lost savings to be assigned to each measure.
- What is the effort involved in verifying each measure? It may be more beneficial to focus on verifying measures that have a high lost savings per hour of inspection time.

Once that additional information is gathered for a valid sample of instances for each measure, then the expected lost savings relative to the verification cost can be identified. This is discussed further in the pilot study (Rosenberg et al. 2016). Once measures are ranked in this way with more field data, then a much smaller set of measures can be included in the measure list for verification in future evaluations.

2.0 Energy Impact Estimation Approach

An important development from the pilot was the decision to collect data only for measures with the potential to have a large impact on building energy use. Given some uncertainty about the actual worst case that would be encountered in the field and which measures would be found to be regularly non-compliant, a broad range of measures was included for this analysis. It is expected that once adequate field information is collected on the range of measures included here, future studies will include fewer measures that will always require data collection.

2.1 Analysis Scope

The purpose of this technical support document is to record the method used to evaluate the lost energy savings of measures found to be non-compliant with energy codes in buildings. The approach used in the pilot methodology test (Rosenberg et al. 2016) was expanded to include more building types, climate zones, and measures. The current analysis was limited to new construction impacting two building types (office and retail buildings) with a range of HVAC systems in three climate zones (2A, 3B, 5A) looking at the requirements of the 2012 International Energy Conservation Code (IECC) (ICC 2012) and ASHRAE Standard 90.1-2010 (ASHRAE 2010). Future research will expand both the building types and climate zones. The rationale for these choices is as follows.

Office and retail buildings were selected because together they represent a large portion (31.3%) of the existing commercial building stock (EIA 2015).[1] The 2012 IECC was chosen because 25 states have adopted it or the parallel version of ANSI/ASHRAE/IES Standard 90.1 (ASHRAE 2010) (DOE 2019), with additional states likely to adopt a more advanced code within the next several years. This code edition was common in the states targeted for this phase of the methodology study.

Limitations in the pilot study that have been resolved for this phase include the following:

- Both simple and complex HVAC systems were chosen to avoid limitations in sampling experienced in the pilot. The pilot was limited to simple systems.
- Projects complying via the performance approach are now accounted for. This does require securing the performance documentation so that performance conditions can be input as the “code required” baseline condition. One of the areas for the current field study is Florida, where many buildings use the performance approach. The pilot was limited to buildings using the prescriptive approach.
- To further develop the methodology, the sample size is expanded so that statistically valid results can be collected for all measures. This will allow better determination of expected compliance levels and actual worst cases for measures.
- Although the analysis was based on the 2012 IECC, some variation is experienced in local codes and is accommodated by indicating either measure applicability or a different base code requirement in the data collection tool.

Limitations that continue to apply include the following:

[1] The Commercial Buildings Energy Consumption Survey (CBECS) defines commercial buildings as all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial, or agricultural.

- The prototypes do not necessarily match the actual building configuration, so savings estimation may not be exact; however, the savings are expected to be accurate enough to get an overall impact of buildings in general in a particular state or climate zone.
- The lost savings results are non-interactive. This could be an issue if there is significant non-compliance in both lighting power and controls; however, a review of interactive issues in the pilot study found that there was not a large impact.
- The tool is currently only fully developed to generate results for two[1] climate zones and two building types.

2.2 Methodology for Determining Energy Impact

This methodology operates at two levels. The meta level involves collection and analysis of results for a sample of buildings to project overall state or climate zone compliance impact. That overall method is discussed in the pilot study (Rosenberg et al. 2016), and is being further developed in the current field study. A subset of that overall methodology is development of lost savings estimation for measures in the field study and development of a tool to collect and process that data to be rolled up in a sample evaluation. The approach to assessing potential lost energy cost savings for a particular building instance can be summarized by the following steps:

1. Identify applicable code requirements for the building types, HVAC system types, and climate zones of interest.

2. Combine related requirements into measures that can be verified and evaluated.

3. Determine if each measure has a discrete or continuous input. Some measures have savings that are parametrically based, i.e., the input is a value related to field and requirement conditions, such as U-factor. Other measures have a discrete input, or are incrementally based, i.e., the input is a selection from a set of descriptions, like commissioning quality.

4. Determine the worst-case condition for non-compliance expected to be encountered in the field assessment. While total non-compliance seems easy to quantify, there are many cases where some minimal, though not fully compliant, installation is to be expected. For example, where a 6-inch wall with R-19 insulation is required, rather than a minimum of a single sheathing wall (theoretical worst case), an unfilled cavity wall may be the actual worst case likely ever to be encountered.

5. Identify a range of conditions for each measure covering the range of expected field conditions from worst to code-compliant to best, with intermediate conditions identified where appropriate. For many parametric measures, the impact is linear relative to the related parameter, so only a minimum and maximum value are needed.

[1] While initial worst-case lost savings were developed for climate zones 2A, 3B, and 5A, once a field contractor was selected mid-way through the analysis process, it was determined that field work would be restricted to climate zones 2A and 5A. Hence, full range of savings analysis including worst, code, and best cases was not developed for climate zone 3B.

6. Perform energy simulation using prototype models of the identified conditions for each measure in each building type, HVAC system type, and climate zone of interest to estimate energy cost impacts.

7. Review the worst or expected case non-compliant results to determine which measures potentially have a strong impact on results and should be included in a field assessment tool.

2.2.1 Identification of Applicable Code Requirements

Before compliance could be assessed, it was first necessary to identify the code requirements that apply to the building type being studied. The first step in that process was to inventory all the requirements in the non-residential provisions of the 2012 IECC. The assessment for the pilot study (Rosenberg et al. 2016) was expanded to include the retail building type and climate zones analyzed: 2A, 3B, and 5A. In addition, since the 2012 IECC allows use of 90.1 as an optional path, several 90.1-2010 measures that were not in the IECC were included. A total of 413 individual requirements were identified. Next, requirements not applicable to this project or those that would not be verified were removed. This was done if:

1. There were no energy savings directly attributable to the requirement. For example, air barriers are permitted on the interior, exterior, or within the building envelope assembly. While the air barrier requirement itself affects energy use, the location of the air barrier does not. Administrative requirements also fall under this category.

2. The requirement does not apply to office or retail buildings with the HVAC systems to be analyzed. For example, requirements for laboratory exhaust or refrigeration systems are not applicable.

3. The requirement does not apply to the climate zones analyzed: 2A, 3B, and 5A. For example, cool roof requirements are not applicable in climate zone 5A.

4. The requirement is a parent requirement to a subset of more specific requirements. For example, there is a general requirement that thermal envelope components comply with the tables containing R-values and U-factors. However, there are also specific sub-requirements for wall, roof, door, and floor U-factors. There is no need for a separate verification of the general requirement.

After applying these filters to the requirements, 328 IECC requirements remained from the original 413 and 7 were added from 90.1, for a total of 335. Next, the 335 requirements were grouped into 96 “measures” containing related requirements. For example, the mass wall insulation measure contains requirements for the U-factor of the assembly and the weight and density of the wall, as well as requirements for how continuous insulation must be installed. These three requirements were grouped into a single “mass wall insulation” measure. There are related requirements that occupancy sensors be present in certain space types, that they shut lights off within 30 minutes, and that they automatically energize no more than 50% of the lights in a space upon detecting occupants. These three requirements were grouped into a single “occupancy sensor” measure. In several cases, after grouping into a single measure, two discrete sub-measures were analyzed. For example, cooling efficiency is analyzed separately for package systems and VAV multiple zone systems. These sub-measures use the same measure number with A & B appended. Table A.1 in Appendix A lists the 96 measures analyzed for the "worst case lost savings impact" and the associated requirements. The assessment of compliance takes place at the measure level.

2.2.2 Development of Range of Conditions

For each of the 96 measures discussed in Section 2.2.1, a range of likely conditions was developed that could reasonably be expected to occur in a building. For each measure, the code-compliant condition was identified along with a reasonable best condition and a worst below-code condition. The worst condition is obviously needed to provide a range of impacts below code to understand the lost savings. Conditions better than minimum code were identified for each measure; they are not factored into the calculation of lost energy cost savings for the reasons discussed in Section 2.1. So, the "best" condition is needed for four reasons:

- The above-code analysis was used to provide energy impacts for a performance path building, where the proposed performance building becomes the code requirement. Above-code conditions may be included to trade off with below-code conditions for other measures.
- Having a regression or impact calculation process that includes "above-code" (above 90.1-2010) conditions allows the field tool to be adapted to local adoptions that have included measures with requirements above the national model code requirements.
- Developing a range of parameters both below and above code allows the tool to adapt to future editions of the energy code as they are adopted.
- The "above-code" range can be applied to a green or advanced code where the "requirement" may be above code.

To set the initial boundaries (best to worst), the authors' professional judgment was used with input from other PNNL engineers and scientists as well as external energy code experts. The best and worst conditions selected are not the best and worst conditions possible, but rather the best and worst conditions expected in the field. If additional conditions are found outside of this range during field investigation, they may need to be added later. Initially, only code and worst conditions were used to determine the energy cost impact of worst-case condition. Then, once measures were prioritized by potential lost savings and selected for inclusion in the field study, a best condition was identified where appropriate. Generally, only the three conditions were identified, since a five-condition approach in the pilot study found that in most cases the relation of energy use to input parameters was linear. In some cases, only two conditions were identified:

- For HVAC efficiency equipment, efficiencies far below code are not available from manufacturers, so the worst condition is limited to the minimum requirements in the previous code edition, which in some cases means that only the code and best conditions are included. Above-code efficiencies are used in performance path applications.
- Window-wall ratios below 30% are not included, as performance paths do not currently allow this tradeoff.
- Other measures that are mandatory and cannot be used or are unlikely to be used in performance tradeoff only had the worst and code conditions. These are indicated in the tables in Appendix A.

In some cases, more than three conditions were identified where three data points did not produce a high enough coefficient of determination (R^2) for acceptable accuracy; these include:

- Roof insulation (5012) and floor insulation (5023A & 5023B).
- Window U-factor (5042A).
- Heating and cooling temperature setback (6019A & 6019B).

The complete list of the measure input conditions is shown in Table B.1 and Table B.2 in Appendix B.

2.2.3 Measure Conditions, Worst, Code, and Best

Once the range of potential found conditions for each measure was identified, input parameters related to each measure and condition were determined. The discrete conditions simulated for a sample of measures is shown in Table 2.1, with the conditions and input parameters simulated for all measures listed in Table B.1 in Appendix B.

Table 2.1. Example of Code Measures and Identified Conditions

Measure Name	Measure Abbreviation	Best Condition	Code Condition	Worst Condition
Roofs shall be insulated to meet CZ requirements	RoofIns	50% req'd U-factor	100% req'd U-factor	No insulation
Above grade frame walls shall be insulated to meet CZ requirements	FrameWallIns	40% req'd U-factor	100% req'd U-factor	No insulation
Window-to-wall ratio meets maximum limits	MaxWWR	5% WWR w/ daylighting controls	30% WWR no daylighting controls	90% WWR no daylighting controls
Packaged air conditioner efficiency	ACCoolingEff	113% code req'd efficiency	100% code req'd efficiency	93% code req'd efficiency (Prior code edition req'mt)
Gas furnace efficiency	FurnaceEff	97% AFUE	78% AFUE or 80% Et	78% AFUE or 80% Et
Thermostat deadband requirement	TempDeadband	Deadband 7°F	Deadband 5°F as req'd	Deadband 1°F
Optimal start controls	OptStart	NA	Optimum start as req'd	No optimum start
Exit sign maximum power	ExitSign	Less than 3W per side	5W per side	Exceeds 10W per side
Interior lighting power allowance	IntLPD	Whole building LPD lower than allowed by 50%	Meets whole building LPD	Exceeds whole building LPD by100%

AFUE = annual fuel utilization efficiency; CZ = climate zone; WWR = window-to-wall ratio.

2.2.4 Delphi Group Review of Case Conditions

Six energy code experts were assembled to advise on the project and provide feedback initially on the worst and best case input conditions to be used for analysis. Once the analysis was complete, an expanded group provided feedback on which measures to include in the actual field study once the simulation-based energy impact of each measure was determined. Once initial proposals were made for input parameters, the proposed input conditions were presented to the experts via a webinar in August 2016. The feedback was collected and applied. Appropriate adjustments were made to the input range of conditions, with final review completed in October 2016.

3.0 Modeling Strategy

3.1 Determining Worst-Case Lost Savings

The primary goal of this phase of work was to review the measures in the 2012 IECC commercial provisions and find the relative energy cost impact of each measure in a worst-case non-compliance situation. The worst-case energy impact results can be used in ranking measures to find which have the most potential for lost savings. Those measures with the highest potential will be evaluated in the field study to determine the actual lost cost due to non-compliant construction practices. These results combined with the time required to verify each measure will allow future evaluations to focus on measures that had a large impact on energy use over the life of the building and those that have the greatest savings recovery potential per verification hour. The general approach for the worst-case analysis was to simulate each measure for a code case and a worst case and compare the energy use impact.

3.1.1 Use of Prototype Simulation Models

As discussed previously, prototype building models were used to quantify lost energy cost savings for this research. PNNL has developed a suite of 16 prototype building models using EnergyPlus to analyze non-residential energy codes (Thornton et al. 2011). Code-compliant versions of each prototype in each of the 17 climate zones in the United States are available for each version of Standard 90.1 and the IECC since 2004 (DOE 2016). These prototype models are available for download (DOE 2016).

The current project used the PNNL medium office and standalone retail prototype models compliant with the 2012 IECC. Simulations were completed in climate zones 2A, 3B, and 5A to determine the energy impact of the worst case vs. code requirements.

While the prototypes include typical construction characteristics, some modification was required to capture as many of the code requirements as possible. For example, the medium office building prototype contains no skylights, but it is likely that they will be encountered if a large enough sample of offices is assessed. The following changes were made to the prototype models:

- **Skylight Curb Insulation, Skylight-to-Roof Ratio, Skylight Solar Heat Gain Coefficient (SHGC) and U-factor**. To capture the various requirements applicable to skylights, ten 4 ft by 4 ft skylights were added to the core zone, resulting in a 3.0% skylight-to-roof ratio.
- **Exterior Floor Insulation.** One of the perimeter zones was changed from slab-on-grade construction to exterior floor construction. This type of construction often occurs in commercial buildings when there is parking located under part of the building below a floor above.
- **Opaque Door U-factor.** Six 3 ft by 7 ft opaque swinging doors with a U-factor = 0.37 Btu/h·ft^2 ·°F were added to the office and five 8 ft by 10 ft opaque roll up doors with a U-factor = 0.21 Btu/h·ft^2 ·°F and eight 3 ft by 7 ft opaque swinging doors with a U-factor = 0.37 Btu/h·ft2 ·°F were added to the retail prototype.
- **Other Office HVAC System Type Heating and Cooling Efficiency.** The original medium office prototype includes a packaged VAV reheat system with direct expansion cooling and electric reheat. To capture system efficiency changes for other HVAC system types, parallel baseline and high-efficiency models were created with the following system types:

  - Hydronic VAV with chilled water and hot water reheat.
  - Packaged rooftop HVAC with heat pump heating.
  - Water source heat pumps with a loop boiler and fluid cooler.
  - Single zone fan coil units served by a hot water gas boiler and air cooled chiller.
  - Single zone fan coil units served by a hot water gas boiler and water cooled chiller.
- **Other Retail HVAC System Type Heating and Cooling Efficiency.** The standalone retail prototype includes a packaged single zone HVAC system with direct expansion cooling and a gas furnace. To capture system efficiency changes for other HVAC system types, parallel baseline and high-efficiency models were created with a packaged air source heat pump system.
- **Demand Control Ventilation and Energy Recovery**. To trigger the code requirements for demand controlled ventilation and energy recovery, it was necessary to add a space with high occupant density requiring substantial outdoor air. One of the office perimeter zones was simulated as a conference room with peak occupancy of 46 people per thousand square feet. Specific conference room occupancy schedules were added for this zone. Prorated savings from the office analysis were used for the retail conference/training room.

3.1.2 Parametric Building Simulation

Once the range of potential found conditions for each measure was identified, input parameters related to each measure and condition were determined. The conditions and input parameters simulated for all measures are listed in Table B.1 and Table B.2 in Appendix B. The baseline prototype buildings followed the code case parametric inputs, while best (where applicable) and worst cases are modeled with appropriate input parameters for those conditions. Then, results from the worst condition are compared to the code results to find potential lost savings from non-compliance. Where needed for above code performance path approaches, the best condition parameters provide a result that can be compared to the baseline as discussed in Section 5.0.

3.1.3 Manual Engineering Calculations

In most cases, EnergyPlus simulation of the prototype models was the basis for worst-case potential lost energy savings. The parametric inputs used in the analysis of each case are shown in Appendix B. In several situations, manual calculations, or results from the pilot study were used rather than attempting to model results with EnergyPlus. These included:

- **Below-Grade Wall Insulation (5021p)**. The pilot included a 724 ft^2 conditioned basement zone added to the small office. Below-grade wall insulation was modeled and the results transferred on a prorated wall area basis to this study.
- **Snow and Ice Melting System Control (6026p)**. Snow and ice melting system control impacts energy used outside the building envelope and does not require energy simulation. The original savings calculations developed when this requirement was added to Standard 90.1 were used on a heated area basis.
- **Duct Insulation (6033p)**. A temperature bin analysis for outside exposed ducts and non-conditioned area ducts was completed as a basis for savings.

- **HVAC & Lighting Commissioning (6045p & 9099p).** For this analysis, commissioning is estimated as a percentage of total building energy usage, based on the results of a composite review of several field evaluation reports of new building commissioning (Mills et al. 2004). This meta review showed new building commissioning saved 11.7% of building energy cost overall. To be conservative on commissioning savings that are difficult to analyze, this was reduced to 8% for this study and allocated to lighting and HVAC based on end use proportion. Conditions between code-required commissioning and no commissioning were based on the overall quality of the commissioning effort, and if it was different from the energy code requirements, then commissioning was adjusted.
- **Water Economizer Capacity (6066p).** The impact for the worst case of this rarely encountered measure was estimated at 75% of typical airside economizer savings.
- **Water Economizer Precooling Coil Pressure Drop (6067p).** Energy impact is based on the design coil pressure drop from 25 ft for worst to 15 ft for code, based on total chilled water flow.
- **Boiler Load Sequencing (6075p).** The energy impact is based on the additional standby losses if both boilers are on during heating period use, vs. sequencing the boilers to avoid standby losses from the second boiler when not needed. Standby losses are estimated at 2% of total boiler capacity.
- **Multiple Chiller Flow Reduction (6091p).** The primary savings here is due to reduced pump energy use when only one chiller is required to meet the cooling load. The impact is based on a two chiller plant with a primary / secondary pumping strategy. For the reduced (code) case, the second primary pump is off when cooling load is below 50% design cooling load.
- **Multiple Boiler Flow Reduction (6093p).** Similar to 6091p, the primary pump for the second boiler can be off with the proper controls.
- **Hot Gas Bypass Restriction (6105p).** Based on a temperature bin analysis, in the worst case without staged cooling output, hot gas bypass is expected to increase cooling energy by 40% during part load conditions that are experienced when outside air temperatures are between 65°F and 80°F.
- **Parking Garage Fan Control (6109pAS).** Based on typical associated parking garage sizes, a continuous airflow scenario is compared to one with carbon monoxide control, where the airflow will be relative to the adjacent retail building occupancy schedule.
- **Lavatory Hot Water Temperature Limit (7004)**. The pilot results from the small office were prorated on a service water heating basis to this study.
- **Service Hot Water Heat Trap (7005p)**. The pilot results from the small office were prorated on a service water heating basis to this study.
- **Non-general Light Fixture Control (9029)**. The pilot results were prorated on a lighting power density (LPD) basis to this study.
- **Light Fixture Tandem Wiring (9034)**. The pilot results were prorated on an LPD basis to this study.

3.2 Assigning Lost Savings to the Worst Case

Once the range of potential found conditions for each measure was identified, a sensitivity analysis was performed to determine the potential lost energy cost savings associated with the worst-case condition. This was accomplished using energy simulation of the prototype models or engineering calculation for the code and worst case. The measure name, reference number, identified conditions for each case, and parameters simulated are shown in Table B.1 (office) and Table B.2 (retail) in Appendix B.

The identified code and worst conditions for each of the 96 measures were simulated and the energy cost for the building was determined under each condition. For each identified condition, the annual energy cost increase compared to the code value was determined and normalized to square feet of conditioned building area and, where appropriate, to a different metric quantifying the building system to which the condition applies. For example, an exterior wall insulation measure is normalized to the area of exterior wall to which the condition applies. An occupancy sensor measure is normalized to the floor area controlled by (or required to be controlled by) occupancy sensors. A cooling equipment efficiency measure is normalized to the cooling capacity (tons) that the measure impacts. These normalized metrics are used to prorate the energy impact determined for the prototypes to actual buildings evaluated in the field studies.

4.0 Energy Impact Results & Measure Selection

4.1 Worst-Case Lost Energy Savings

To estimate the energy cost, PNNL used annual average commercial building energy prices for states associated with the region where anticipated field work would be completed, as shown in Table 4.1. The prices are based on Energy Information Administration statistics for 2015.[1]

Table 4.1. Energy Prices Used for Worst-Case Analysis

Climate Zone	Representative State	$/kWh	$/therm
2A	Florida	$0.0950	$1.053
3B	Nevada	$0.0892	$0.835
5A	Iowa	$0.0952	$0.627

4.1.1 A Life-Cycle Perspective: Present Value of Lost Savings

The results from the simulation or calculation provide the annual energy cost impact from the perspective of the first year of building operation. From a codes perspective, the impact on a building related to the life of improvements made as a result of code provisions is important. The value of lost savings for the life of the building or the life of the component that is primarily affected is considered. To account for the time value of money, future savings are discounted using a real discount rate of 3.0% with a factor accounting for escalation of energy prices faster than general inflation. Using a simplified method of projecting life-cycle value of savings, a uniform present value (UPV) factor[2] is applied to the annual savings to reflect the discounted value of savings over the measure life. This approach generally follows the methodology established by the Federal Energy Management Program for federal building energy projects (Lavappa et al. 2017).

This analysis ignores replacement costs and in general uses the life of the components. For example, lighting fixtures may last 40 years and have multiple lamp and ballast replacements, or one can simply look at the 15-year ballast life, as when ballasts or electronics are replaced and an opportunity for higher efficiency technology can be used. A longer life than 30 years could be used for some envelope components; however, standard energy escalation rates are not available past 30 years. The different types of measures are listed in Table 4.2 along with their lifetimes. The UPV factors by life and fuel are shown in Table 4.3. These factors are applied to the annual lost energy cost savings previously calculated to find the long-term savings that could accrue from better adherence to the energy code.

[1] These prices are from the EIA for 2015 commercial retail prices and are listed in the State Energy Data Systems, https://www.eia.gov/state/seds/.
[2] UPV factors are precalculated factors used to project the present value of annually recurring energy costs based on measure life, current DOE discount rates, and projected energy price escalation rates that are variable during the measure life, as determined by DOE’s Energy Information Administration.

Table 4.2. Measure Lives for Simplified Present Value Savings Analysis

Measure Type	Life
HVAC controls	15
Lighting controls	15
Building envelope	30
Light fixture (ballasts)	15
HVAC equipment (gas heat)	15
Service hot water (gas)	15
HVAC equipment (heat pump)	15
Service hot water (electric)	15

Table 4.3. Measure UPV for Simplified Present Value Savings Analysis

Life	UPV Elec	UPV Gas
15	12.81	15.5
18	14.82	18.11
20	16.07	19.76
23	17.8	22.09
30	21.27	26.88
NIST 2017 supplement, FEMP UPV*, 3% discount rate		

4.1.1.1 Present Value of Worst-Case Lost Savings

The measures and the lost energy savings of the worst-case condition compared to code requirements are shown in Table 4.4. For each measure, the potential present lost savings value per thousand square feet of applicable floor area is shown. Where a measure is not applicable in the building type by climate zone "NA" is listed. The table also includes information about which measures were selected for inclusion in the field study. An "x" in the right two columns indicates selection by building type. When the measure is selected for only one climate zone, the zone number is included (e.g., "x,5"). The measure selection process is further described in Section 4.1.2.

Table 4.4. Measures with Lost Savings, Present Value $/1000 ft^2

		Present Value of Lost Energy Cost Savings per 1,000 ft^2						Selected for Field Study	
		Office			Retail				
Measure Number	Measure Name	CZ 2A	CZ 3B	CZ 5A	CZ 2A	CZ 3B	CZ 5A	for Office	for Retail
5012	Roofs shall be insulated to meet CZ requirements	$ 2,873	$ 3,330	$ 4,342	$ 9,526	$11,003	$15,114	x	x
5013	Skylight curbs shall be insulated	$ 26	$ 29	$ 40	$ 45	$ 43	$ 123		
5014	Low slope roofs in CZ 1-3 shall be cool roofs	$ 311	$ 339	NA	$ 707	$ 597	NA	x	x
5018A	Above grade frame walls shall be insulated to meet CZ requirements	$ 1,149	$ 1,259	$ 1,664	$ 2,729	$ 3,209	$ 3,929	x	x
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	$ 606	$ 690	$ 2,618	$ 1,417	$ 1,588	$ 3,731	x	x
5021p	Below grade wall insulation requirements and protection	NA	NA	$ 105	NA	NA	$ 57		

Measure Number	Measure Name	Present Value of Lost Energy Cost Savings per 1,000 ft²						Selected for Field Study	
		Office			Retail			for Office	for Retail
		CZ 2A	CZ 3B	CZ 5A	CZ 2A	CZ 3B	CZ 5A		
5023A	Exterior frame floors shall meet the insulation requirements	$ 181	$ 229	$ 665	NA	NA	NA	x,5	
5023B	Exterior mass floors shall meet the minimum R-value or U-factor by assembly type	$ 111	$ 156	$ 555	NA	NA	NA	x	
5025	Slab-on-grade floors shall meet insulation requirements and be protected	NA	NA	$ 15	NA	NA	$ 78		
5029A	Opaque swing doors shall meet U-factor requirements	$ 1	$ 1	$ 8	$ 4	$ 4	$ 21		
5029B	Opaque rollup doors shall meet U-factor requirements	NA	NA	NA	$ 94	$ 93	$ 136		x
5034	Window-to-wall ratio shall meet maximum limits	$ 1,689	$ 1,807	$ 1,809	$ 2,594	$ 2,838	$ 3,005	x	x
5035	Skylight to roof ratio shall meet maximum limits	$ 467	$ 493	$ 385	$ 1,232	$ 1,314	$ 1,091	x	x
5036	Daylighting control when required	$ 1,214	$ 1,212	$ 1,031	$ 1,629	$ 1,353	$ 1,444	x	x
5038	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	$ 236	$ 216	$ 195	$ 568	$ 472	$ 504	x	x
5042A	Windows shall meet U-factor requirements	$ 324	$ 340	$ 786	$ 448	$ 527	$ 1,274	x	x
5042B	Windows shall meet SHGC requirements	$ 1,275	$ 1,388	$ 714	$ 1,330	$ 1,479	$ 783	x	x
5043A	Skylights shall meet U-factor requirements	$ 281	$ 334	$ 489	$ 593	$ 645	$ 1,262	x	x
5043B	Skylights shall meet SHGC requirements	$ 533	$ 582	$ 267	$ 641	$ 728	$ 237	x	x
5056	Building shall meet continuous air barrier requirements	$ 173	$ 111	$ 842	$ 170	$ 150	$ 659	x,5	x
5063	Recessed lighting shall be sealed, rated and labeled	$ 8	$ 5	$ 27	$ 39	$ 33	$ 157		
5075	Fenestration assemblies shall meet air leakage requirements	$ 229	$ 166	$ 530	$ 103	$ 74	$ 223		
5077	Stair and shaft vent leakage	$ 126	$ 40	$ 140	$ 193	$ 143	$ 367		x,5
5082	Loading dock doors shall be equipped with weather seals	$ (0)	$ -	$ 0	$ 0	$ 0	$ 1		
5083	Building entrances shall be protected with an enclosed vestibule	NA	$ 17	$ 38	NA	$ 374	$ 689	x	x
5089	Fenestration orientation	$ 263	$ 261	$ 509	$ 450	$ 525	$ 1,189	x	x
6004A	Equipment sizing req'mt for packaged AC	$ 2,458	$ 2,713	$ 2,057	$ 2,636	$ 2,997	$ 2,300	x	x

Measure Number	Measure Name	Present Value of Lost Energy Cost Savings per 1,000 ft^2 — Office CZ 2A	Office CZ 3B	Office CZ 5A	Retail CZ 2A	Retail CZ 3B	Retail CZ 5A	Selected for Field Study for Office	Selected for Field Study for Retail
6004B	Equipment sizing requirement for VAV with electric reheat	$ 2,615	$ 2,467	$ 2,418	NA	NA	NA	x	
6005A	Packaged air conditioner efficiency	$ 769	$ 547	$ 330	$ 351	$ 233	$ 130	x	x
6005B	Packaged heat pump efficiency	$ 352	$ 254	$ 206	$ 337	$ 216	$ 129	x	x
6005C	Gas furnace efficiency	$ 14	$ 12	$ 88	$ 98	$ 85	$ 342	x	x
6005D	Boiler efficiency	$ 78	$ 59	$ 266	NA	NA	NA	x	
6005E	WSHP efficiency	$ 1,364	$ 1,132	$ 800	NA	NA	NA	x	
6007A	Air-cooled chiller efficiency	$ 1,212	$ 694	$ 317	NA	NA	NA	x	
6007B	Water-cooled chiller efficiency	$ 961	$ 481	$ 301	NA	NA	NA	x	
6014	Thermostatic control is used for individual zones	$ 54	$ 84	$ 60	$ 497	$ 304	$ 245		
6016	Humidity control device for each humidity system	$ 149	NA	$ 206	$ 527	NA	$ 407		
6017	Heat pump supplementary heat control	$ 26	$ 40	$ 438	$ 84	$ 174	$ 1,326	x,5	x
6018	Thermostat deadband requirement	$ 428	$ 334	$ 341	$ 1,127	$ 802	$ 841	x	x
6019A	Thermostat setback	$ 350	$ 312	$ 327	$ 944	$ 924	$ 1,491	x	x
6019C	Night fan control	$ 2,065	$ 2,228	$ 1,814	$ 1,868	$ 2,033	$ 2,244	x	x
6023	Optimal start controls	$ 51	$ 47	$ 28	$ 227	$ 236	$ 260		x
6025	Damper control when space is unoccupied	NA	NA	$ 49	NA	NA	$ 219		
6026p	Snow and ice-melting system control	NA	$ 216	$ 529	NA	$ 929	$ 2,271	x	x
6029	Demand control ventilation	$ 97	$ 48	$ 129	$ 7	$ 3	$ 9	x	
6030	Energy recovery requirement	$ 109	$ (0)	$ 114	$ 350	$ 124	$ 784		x
6033p	Duct insulation requirement	$ 905	$ 770	$ 258	$ 2,714	$ 2,310	$ 773	x	x
6035	Duct leakage requirement	$ 1,204	$ 929	$ 1,845	$ 1,552	$ 1,334	$ 2,609	x	x
6042A	Hydronic piping insulation requirement CHW	$ (17)	$ (7)	$ (3)	NA	NA	NA		
6042B	Hydronic piping insulation requirement HW	$ 1,407	$ 1,143	$ 774	NA	NA	NA	x	
6045p	Commissioning requirement	$ 128	$ 116	$ 113	$ 246	$ 212	$ 236	x	x
6046A	Fan power limit requirement for package AC and heat pumps	$ 1,223	$ 1,376	$ 1,075	$ 1,306	$ 1,448	$ 1,045	x	x
6046B	Fan power limit requirement for VAV	$ 372	$ 382	$ 284	NA	NA	NA	x	
6051	Outdoor heating shall be radiant and controlled with occupancy sensor	NA	NA	NA	$ 494	$ 495	$ 464		x
6056	Economizer supplies 100% design supply air	$ 286	$ 434	$ 365	$ 141	$ 202	$ 166	x	x

Measure Number	Measure Name	Present Value of Lost Energy Cost Savings per 1,000 ft^2						Selected for Field Study	
		Office			Retail			for Office	for Retail
		CZ 2A	CZ 3B	CZ 5A	CZ 2A	CZ 3B	CZ 5A		
6058	Economizers should have appropriate high-limit shutoff control and be integrated	$ 139	$ 309	$ 194	$ 41	$ 188	$ 76		
6066P	Water economizer capacity meets requirements	$ 350	$ 530	$ 447	NA	NA	NA	x	
6067P	Pre-cooling coils have low pressure drop	$ 17	$ 36	$ 39	NA	NA	NA		
6070	Multi-zone systems shall be VAV and fans with motors ≥threshold hp shall have variable speed, variable pitch axial, or fan demand reduction	$ 1,405	$ 1,519	$ 1,150	NA	NA	NA	x	
6071	Static pressure sensors used to control VAV fans shall be properly placed	$ 464	$ 500	$ 384	NA	NA	NA	x	
6075P	Multiple boiler systems must include sequencing controls	$ 37	$ 31	$ 101	NA	NA	NA		
6082	WSHP shall have a deadband between heat rejection and addition	$ (188)	$ (290)	$ (140)	NA	NA	NA		
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	$ 618	$ 619	$ 580	NA	NA	NA	x	
6090	Hydronic systems > 300 MBH shall reset supply water temp or reduce system flow	$ 163	$ 119	$ 129	NA	NA	NA		
6091P	Multiple chiller shall reduce flow when a chiller is shut down	$ 411	$ 222	$ 238	NA	NA	NA	x	
6093P	Multiple boilers plants shall reduce flow when a boiler is shut down	$ 43	$ 38	$ 123	NA	NA	NA		
6094	Tower fans ≥ 75 hp shall have variable speed control	$ 8	$ 33	$ 14	NA	NA	NA		
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	$ 161	$ 241	$ 307	NA	NA	NA	x	
6105p	Hot gas bypass only allowed with multiple steps of unloading or capacity modulation	$ 28	$ 20	$ 11	$ 33	$ 22	$ 11		
6106AS	Dynamic ventilation reset for MZ systems	$ 730	$ 241	$ 500	NA	NA	NA	x	
6108AS	Single zone VAV	$ 802	$ 1,061	$ 943	$ 663	$ 860	$ 785	x	x
6109PAS	Parking garage fan controls	$ 1,225	$ 1,228	$ 1,150	$ 2,002	$ 2,006	$ 1,879	x	x
6110PAS	Zone Isolation	$ 345	$ 380	$ 376	NA	NA	NA	x	
7002A	Water heater efficiency, gas	$ 14	$ -	$ 12	$ 24	$ 20	$ 18		

Measure Number	Measure Name	Present Value of Lost Energy Cost Savings per 1,000 ft^2						Selected for Field Study	
		Office			Retail			for Office	for Retail
		CZ 2A	CZ 3B	CZ 5A	CZ 2A	CZ 3B	CZ 5A		
7002B	Water heater efficiency, electric	$ 31	$ 31	$ 28	$ 43	$ 43	$ 37		
7004	Outlet temperature of lavatories in public facility rest rooms is limited to 110°F (43°C)	$ 24	$ 19	$ 13	$ 10	$ 8	$ 6		
7005p	SWH heat trap	$ 1	$ 0	$ 0	$ 1	$ 1	$ 1		
7006	SWH pipe insulation - recirculated	$ 325	$ 258	$ 194	$ 745	$ 591	$ 444	x	x
7007	SWH pipe insulation - non-recirculated	$ 2	$ 1	$ 1	$ 3	$ 3	$ 2		
7008	Circulating hot water system pumps and heat trace must have readily-accessible controls to turn them off when not needed	$ 39	$ 31	$ 24	$ 90	$ 72	$ 55		
9003	Manual lighting control	$ 1,499	$ 1,452	$ 1,242	$ 195	$ 189	$ 164	x	
9009	Automatic time switch control	$ 2,974	$ 2,887	$ 2,470	$ 6,295	$ 6,103	$ 5,413	x	x
9011	Occupancy sensor control	$ 422	$ 408	$ 351	$ 377	$ 367	$ 316	x	x
9025	Display lighting control	NA	NA	NA	$ 282	$ 272	$ 236		x
9028	Task lighting control	$ 189	$ 183	$ 157	$ 19	$ 19	$ 16		
9029	Lighting for nonvisual applications shall be controlled separately	NA	NA	NA	$ 395	$ 389	$ 331		x
9031	Exterior lighting control	$ 779	$ 781	$ 733	$ 991	$ 993	$ 931	x	x
9034	Tandem wiring	$ 79	$ 79	$ 66	$ 133	$ 146	$ 119		
9035	Exit sign maximum power	$ 32	$ 31	$ 26	$ 28	$ 29	$ 23		
9037	Interior lighting power allowance	$ 3,637	$ 3,615	$ 3,022	$ 6,588	$ 6,686	$ 5,447	x	x
9047	Additional retail lighting power allowance	NA	NA	NA	$ 3,629	$ 3,609	$ 2,996		x
9048	Exterior lighting power allowance	$ 774	$ 776	$ 726	$ 986	$ 987	$ 925	x	x
9049pAS	Electric feeder and branch circuit maximum voltage drop	$ 26	$ 25	$ 21	$ 40	$ 38	$ 32		
9054AS	Parking garage lighting controls	$ 363	$ 363	$ 340	$ 581	$ 582	$ 546	x	x
9055pAS	Plug load controls	$ 455	$ 456	$ 427	$ 16	$ 16	$ 15		
15007	Optional onsite renewable	$ 436	$ 533	$ 373	$ 868	$ 1,060	$ 741	x	x

CHW = chilled water; HW = heated water; MBH = thousands of British thermal units per hour; MZ = multi-zone; SWH = service water heating; WSHP = water source heat pump.

Figure 4.1 and Figure 4.2 show sample office and retail rankings of measures in climate zone 5A by the present value savings. Measure abbreviations documented in Appendix B are used and measure reference numbers match those in Table 4.4. Only measures with LCC lost savings greater that $200 are included here. The full graphs for all measures and climate zones are included in Appendix C.

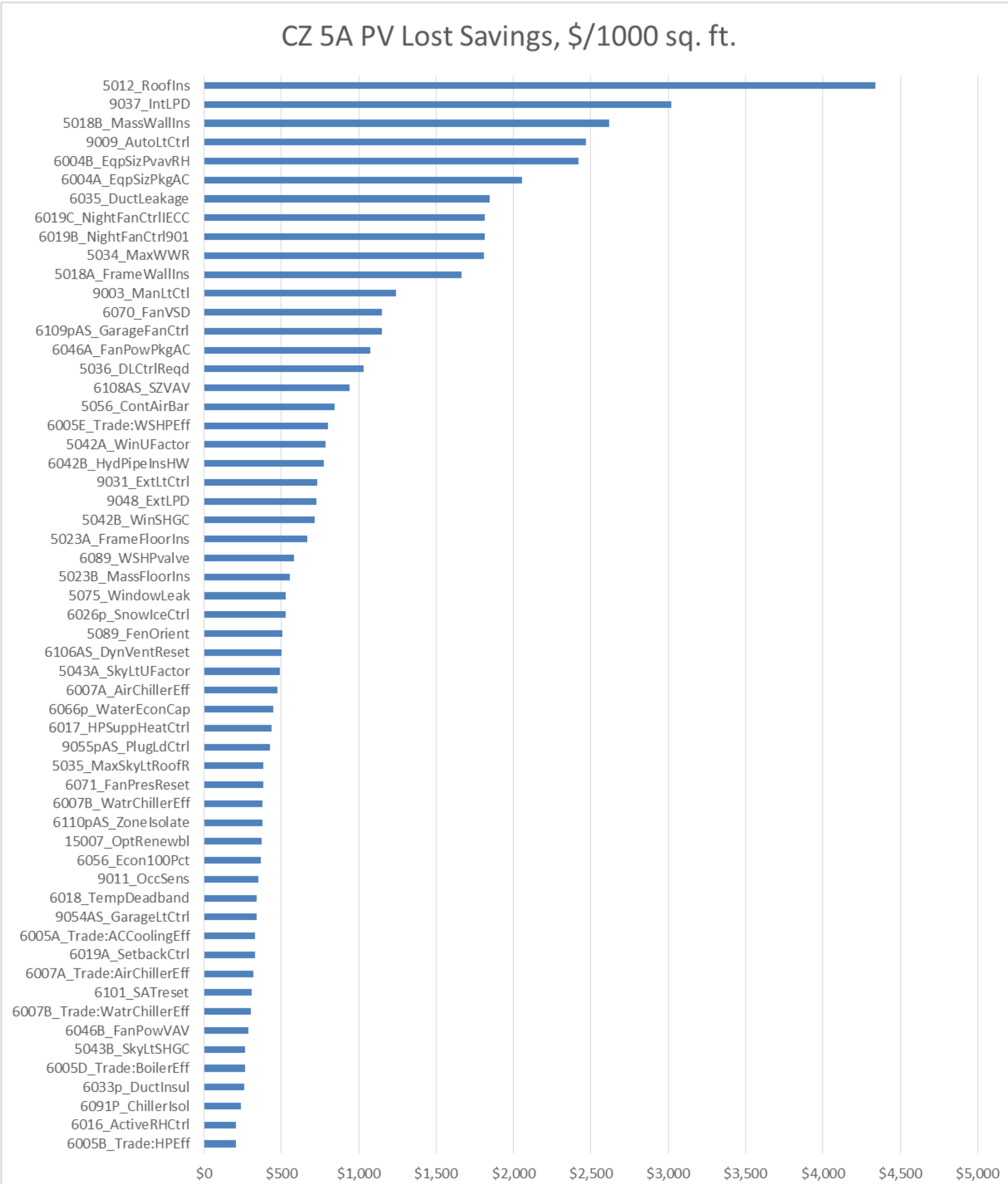

Figure 4.1. Office Worst Case Energy Present Value of Lost Life-Cycle Cost Impact

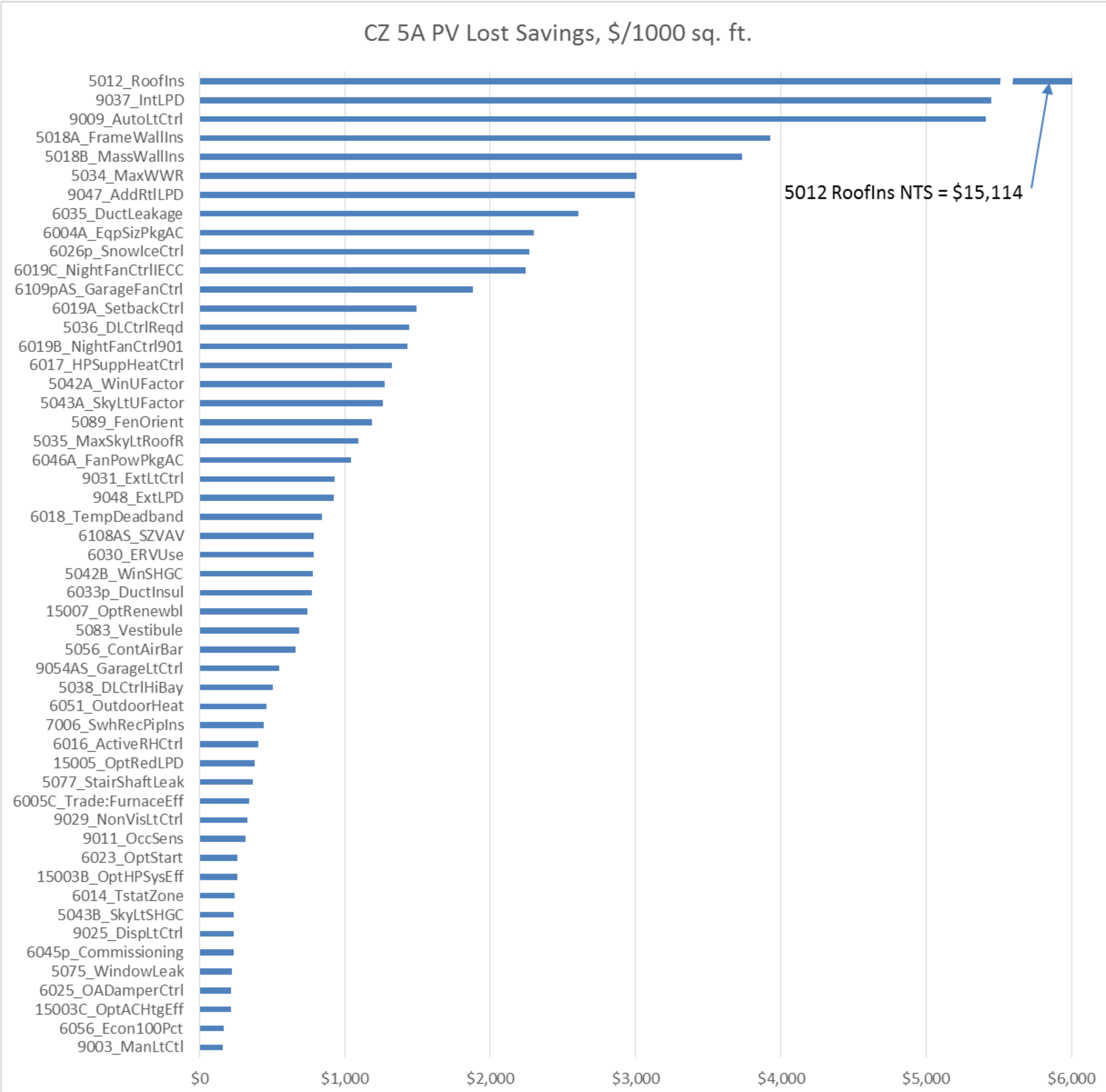

Figure 4.2. Retail Worst Case Energy Present Value of Lost Life-Cycle Cost Impact

4.1.2 Measure Selection for Field Study

Commercial code compliance verification requires a great deal of field time and can be costly. To reduce the cost of verification, the pilot method (Rosenberg et al. 2016) recommended a Pareto principle approach—looking at the measures likely to have the largest impact if compliance is poor. To this end, the measures were identified as discussed in Section 2.0, then evaluated using energy simulation or calculation to identify the largest potential contributors to lost savings. The results of this analysis are shown in a present cost basis in Table 4.4.

Based on these results, the project team selected measures for inclusion in the field study. Generally, measures with a present value lost savings potential greater than $200 were selected. In some cases, a higher cutoff was used where verification was thought to be difficult. In other cases, a lower cutoff was used where there were similar measures that were being inspected or verification was thought to be easier. The count of selected measures by climate zone and building type is shown in Table 4.5.

Table 4.5. Measures Identified and Selected for Field Study

Building Type	Office			Retail		
Climate Zone	2A	3B	5A	2A	3B	5A
Applicable Measures	86	87	90	67	68	71
Selected Measures	55	55	58	46	46	47
Percentage Selected	64%	63%	64%	69%	68%	66%

The results of individual measure selection are shown in Table 4.4, where an X in the selection columns to the right indicates that the measure is included in the next phase of field studies for office and retail. If a measure was selected for only one climate zone, that is shown in the selection columns. The summary of selected measures in Table 4.5 indicates a high percentage of measures were selected for the next phase of field study. The reason was to make sure that any potentially large contributor to lost savings was captured. The purpose of the field study is to further reduce the number of measures that need verification by gathering actual data in four areas:

- What is the actual worst case for each measure discovered in the field? In many cases it may not be as bad as the theoretical worst case that was modeled and that would limit the impact of the measure on lost energy cost savings.
- What is the applicability of each measure in an actual sample of buildings? Measures that rarely occur will have a lesser impact on the total lost savings related to energy codes.
- What is the typical condition for each measure found in the field? Understanding the typical distribution of as-found conditions can allow an expected value of lost savings to be assigned to each measure.
- What is the effort involved in verifying each measure? It may be more beneficial to focus on verifying measures that have a high lost savings per hour of inspection time.

Once that additional information is gathered for a valid sample of instances for each measure, then the expected lost savings relative to the verification cost can be identified. This is discussed further in the pilot study (Rosenberg et al. 2016). Once measures are ranked in this way with more field data, then a much smaller set of measures can be included in the measure list for verification in future evaluations.

4.1.3 Field Study Adjustments

As the field study was launched, several changes were made in the field data collection tool:

- It was determined that only climate zones 2A and 5A would be included in the actual field work, so final measure analysis results for climate zone 3A were not developed.
- Measures 6004A and 6004B were dropped. These measures were based on requirements that HVAC systems not be oversized. The analyzed lost savings were fairly large for these measures due to fan savings on oversized constant volume systems and high minimum box positions on oversized VAV systems. However, there was no way to actually determine what a reasonable "code" system size should be. There is extensive latitude for the designer to consider future internal load growth, change of occupancy, and even higher loads due to climate change. So, after much consideration, it was decided that a code sizing condition cannot readily be determined and the measure was dropped.
- Night fan control measure 6019C was initially modeled separately for ASHRAE 90.1 and IECC for retail to reflect differences in outside air damper requirements. These were consolidated into one measure, as results were very close.
- Thermostat setback was originally one measure, and was split into two – 6019A for heating and 6019B for cooling – to facilitate correct entry of separate setbacks.
- There were several other adjustments in the field tool to clarify exactly what inputs were needed, more clearly define discrete inputs, or allow for metric inputs for special cases.

5.0 Application to Field Study

5.1 Translating Prototype Impact to Field Impact

To convert the found field condition for each measure to lost energy cost savings, mathematical relationships were developed based on the simulations of measure conditions discussed in Section 4.0.

5.1.1 Developing Regressions for Lost Savings Projection

Three types of input for field measures are expected:

- Direct Parameter Input is a case where the parametric values used in the simulation model can be matched with input verified on the plans or in the field. These have two types:
  - Straight parameters – the code required, design, or field parameter matches the simulated parameter, such as U-factor, LPD, or brake horse power limit.
  - Field parameters are adjusted to modeled parameters. There are three general cases:
    - One type of efficiency metric is modeled but another is found in the actual building; for example, cooling coefficient of performance (COP) without fan energy is modeled for packaged equipment, so accommodations are made to adjust energy efficiency ratio (EER) to COP. A similar approach is used to adjust rated AFUE to modeled Et for furnaces or heating seasonal performance factor (HSPF) to COP for heat pumps.
    - R-value is input for duct or pipe insulation, then adjusted to U-factor by adding air surface resistance.
    - Input field takeoff adjusted to match modeled scalar parameters such as input lighting watts and area adjusted to LPD and input of water economizer capacity required and actual transformed to percent of provided capacity.
- Quality Adjusted Direct Parameter Input – use code or calculated input parameter, then adjust input based on quality, e.g., insulation installation quality adjusts the input U-factor.
- Select; user selects from a list of discrete code and field conditions.

Separate regressions were developed for each energy type (gas and electric). In all cases, the regressions were non-interactive and restricted to the measure parameters, so they were simple with one parametric input value and results normalized to a metric in the simulation model. Two types of regression calculations were used:

- First order linear regression was applied for most cases. In almost all cases, there were at least three data points (worst, code, and best), so the validity of linearity could be observed.
- Second order regression is used when the curve fit was non-linear, indicated by a linear regression with a coefficient of determination (R^2) lower than 0.98. This primarily applied to floor, roof and door insulation, fenestration factors, cool roof, air barrier, LPD, and setback control temperature. For many of the second order regressions, a fourth “below code” case between worst and code was added to improve the curve accuracy.

5.1.2 Applying Regression Results to Field Buildings

Section 4.0 presents the lost energy cost savings from code to worst as determined from the sensitivity analysis. Using these results and the developed regressions, requirements and actual found conditions can be documented for a building and lost energy cost savings can then be attributed to a similar building based on the quantity of each metric to which a given condition applies. Two approaches were used to capture the field condition where inputs are either parametric or discrete.

5.1.2.1 Parametric Field Inputs

For most measures, an infinite number of conditions could occur between the best and worst conditions. An example is LPD. While it would be impossible to simulate every LPD that may be found in a building, by capturing the endpoints (range) of possibilities and some intermediate conditions, application of a regression formula can be used when conditions in the field do not exactly correspond to a simulated condition. Other examples include envelope assembly U-factors, system efficiencies, and thermostat setback/setup. Direct parameters can be input for the required (or performance), plan takeoff, and as-found conditions. Good examples of this type of input are building envelope assembly U-factor or equipment efficiencies. In some cases, particularly for insulation, a discrete installation quality condition is selected and a quality multiplier is applied to the parametric input.

5.1.2.2 Discrete Field Inputs

About 45% of the measures are better captured with a discrete condition input rather than a scalar parameter. Examples include vestibules, demand controlled ventilation, control of outdoor heat, and commissioning quality. Some measures that could be characterized with a parameter are set up as discrete inputs to facilitate field data capture where the exact parameter was difficult to obtain. A prime example is air barrier evaluation. While the actual tested envelope leakage seems a reasonable input, that value is not available unless envelope testing is completed, which is not a code requirement. If not, then air barrier results must be determined by qualitative assessment, so a discrete range of options that covers both inspections and testing was appropriate. To accommodate these measures, each discrete condition is assigned a point rating. To aid in that process, each condition was assigned an energy cost rating (ECR) from +10 for the best condition (exceeding code) to -10 for the worst condition (below code). Conditions meeting code were assigned a rating of 0. Conditions in between were scored by the ratio of their cost savings or loss compared to the savings and loss of the best and worst conditions.

$$ECR_{above} = 10 \times \frac{(condition\ cost - baseline\ cost)}{(best\ condition\ cost - baseline\ cost)} \quad (5.1)$$

$$ECR_{below} = 10 \times \frac{(baseline\ cost - condition\ cost)}{(worst\ condition\ cost - baseline\ cost)} \quad (5.2)$$

Where:

ECR_{above} = energy cost rating of conditions above code
ECR_{below} = energy cost rating of conditions below code
Condition cost = annual utility cost of a building given a single measure not equal to code
Baseline cost = annual utility cost of a building given all measures equal to code

5.2 Data Collection Forms

To ensure field data will be collected consistently and all needed information is collected, forms were given to field verification teams to complete for each building and training was provided. The intent is to make the results as consistent and unbiased as possible by determining conditions for each measure in an objective and repeatable way. In general, the forms collect descriptive information about the building (size, location, occupancy type, area, etc.) and specific information regarding the conditions encountered for each code measure. In addition, the field team was asked to record the amount of time spent verifying each measure during plan review and in the field. Time for general activities (meeting with the owner's representatives, collecting plans, travel to site, etc.) was also collected. Parts of a sample data collection form are shown in Appendix D. The forms include the following data fields to be completed by the field verification team.

General Building Information

The following fields are completed for each building in the field study.

Conditioned Floor Area:	Conditioned floor area
Building type:	Office or Retail
ASHRAE Climate Zone:	2A or 5A
Number of Floors:	Number of floors, both above and below grade
Scope	Full building; Part of building; Shell/fill; Second infill
Option Path:	IECC C406 extra efficiency option used
Compliance Path:	Prescriptive; Envelope Tradeoff; Performance (Section C407).
Building Identifier:	A unique number given to each building to anonymize the results.
City/State:	City and state location of the audited building.
Actual Code:	Specific energy code project was permitted under.
HVAC System Type:	Identify main system type serving the building.
Occupancy:	For mixed occupancies, percent of floor area for main and other types is noted.
General Comments:	Any special comments the auditor thinks might be pertinent.
Equipment in building:	Check off which of 8 types of HVAC equipment are in the building.
Time Accounting:	The contractor is asked to record the time spent for the categories of general activities, travel and indirect, envelope, lighting power, lighting controls, mechanical and SWH equipment, and mechanical and SWH controls.

Measure Specific Information

The following fields are collected for each of the 96 measures that were applicable to each building.

Applies to Building:	Indicate whether specific measure applies to the building.
Factor Units:	Where more than one type of unit could apply, select; e.g., EER vs. SEER.
Plan:	Indicate whether compliance was verified in building plans.

Condition or Input Factor:	Select the measure condition closest to that observed from pull down menu or input the condition parameter. These are input separately for the code requirement; plan takeoff; and as-found condition. Examples include EER, U-factor, LPD, window-to-wall ratio.
Field Verification Level:	Indicate whether compliance was verified by actual in-field inspection; inferred or unknown.
Applicable Quantity Affected:	The quantity of systems or components to which the specific condition applies. Examples include cfm, tons, MBH, ft^2, watts, etc.
Measure Specific Comments:	Any comments pertaining to the measure, particularly, variations from the condition chosen from the pull down menu.
Measure Time:	Auditor enters the estimated time in hours spent verifying the measure during plan review.
Surveyed Floor Area:	If less or more than the conditioned area is surveyed for this measure, overwrite the default building value.

5.2.1 Cost of Compliance Verification

One goal of the field work is to further test a methodology to identify measures that have the highest potential of lost savings for the effort required to find their compliance condition. During the plan reviews and site inspections, the reviewer will identify hours spent specifically verifying individual measures. This allows the lost savings cost to be calculated in dollars per verification hour. In other words, what possible savings could occur through better compliance per hour spent on the verification process based on this field study?

6.0 Conclusions

The following conclusions can be made at this phase of the overall investigation into energy code compliance.

- About two-thirds of energy code measures have worst-case potential LCC savings greater than $200 and are included for phase two field investigation.
- Both parametric and discrete inputs are required to cover the range of measures included.
- Simple first and second order regressions based on simulations allow a reasonable estimate of lost savings to be made when measures do not meet code or performance requirements.

Table 6.1 shows the top 20 measures based on including the top 10 measures (bolded) from each case of building type and climate zone combination. They are then ranked by the average of case rankings. This ranking is highly preliminary, as it does not include the important information that will come from the field studies as discussed in Section 4.1.2: actual worst case in the field, actual field applicability, typical as found field condition, and effort required to verify each measure's condition.

Table 6.1. Top 20 Measures Based on Worst Case Analysis*

Measure ID	Measure Name	**Present Value of Lost Energy Cost Savings per 1,000 ft^2** Office 2A	Office 3B	Office 5A	Retail 2A	Retail 3B	Retail 5A	Average Impact
5012	Roofs insulated per CZ requirements	**$2,873**	**$3,330**	**$4,342**	**$9,526**	**$11,003**	**$15,114**	$7,698
9037	Interior lighting power allowance	**$3,637**	**$3,615**	**$3,022**	**$6,588**	**$6,686**	**$5,447**	$4,832
9009	Automatic time switch control	**$2,974**	**$2,887**	**$2,470**	**$6,295**	**$6,103**	**$5,413**	$4,357
9047	Additional retail lighting power allowance	NA	NA	NA	**$3,629**	**$3,609**	**$2,996**	$3,411
5034	Window-to-wall ratio shall meet maximum limits	**$1,689**	**$1,807**	**$1,809**	**$2,594**	**$2,838**	**$3,005**	$2,290
6019C	Night fan control	**$2,065**	**$2,228**	**$1,814**	**$1,868**	**$2,033**	**$2,244**	$2,042
5018A	Frame walls insulated per CZ req'mt	$1,149	**$1,259**	**$1,664**	**$2,729**	**$3,209**	**$3,929**	$2,323
6070	Multi-zone systems shall be VAV with VSD motors where required	**$1,405**	**$1,519**	**$1,150**	NA	NA	NA	$1,358
6109pAS	Parking garage fan controls	$1,225	$1,228	$1,150	**$2,002**	**$2,006**	$1,879	$1,582
5018B	Above grade mass walls insulated per CZ and density requirements	$606	$690	**$2,618**	$1,417	**$1,588**	**$3,731**	$1,775
6035	Exterior duct leakage requirement	$1,204	$929	**$1,845**	$1,552	$1,334	**$2,609**	$1,579
6042B	Hydronic piping insulation	**$1,407**	$1,143	$774	NA	NA	NA	$1,108
5036	Daylighting control when required	$1,214	$1,212	$1,031	**$1,629**	$1,353	$1,444	$1,314
6046A	Fan power limit for unitary AC	$1,223	**$1,376**	$1,075	$1,306	$1,448	$1,045	$1,245
6005E	WSHP efficiency	**$1,364**	$1,132	$800	NA	NA	NA	$1,099
5042B	Windows meet SHGC requirements	**$1,275**	**$1,388**	$714	$1,330	$1,479	$783	$1,162
6033p	Exterior duct insulation requirement	$905	$770	$258	**$2,714**	**$2,310**	$773	$1,288
6026p	Snow and ice-melting system control	NA	$216	$529	NA	$929	**$2,271**	$986
9003	Manual lighting control	**$1,499**	**$1,452**	**$1,242**	$195	$189	$164	$790
6019A	Thermostat setback, heating	$350	$312	$327	$944	$924	$1,491	$725

* Equipment sizing measures were eliminated from the field study, as discussed in Section 4.1.3.
VSD = variable speed drive.

7.0 References

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Appendix A

2012 IECC Code Measures and Associated Requirements

Appendix A

Code Measures and Associated Requirements

Table A.1. Code Requirements and Measures from the 2012 IECC

Standard 90.1-2013 measures are shown with red section numbers

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
Envelope			
5012	Roofs shall be insulated to meet CZ requirements	C402.2.1	Roofs shall meet minimum R-value or U-factor by assembly type.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.1.1	Blown-in or sprayed roof/ceiling insulation shall have thickness markers.
		C303.1.1.1	The thickness markers shall be affixed to the trusses or joists.
		C303.1.1.1	Markers shall face the attic access opening.
		C303.1.1.1	Spray foam thickness and installed R shall be on the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C402.2	Multiple layers of continuous insulation must be overlapped properly.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
5013	Skylight curbs shall be insulated	C402.2.1	Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.
5014	Low slope roofs in CZ 1-3 shall be cool roofs	C402.2.1.1	Low-sloped roofs in climate zones 1-3 shall be cool roofs (various exceptions).
5018A	Above grade frame walls shall be insulated to meet CZ requirements	C402.2.3	Above grade walls shall meet minimum R-value or U-factor by assembly type.
		C402.2	Multiple layers of continuous insulation must be overlapped properly.
		C402.2	If manufacturer's instructions for continuous insulation do not address multiple layers, edges shall be staggered.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	C402.2.3	Above grade walls shall meet minimum R-value or U-factor by assembly type.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
		C402.2	Multiple layers of continuous insulation must be overlapped properly.
		C402.2	If manufacturer's instructions for continuous insulation do not address multiple layers, edges shall be staggered.
		C402.2.3	Mass walls meet specified pound per square foot of surface area and may require a specified density.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
5021p	Below grade walls shall meet insulation requirements and be protected	C402.2.4	Below grade walls shall meet minimum R-value or C-value.
		C402.2.4	Below-grade wall insulation shall extend to the level of the floor or 10' whichever is less.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
		C303.2.1	Exterior insulation for SOG and basement walls shall have ridged protective covering extending at least 6" below grade.
5023	Exterior floors shall meet the minimum R-value or U-factor by assembly type	C402.2.5	Exterior floors shall meet minimum R-value or U-factor by assembly type.
		C402.2.5	Mass floors must have a specified pound per square foot of wall area and may require a specified density.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
5025	Slab-on-grade floors shall meet insulation requirements and be protected	C402.2.6	Slab-on-grade floors shall meet minimum R-value or F-factor requirements.
		C402.2.6	Slab-on-grade insulation shall be positioned and of the appropriate length, by assembly type.
		C402.2.6	Exterior slab-on-grade insulation extending horizontally shall be protected by soil or paving.
		C303.1.1	Insulation shall have an R-value identification mark.
		C303.1.1	Blown or sprayed insulation shall have a certification letter.
		C303.1.1	Spray polyurethane foam shall have a certification letter.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
		C303.1.1	The insulation installer shall sign, date, and post the certification.
		C303.1.2	Manufacturer's R-value marks must be observable.
		C303.1.4	R-value of insulation shall be determined in accordance with FTC rules.
		C303.2.1	Exterior insulation for SOG and basement walls shall have ridged protective covering extending at least 6" below grade.
5029	Opaque doors shall meet U-factor requirements	C402.2.7	Opaque doors shall meet maximum U-factor requirements by door type.
5034	Window-to-wall ratio shall meet maximum limits	C402.3.1	Vertical fenestration area shall not exceed 30% of gross above-grade wall area.
5035	Skylight area shall meet maximum limits	C402.3.1	Skylight area shall not exceed 3% of gross roof area.
		C402.3.1.2	Up to 5% of roof area in skylights is allowed if daylighting controls are provided.
9014A	Automatic daylighting controls when required	C402.3.1.1	In climate zones 1-6, up to 40% of gross above-grade wall area is allowed for vertical fenestration if >50% floor is daylit and daylighting controls are provided.
		C405.2.2.3	Daylight zone lights shall be controlled independently of general area lighting.
		C402.3.2.1	Lighting in daylight zones from skylights shall be controlled by multilevel lighting controls.
		C405.2.2.3	Daylight control zones shall be smaller than 2,500 square feet.
		C405.2.2.3	Contiguous daylight zones by vertical fenestration may be controlled by a single controlling device.
		C405.2.2.3	Daylight zones under skylights shall be controlled separately from daylight zones adjacent to vertical fenestration.
		C405.2.2.3.1	Manual controls shall be installed in daylight zones unless automatic controls are installed.
		C405.2.2.3.2	Set-point and other controls for calibrating the lighting control device shall be readily accessible.
		C405.2.2.3.2	Daylighting controls shall be continuous dimming or step dimming.
		C405.2.2.3.2	Daylighting controls shall provide at least two control channels per zone and a minimum of three controls steps.
		C405.2.2.3.3	When multi-level controls are required, general lighting in daylight zones shall be controlled by multi-level lighting controls.
		C405.2.2.3.3	When daylit illuminance is greater than rated illuminance of general lighting, the power of the general lighting shall be reduced.
9014B	Total daylight zone under skylights at least 1/2 of floor area	C402.3.2	In large spaces >10,000 ft2 with >15' ceilings of certain space types, the total daylight zone under skylights shall be no less than the half the floor area.
		C402.3.2	In large spaces >10,000 ft2 with >15' ceilings of certain space types, shall have a minimum skylight area equal to not less than 3% of roof with a VT of at least 0.40 or an effective aperture of at least 1%.
		C402.3.2.2	Skylights in some spaces must have skylights with diffuse lighting characteristics.
		C405.2.2.3	Daylight zone lights shall be controlled independently of general area lighting.

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		C402.3.2.1	Lighting in daylight zones from skylights shall be controlled by multilevel lighting controls.
		C405.2.2.3	Daylight control zones shall be smaller than 2,500 square feet.
		C405.2.2.3	Contiguous daylight zones by vertical fenestration may be controlled by a single controlling device.
		C405.2.2.3	Daylight zones under skylights shall be controlled separately from daylight zones adjacent to vertical fenestration.
		C405.2.2.3.1	Manual controls shall be installed in daylight zones unless automatic controls are installed.
		C405.2.2.3.2	Set-point and other controls for calibrating the lighting control device shall be readily accessible.
		C405.2.2.3.2	Daylighting controls shall be continuous dimming or step dimming.
		C405.2.2.3.2	Daylighting controls shall provide at least two control channels per zone and a minimum of three controls steps.
		C405.2.2.3.3	When multi-level controls are required, general lighting in daylight zones shall be controlled by multi-level lighting controls.
		C405.2.2.3.3	When daylit illuminance is greater than rated illuminance of general lighting, the power of the general lighting shall be reduced.
5042A	Windows shall meet U-factor requirements	C402.3.3	Vertical fenestration shall meet maximum U-factor and SHGC requirements.
		C402.3.4	Area-weighted averages of glazing U-factor are allowed.
		C303.1.3	U-factors of fenestration shall be NFRC rated.
		C303.1.3	Products without an NFRC U-factor rating shall use default values.
5042B	Windows shall meet SHGC requirements	C402.3.3	Vertical fenestration shall meet maximum U-factor and SHGC requirements.
		C402.3.3	The window projection factor shall be determined as the ratio of the length of the overhang horizontally (from the face of the window) divided by the height of the overhang vertically (from the bottom of the window).
		C402.3.3.1	Vertical fenestration SHGC is to be adjusted for projection factor.
		C402.3.3.2	For climate zones 1-3, vertical fenestration entirely located more than 6 feet above the finished floor is allowed a height SHGC.
		C402.3.3.5	VT/SHGC for dynamic glazing shall be determined using the maximum VT and maximum SHGC.
		C402.3.3.5	Dynamic glazing should be considered separately from other glazing and not area-weighted averaged with other glazing.
		C303.1.3	SHGC and VT shall be NFRC rated.
		C303.1.3	Products without an NFRC SHGC or VT shall use default values.
		C402.3.3.5	SHGC for dynamic glazing is the manufacturer's lowest-rated SHGC.
5043A	Skylights shall meet U-factor requirements	C402.3.3	Skylights shall meet maximum U-factor and SHGC requirements.
		C402.3.3.4	Skylights above daylight zones with automatic controls may have higher U-factors.
		C303.1.3	U-factors of fenestration shall be NFRC rated.

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		C303.1.3	Products without an NFRC U-factor rating shall use default values.
5043B	Skylights shall meet SHGC requirements	C402.3.3	Skylights shall meet maximum U-factor and SHGC requirements.
		C402.3.3.3	In climate Zones 1 through 6, skylights shall be permitted a maximum SHGC of 0.60 where located above daylight zones provided with automated daylighting controls.
		C303.1.3	U-factors of fenestration shall be NFRC rated.
		C303.1.3	SHGC and VT shall be NFRC rated.
		C303.1.3	Products without an NFRC SHGC or VT shall use default values.
		C402.3.3.5	SHGC for dynamic glazing is the manufacturer's lowest-rated SHGC.
5056	Building shall meet continuous air barrier requirements	C402.4.1	A continuous air barrier shall be provided throughout the building thermal envelope.
		C402.4.1.1	Air barriers shall be continuous across all assemblies in the thermal envelope of the building and across the joints and assemblies.
		C402.4.1.1	Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials.
		C402.4.1.1	Air barrier penetrations shall be sealed.
		C402.4.1.1	Joints and seals should be installed securely to resist positive and negative pressure.
		C402.4.1.1	The air barrier must be maintained around penetrations.
		C402.4.2	Air barrier penetrations shall be caulked, gasketed, or sealed.
		C402.4.2	Joints and seams shall be caulked, gasketed, or sealed.
		C402.4.2	Sealing materials shall be appropriate to the construction materials being sealed.
		C402.4.2	Joints and seals should be installed securely to resist positive and negative pressure.
		C402.4.1.2	The continuous air barrier must comply with one of three options - materials, assemblies, or testing.
		C402.4.1.2.1	Materials with low air permeability are acceptable air barriers.
		C402.4.1.2.1	Fifteen specific low permeability materials are listed.
		C402.4.1.2.2	Assemblies with low air leakage are acceptable as air barriers.
		C402.4.1.2.2	Coated concrete masonry walls and Portland cement/sand purge, stucco or plaster are acceptable as air barriers.
		C402.4.1.2.3	A completed building with a low tested air leakage rate is acceptable for air barrier requirements.
5063	Recessed lighting shall be sealed, rated and labeled	C402.4.1.1	Recessed lighting fixtures shall be sealed and IC-rated and labeled.
		C402.4.8	Recessed lighting shall be sealed.
		C402.4.8	Recessed luminaires shall be IC-rated and labelled.
		C402.4.8	Recessed luminaires shall be sealed between housing and wall or ceiling covering.
5075	Fenestration assemblies shall meet air leakage requirements	C402.4.3	The air leakage of fenestration assemblies shall meet maximum values by assembly type.
		C402.4.3	Fenestration air leakage testing shall use the applicable reference standard and be done by an accredited independent testing laboratory.

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5077	Building openings to shafts, chutes, stairways, and elevator lobbies shall meet air leakage requirements	C402.4.4	Doors and access openings to shafts, chutes, stairways, and elevator lobbies shall be labeled for leakage or gasketed, weather-stripped or sealed.
5079	Stairway and shaft vents shall be provided with Class I motorized dampers	C402.4.5.1 C402.4.5 C402.4.5.1	Stairway and shaft vents shall be provided with Class I motorized dampers Stairway enclosures and elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be provided with dampers Stairway and shaft vent dampers shall be installed with automatic controls and normally closed.
5082	Loading dock doors shall be equipped with weather seals	C402.4.6	Cargo doors and loading dock doors shall be equipped with weather seals
5083	Building entrances shall be protected with an enclosed vestibule	C402.4.7 C402.4.7 C402.4.7	All building entrances shall be protected with an enclosed vestibule Vestibules shall be designed so that it is not necessary for the interior and exterior doors to open at the same time. The installation of revolving doors shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.
5089	Fenestration orientation	90.1: 5.5.4.5	The area of vertical fenestration on the south must be greater than the area of vertical fenestration on the east and on the west.
Mechanical Systems			
6004	Equipment sizing requirement	C403.2.2 C403.2.1 C302.1	Heating and cooling equipment and systems shall not be oversized. Design loads must be calculated in accordance with ANSI/ASHRAE/ACCA Standard 183 or approved alternative. Interior design temperatures are set by this code.
6005A	Packaged air conditioner efficiency	C403.2.3 C403.2.3	Heating and cooling equipment shall meet minimum efficiency requirements by equipment type. If the designer combines components from different manufacturers, it is the designer's responsibility to show that equipment meets requirements.
6005B	Packaged heat pump efficiency	C403.2.3 C403.2.3	Heating and cooling equipment shall meet minimum efficiency requirements by equipment type. If the designer combines components from different manufacturers, it is the designer's responsibility to show that equipment meets requirements.
6005C	Gas furnace efficiency	C403.2.3	Heating and cooling equipment shall meet minimum efficiency requirements by equipment type.
6005D	Boiler efficiency	C403.2.3	Heating and cooling equipment shall meet minimum efficiency requirements by equipment type.
6005E	Water Source Heat Pump Efficiency	C403.2.3	Heating and cooling equipment shall meet minimum efficiency requirements by equipment type.
6007	Chiller efficiency	C403.2.3	Equipment efficiency shall be verified through an approved verification program or if no program exists, by information supplied by manufacturer. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements.

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			Water-cooled centrifugal chilling packages not designed for operation at AHRI Standard 550/590 test conditions shall have maximum full-load KW-ton and NPLV ratings adjusted. The adjustments shall only be used for centrifugal chillers that meet 3 specified design ranges. Positive displacement chilling packages with a leaving temperature greater than 32°F shall meet minimum efficiency requirements.
6014	Thermostatic control is used for individual zones	C403.2.4 C403.2.4.1	Heating and cooling systems shall have thermostatic controls. Individual heating and cooling zones shall have individual thermostatic controls.
6016	Humidity control device for each humidity system	C403.2.4.1	At least one humidity control device shall be supplied for each humidity control system.
6017	Heat pump supplementary heat control	C403.2.4.1.1	Heat pumps with supplementary heat shall have controls that lock out resistance heat when heat pump can meet heating load; e.g. OA lockout <= 40F or ramped startup setpoint.
6018	Thermostat dead band requirement	C403.2.4.2	Thermostatic controls shall have a 5°F dead band.
6019	Thermostat setback and start/stop controls	C403.2.4.3 C403.2.4.3.1 C403.2.4.3.2 C403.2.4.3.2	Each zone shall have thermostatic setback controls. Thermostatic setback controls shall have capability to set back or operate system to maintained higher or lower setpoints. Thermostatic setback controls shall start & stop system on seven daily schedules and retain programming during power loss. Thermostatic setback controls shall have a manual override.
6023	Optimal start controls	C403.2.4.3.3 C403.2.4.3.3	HVAC systems shall have optimal start controls. Automatic start controls shall adjust the HVAC start time to bring spaces to desired occupied temperature immediately prior to scheduled occupancy.
6025	Damper control when space is unoccupied	C403.2.4.4 C403.2.5 C402.4.5.2	Outdoor air supply and exhaust ducts shall have motorized dampers. Mechanical ventilation systems shall have the capability to reduce outdoor air supply to the minimum required in Chapter 4 of the IMC. Outdoor air supply and exhaust openings shall be provided with Class IA motorized dampers.
6026	Snow and ice-melting system control	C403.2.4.5	Snow and ice-melting systems shall have automatic controls.
6029	Demand control ventilation	C403.2.5.1	Demand control ventilation is required for spaces > 500 sf with >= 25 p/sf. Ex: ERV; des OA < 1200 cfm; or process.
6030	Energy recovery requirement	C403.2.6 C403.2.6 C403.2.6	Fan systems with large supply airflow and OA rates (Table C403.2.6) shall include an energy recovery system. The energy recovery system shall provide a change in the enthalpy of the outdoor air supply of not less than 50 percent of the difference between outdoor air and return air. Energy recovery systems shall have bypass and controls to work with economizers, where required.
6033	Duct insulation requirement	C403.2.7	Supply and return air ducts and plenums shall be insulated.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
		C403.2.7.1.2	Duct and plenums operating at medium pressure shall be insulated and sealed.
6035	Duct leakage requirement	C403.2.7.1.1	Longitudinal and transverse joints, seams, and connections in low-pressure ducts shall be fastened and sealed.
		C403.2.7.1.1	Pressure classification of duct systems shall be marked on construction documents in accordance with the IMC.
		C403.2.7.1.2	Duct and plenums operating at medium pressure shall be insulated and sealed.
		C403.2.7.1.2	Pressure classification of duct systems shall be marked on construction documents in accordance with the IMC.
		C403.2.7.1.3	High-pressure ducts shall be insulated and sealed.
		C403.2.7.1.3	Duct and plenums shall be leak tested.
		C403.2.7.1.3	Documentation that at least 25% of duct area has been leak tested shall be furnished by the designer.
		C403.2.8.1	Adhesive tape is not permitted as a duct seal.
6042	Piping insulation Requirement	C403.2.8	Piping in a heating or cooling system shall be insulated.
		C403.2.8.1	Piping insulation exposed to weather shall be protected.
6045	Commissioning requirement	C403.2.9	Mechanical systems shall be commissioned.
		C408.2	Registered design professional shall provide evidence of mechanical systems commissioning.
		C408.2.1	A commissioning plan must be developed.
		C408.2.2	HVAC systems shall be balanced.
		C408.2.2.1	Supply air outlets and zone terminal devices shall have means for air balancing.
		C408.2.2.2	Hydronic heating and cooling coils shall have means for balancing.
		C408.2.3.1	Equipment functional performance testing is required.
		C408.2.3.2	HVAC control system testing is required.
		C408.2.3.3	Air economizer functional testing is required.
		C408.2.4	A preliminary commissioning report is required.
		C408.2.4.1	The building owner must acknowledge receipt of the preliminary commissioning report.
		C408.2.5.2	Operating and maintenance manuals shall be provided.
		C303.3	Maintenance instructions shall be furnished.
		C303.3	Regular maintenance actions shall be on an accessible label.
		C303.3	The label shall refer to the maintenance manual.
		C408.2.5.3	A written report on testing and balancing is required.
		C408.2.5.4	A final commissioning report is required.
		C408.3.1	Lighting control hardware and software shall be calibrated, adjusted, and in proper working condition.
6046	Fan power limit requirement	C403.2.10	HVAC systems with total fan system motor nameplate hp greater than 5 hp shall be properly sized.
		C403.2.10.1	Fan system motor nameplate hp or fan system bhp shall be limited.
		C403.2.10.1	Single zone VAV systems shall comply with constant volume fan power limitations.
		C403.2.10.2	The fan motor shall be no larger than the first available motor size greater than the bhp.
		C403.2.10.2	The bhp shall be indicated on design documents.
6051	Outdoor heating shall be radiant	C403.2.11	Radiant systems must be used for outdoor heating.
		C403.2.11	Outdoor heating systems shall be controlled to turn it off when no occupants are present.

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6056	Economizer supplies 100% design supply air	C403.3.1	Cooling systems with fans shall include an air or water economizer.
		C403.3.1.1	Air economizers shall comply with a number of requirements.
		C403.3.1.1.1	Air economizer systems must be capable of providing 100% of design supply air as outdoor air for cooling.
		C403.3.1.1.4	Economizer system shall be capable of relieving excess air (with motorized damper if required under C403.2.4.4).
		C403.3.1.1.4	Relief air outlets shall be located to avoid recirculation.
		C403.4.1	Economizers in complex systems shall be controlled.
6058	Economizers should have appropriate high-limit shutoff control and sequence with mechanical cooling	C403.3.1.1.2	Economizer dampers must be capable of being sequenced with mechanical cooling. Modulating OA and Return dampers are required.
		C403.3.1.1	Air economizers shall comply with a number of requirements.
		C403.3.1.1.3	Air economizers shall be capable of reducing outdoor air intake to the minimum outdoor air quantity when economizer is not needed.
		C403.3.1.1.3	Economizers should have appropriate high-limit shutoff control type.
		C403.3.1.1.3	Economizers should have appropriate high-limit shutoff control settings.
		C403.4.1	Economizers in complex systems shall be controlled.
		C403.4.1.3	Economizers shall be integrated with mechanical cooling systems.
		C403.4.1.4	Economizer operation shall not increase building heating energy use during normal operation.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6066	Water economizer capacity meets requirements	C403.4.1.1	Water economizers shall be capable of providing 100% of cooling load at specified temperature and humidity.
6067P	Pre-cooling coils have low pressure drop	C403.4.1.2	Precooling coils and water-to-water heat exchangers in water economizer systems shall have a low pressure drop.
6070	Multi-zone systems shall be VAV and fans with motors ≥ 7.5 hp shall have variable speed, variable pitch axial, or fan demand reduction	C403.4.2	VAV fans with motors 7.5 hp or larger shall have variable speed, variable pitch axial, or fan demand reduction.
		C403.4.5	Supply air systems serving multiple zones shall be VAV systems.
		C403.4.5.1	Single duct VAV systems shall have terminal units that reduce primary supply air before reheating or recooling occurs.
6071	Static pressure sensors used to control VAV fans shall be properly placed	C403.4.2.1	Static pressure sensors used to control VAV fans shall be properly placed.
		C403.4.2.1	One sensor must be installed in each major branch downstream of a major duct split.
		C403.4.2.2	Systems with DDC of individual zone boxes must have static pressure set point reset.

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6074	Reduce hydronic overlapping heating and cooling -- Dropped as rare and difficult to analyze	C403.4.3	Heating of previously cooled fluids and cooling of previously heated fluids shall be limited.
		C403.4.3.1	Common return systems for both hot and chilled water are prohibited.
		C403.4.3.2	Common distribution systems for both heated and chilled water must have a dead band between change-over.
		C403.4.3.2	Common distribution systems for both heated and chilled water must have controls to allow operation in one mode for at least 4 hours before changing over.
		C403.4.3.2	Common distribution systems for both heated and chilled water must have controls that allow heating and cooling temps at the changeover point of no more than 30°F.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6075	Multiple boiler systems must include sequencing controls	C403.4.3	Multiple boiler systems must include sequencing controls.
		C403.4.3	Large boilers must include multistage or modulating burners.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6082	WSHP shall have a dead band between heat rejection and addition	C403.4.3.3.1	Hydronic heat pumps connected to a common loop shall have a dead band between initiation of heat rejection and heat addition.
		C403.4.3.3.2.1	Closed circuit cooling towers shall have an automatic valve or positive closure dampers to bypass the cooling tower.
		C403.4.3.3.2.1	Open circuit cooling towers shall have an automatic valve to bypass the cooling tower.
		C403.4.3.3.2.1	Cooling towers used in conjunction with a separate heat exchanger in a heat pump loop shall control heat loss by shutting down the circulation pump.
		C403.4.3.3.2.2	Cooling towers shall be isolated from the heat pump loop by a separate heat exchanger.
		C403.4.3.3.2.2	Cooling towers shall control heat loss by shutting down the circulation pump.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	C403.4.3.3.3	Hydronic pumps in a system exceeding 10 hp shall have a two-position valve.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6090	Hydronic systems > 300 MBH shall reset supply water temp. or reduce system flow	C403.4.3.4	Large hydronic systems shall have controls to automatically reset supply water temperatures or reduce system pump flow.
		C403.3.2	Large simple hydronic systems shall have controls like complex systems.
6091P	Multiple chillers shall reduce flow when a chiller is shut down.	C403.4.3.5	Chilled water plants with more than one chiller shall have the capability to reduce flow through the chiller plant when a chiller is shut down.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
6093	Multiple boiler plants shall reduce flow when a boiler is shut down	C403.4.3.5 C403.3.2	Boiler plants with more than one boiler shall have the capability to reduce flow through the boiler plant when a boiler is shut down. Large simple hydronic systems shall have controls like complex systems.
6094	Tower Fans ≥ 7.5 hp shall have variable speed control	C403.4.4 C403.4.4	Tower Fans ≥ 7.5 hp shall have variable speed control. Fans with a motor of 7.5 hp or greater shall have controls that change the fan speed to control leaving fluid temperatures.
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	C403.4.5.4 C403.4.5.4	Multiple zone HVAC systems shall have supply-air temperature reset controls. Supply-air temperature reset controls shall reset the temperature to at least 25% of the difference between design supply-air and design room air temperatures.
6105	Hot gas bypass only allowed with multiple steps of unloading or capacity modulation	C403.4.7 C403.4.7	Cooling systems shall not use hot gas bypass unless system is designed with multiple steps of unloading or capacity modulation. Capacity of hot gas bypass is limited.
6106AS	Dynamic ventilation reset for MZ systems	90.1: 6.5.3.3	Multizone VAV systems with DDC must dynamically reset OA intake in response to ventilation system efficiency.
6108PAS	Single zone VAV	90.1: 6.4.3.10	AHUs and FCUs with fan motors 5 hp or larger and chilled water coils must be 2-speed or VAV with VFD. Fan speed is limited at 50% cooling to the greater of 50% flow or minimum OA requirements. Single zone systems with dx cooling 110,000 Btu or greater must also be 2-speed or VFD with fan speed limited to 2/3 full speed at 50% cooling demand.
6109PAS	Parking garage fan controls	90.1: 6.4.3.4.5	Enclosed parking garage ventilation fans must reduce airflow to at least 50% based on contaminants.
6110AS	Zone isolation	90.1: 6.4.3.5	HVAC systems serving zones that are not intended to operate or be occupied at the same time must be able to automatically shut off the supply of conditioned, outdoor air, and exhaust air to any zone that is not occupied. Zones that do simultaneously operate cannot be grouped into a single isolation zone >25,000 ft2 and cannot span more than one floor.
7002A	Gas water heater efficiency	C404.2	Water-heating equipment and hot water storage tanks must meet minimum efficiency standards.
7002B	Electric water heater efficiency	C404.2	Water-heating equipment and hot water storage tanks must meet minimum efficiency standards.
7003	Service water-heating equipment shall be provided with temperature setpoint controls	C404.3	Service water-heating equipment shall be provided with temperature setpoint controls.
7004	Outlet temperature of lavatories in public facility rest rooms is limited to 110°F (43°C)	C404.3	Outlet temperature of lavatories in public facility rest rooms is limited to 110°F (43°C).
7005	SWH heat trap	C404.4	Water-heating equipment must have a heat trap.

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7006	SWH pipe insulation - recirculated	C404.5	Water-heating piping in automatic circulating and heat-traced systems must have 1" of insulation, minimum conductivity of 0.27 Btu per inch/h × ft2 × °F.
7007	SWH pipe insulation - non-recirculated	C404.5	First 8 feet of piping in water-heating piping served by equipment without integral heat traps shall be insulated.
7008	Circulating hot water system and heat trace controls	C404.6	Circulating hot water system pumps and heat trace must have readily-accessible controls to turn them off when not needed.
Lighting			
9003	Manual lighting control	C405.2.1 C405.2.1.1 C405.2.1.1 C405.2.1.2 C405.2.1.2 C405.2.2.3.3 C405.2.3	All buildings shall have manual lighting controls. Each room shall have at least one manual control. Required controls shall be accessible. Each area with a manual control shall have an occupant-controlled way of reducing connected lighting load by 50%. 4 acceptable options for manually reducing connected lighting load by 50%. Multi-level lighting controls shall be readily accessible. Lighting in cases for display shall be controlled separately.
9009	Automatic time switch control	C405.2.2 C405.2.2.1 C405.2.2.1 C405.2.4	Each area with a manual control shall also have automatic lighting controls. Automatic time switch controls shall be installed to control lighting in all areas of the building. Automatic time switch controls shall include an override switch. Time switches shall be capable of retaining settings during a 10-hour power loss.
9011	Occupancy sensor control	C405.2.2 C405.2.2.2 C405.2.2.2 C405.2.2.2	Each area with a manual control shall also have automatic lighting controls. Occupancy sensors are required in specific space types. Occupancy sensors shall turn off lights within 30 minutes of all occupants leaving. Occupancy sensors shall be manual on or automatic on to no more than 50% power.
9025	Display lighting control	C405.2.3	Display and accent lighting shall be controlled separately.
9028	Task lighting control	C405.2.3	Supplemental task lighting shall have a luminaire mounted control device or accessible wall-mounted control device.
9029	Lighting for nonvisual applications shall be controlled separately	C405.2.3 C405.2.3	Lighting for nonvisual applications shall be controlled separately. Lighting equipment for sale or demonstration shall be controlled separately.
9031	Exterior lighting control	C405.2.4 C405.2.4	Lighting not designated for dusk-to-dawn operation shall be controlled by either a combination of a photosensor and a time switch, or an astronomical time switch. Lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or photosensor.
9034	Tandem wiring	C405.3	Tandem wiring of 1 or 3 lamp fluorescent luminaires is required.
9035	Exit sign maximum power	C405.4	Internally illuminated exit signs shall not exceed 5 watts per side.
9037	Interior lighting power allowance	C405.5.1 C405.5	The total connected interior lighting power (watts) shall be the sum of the watts of all interior lighting equipment. Total connected lighting power shall be less than or equal to the interior lighting power allowance.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
		C405.5.1.1	The wattage shall be the maximum labeled wattage of the luminaire.
		C405.5.1.2	The wattage shall be the specified wattage of the transformer supplying the system.
		C405.5.1.3	The wattage of all other lighting equipment shall be the wattage of the lighting equipment verified through data furnished by the manufacturer or other approved sources.
		C405.5.1.4	The wattage of the luminaires may be calculated three ways.
		C405.5.2	Total interior power lighting allowance can be determined by Building Area Method or Space-by-Space Method.
		C405.5.2	For the Building Area method, the ILPA equals the floor area of the building type times the allowed LPD for that building type.
		C405.5.2	Building areas are defined as contiguous spaces that are associated with a single building area type.
		C405.5.2	Building area types must be treated separately.
		C405.5.2	For the Space-by-Space method, ILPA equals the floor area of each space times the allowed LPD for that space type. Tradeoffs among spaces are permitted.
		C406.1	Individual tenant spaces shall comply with minimum equipment efficiency option or lighting efficiency option unless whole building complies with the renewable energy option.
9047	Additional retail lighting power allowance	C405.5.2	Additional lighting allowances for retail display lighting is calculated per the footnotes to Table C405.5.2(2). Tradeoffs with general LPD spaces are not permitted.
9048	Exterior lighting power allowance	C405.6	Exterior lighting power through the building is subject to the code.
		C405.6.1	Exterior building grounds luminaires shall have a minimum efficacy of 60 lumens per watt.
		C405.6.2	Total ELPA equals the sum of the base site allowance plus the individual allowances for areas that are illuminated and permitted.
		C405.6.2	Tradeoff among exterior spaces are allowed only for Tradable Surfaces.
		C405.6.2	Exterior lighting is to be categorized into the appropriate lighting zone.
		C405.6.2	Exterior lighting luminaires shall have a minimum efficacy of 60 lumens per watt.
9049pAS	Electric feeder and branch circuit maximum voltage drop	90.1: 8.4.1	The feeder conductors and branch circuits combined shall be sized for a maximum of 5% voltage drop total.
9054AS	Parking garage lighting controls	90.1: 9.4.1.3	Lighting for parking garages shall comply with the following requirements: a. Automatic lighting shutoff. b. Lighting power reduced by at least 30% with occupancy sensors in zones no larger than 3600 ft2. c. Lighting for covered vehicle entrances and exits automatically reduce at least 50% from sunset to sunrise. d. Daylight control within 20 ft of perimeter wall openings with at least 50% reduction.

Measure ID	Measure name	2012 IECC or 90.1-2010 Section	Requirement Summary
9055pAS	Plug load controls	90.1: 8.4.2	Automatically schedule or occupancy control of: a. At least 50% of all 125 V, 15 and 20 amp receptacles in all private offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, classrooms, and individual workstations. b. At least 25% of branch circuits for modular furniture not shown on the construction documents. Controlled areas no more than 5000 ft2 and not more than one floor. Schedule control has 2-hour manual override. Controlled receptacles permanently marked and uniformly distributed throughout the space.
Options			
15007	Optional onsite renewable	C406.4 C406.1	The renewable energy option requires either 0.5 watts per square foot or 3% of the energy used for regulated loads. Buildings shall comply with one of 3 additional efficiency options.

Appendix B

Code Measures, Identified Conditions, and Input Parameters

Appendix B

Code Measures, Identified Conditions, and Input Parameters

Table B.1. Code Measures, Conditions, and Input Parameters – Office Building

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
15007	Optional onsite renewable	15	Worst	No option installed	No option installed	No option installed	Peak design W/sf	0	0	0
OptRenewbl			Code	Min requirement for renewable energy option	Min requirement for renewable energy option	Min requirement for renewable energy option		0.5	0.5	0.5
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		1	1	1
5012	Roofs shall be insulated to meet CZ requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.89	0.89	0.89
RoofIns			Code	Insulated per code	Insulated per code	Insulated per code		0.048	0.048	0.039
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		0.024	0.024	0.0195
5013	Skylight curbs shall be insulated	30	Worst	No insulation	No insulation	No insulation	Insulation R-value	R-0	R-0	R-0
SkylCurbIns			Code	Insulated per code	Insulated per code	Insulated per code		R-5	R-5	R-5
			Best	Insulated to 75% of roof U	Insulated to 75% of roof U	Insulated to 75% of roof U		R-28	R-28	R-28
5014	Low slope roofs in CZ 1-3 shall be cool roofs	30	Worst	Asphalt roof	Asphalt roof	NA	Solar Reflectance	0.1	0.1	NA
CoolRoof			Code	Code reflective roof	Code reflective roof	NA		0.55	0.55	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	Highly reflective roof membrane, clean	Highly reflective roof membrane, clean	NA		0.87	0.87	NA
5018A	Above grade frame walls shall be insulated to meet CZ requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.459	0.459	0.459
FrameWallIns			Code	Insulated per code	Insulated per code	Insulated per code		0.077	0.064	0.064
			Best	Insulated to 2.4 times code requirement	Insulated to 2.4 times code requirement	Insulated to 2.4 times code requirement		0.032	0.026	0.026
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.555	0.555	0.555
MassWallIns			Code	Insulated per code	Insulated per code	Insulated per code		0.142	0.11	0.078
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		0.071	0.055	0.039
5021p	Below grade wall insulation requirements and protection	30	Worst	No insulation	No insulation	No insulation	Wall C-Factor	1.140	1.140	0.119
BelowGradeIns			Code	No insulation (per code)	No insulation (per code)	Insulated per code		1.140	1.140	0.119
			Best	NA	NA	NA		NA	NA	NA
5023A	Exterior frame floors shall meet the insulation requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.32	0.32	0.32
FrameFloorIns			Code	Insulated per code	Insulated per code	Insulated per code		0.033	0.033	0.033
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		0.0165	0.0165	0.0165

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
5023B	Exterior mass floors shall meet the minimum R-value or U-value by assembly type	30	Worst	No insulation	No insulation	No insulation	U-factor	0.348	0.348	0.348
MassFloorIns			Code	Insulated per code	Insulated per code	Insulated per code		0.107	0.076	0.074
			Best	Double the minimum requirement	Insulated to 1.4 times code requirement	Insulated to 1.4 times code requirement		0.0535	0.0535	0.0535
5025	Slab-on-grade floors shall meet insulation requirements and be protected	30	Worst	NA	NA	No insulation	F-factor	NA	NA	0.73
SlabIns			Code	NA	NA	Insulated per code		NA	NA	0.54
			Best	NA	NA	Insulated to 1.3 times code requirement		NA	NA	0.419
5029A	Opaque swing doors shall meet U-factor requirements	30	Worst	Uninsulated double layer metal door	Uninsulated double layer metal door	Uninsulated double layer metal door	U-factor	0.7	0.7	0.7
SwingDoorU			Code	Code insulated door	Code insulated door	Code insulated door		0.61	0.61	0.37
			Best	200% of code requirement	200% of code requirement	200% of code requirement		0.305	0.305	0.185
5029B	Opaque rollup doors shall meet U-factor requirements	30	Worst	NA	NA	NA	U-factor	NA	NA	NA
RollupDoorU			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
5034	Window-to-wall ratio shall meet maximum limits	30	Worst	2.6 times max code limit	2.6 times max code limit	2.6 times max code limit	WWR	79.50%	79.50%	79.50%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
MaxWWR			Code	Max WWR per code	Max WWR per code	Max WWR per code		30%	30%	30%
			Best	NA	NA	NA		NA	NA	NA
5035	Skylight to roof ratio shall meet maximum limits	30	Worst	2.3 times max code limit	2.3 times max code limit	2.3 times max code limit	SRR	7%	7%	7%
MaxSkyLtRoofR			Code	Max per code	Max per code	Max per code		3%	3%	3%
			Best	NA	NA	NA		NA	NA	NA
5042A	Windows shall meet U-factor requirements	30	Worst	Single pane, fixed, thermally unbroken metal frame	Single pane, fixed, thermally unbroken metal frame	Single pane, fixed, thermally unbroken metal frame	U-factor	1.25	1.25	1.25
WinUFactor			Code	Code U-factor	Code U-factor	Code U-factor		0.5	0.46	0.38
			Best	250% of code requirement	250% of code requirement	250% of code requirement		0.2	0.2	0.2
5042B	Windows shall meet SHGC requirements	30	Worst	Single pane, clear	Single pane, clear	Single pane, clear	SHGC	0.82	0.82	0.82
WinSHGC			Code	Code SHGC	Code SHGC	Code SHGC		0.25	0.25	0.4
			Best	Low-e coating on tint	Low-e coating on tint	Low-e coating on tint		0.2	0.2	0.2
5043A	Skylights shall meet U-factor requirements	30	Worst	Single pane clear, w/metal thermally unbroken frame	Single pane clear, w/metal thermally unbroken frame	Single pane clear, w/metal thermally unbroken frame	U-factor	1.98	1.98	1.98
SkyLtUFactor			Code	Code U-factor	Code U-factor	Code U-factor		0.65	0.55	0.5
			Best	210% of code requirement	210% of code requirement	210% of code requirement		0.31	0.31	0.31
5043B	Skylights shall meet SHGC requirements	30	Worst	Clear, 1/8" glass, metal frame w/o thermal break	Clear, 1/8" glass, metal frame w/o thermal break	Clear, 1/8" glass, metal frame w/o thermal break	SHGC	0.82	0.82	0.82
SkyLtSHGC			Code	Code SHGC	Code SHGC	Code SHGC		0.35	0.35	0.4

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	Low-e coating on tint	Low-e coating on tint	Low-e coating on tint		0.2	0.2	0.2
5056	Building shall meet continuous air barrier requirements	30	Worst	3 x base leakage	3 x base leakage	3 x base leakage	cfm/ft2 exterior surface at 75Pa	3.00	3.00	3.00
ContAirBar			Code	equivalent to a CAB as required	equivalent to a CAB as required	equivalent to a CAB as required		1.00	1.00	1.00
			Best	1/4 x code leakage	1/4 x code leakage	1/4 x code leakage		0.25	0.25	0.25
5063	Recessed lighting shall be sealed, rated and labeled	15	Worst	30 cfm at 75 Pa per fixture, Unsealed recessed lights	30 cfm at 75 Pa per fixture, Unsealed recessed lights	30 cfm at 75 Pa per fixture, Unsealed recessed lights	cfm per fixture @ 75 Pa	30	30	30
RecsLtgLeak			Code	2 cfm at 75 Pa per fixture	2 cfm at 75 Pa per fixture	2 cfm at 75 Pa per fixture		2	2	2
			Best	NA	NA	NA		NA	NA	NA
5075	Fenestration assemblies shall meet air leakage requirements	30	Worst	Leaky windows 5x code requirement	Leaky windows 5x code requirement	Leaky windows 5x code requirement	cfm/ft2 at 75 Pa	1.5	1.5	1.5
WindowLeak			Code	Code requirement for window leakage	Code requirement for window leakage	Code requirement for window leakage		0.3	0.3	0.3
			Best	66% less leakage for windows	66% less leakage for windows	66% less leakage for windows		0.1	0.1	0.1
5077	Stair and shaft vent leakage	30	Worst	Open damper, leaky door	Open damper, leaky door	Open damper, leaky door	Leakage	High	High	High
StairShaftLeak			Code	Damper closed, doors sealed	Damper closed, doors sealed	Damper closed, doors sealed		Low	Low	Low
			Best	NA	NA	NA		NA	NA	NA
5082	Loading dock doors shall be equipped with weather seals	15	Worst	doors not weatherstripped or sealed	doors not weatherstripped or sealed	doors not weatherstripped or sealed	Actual condition	doors not weathers tripped or sealed	doors not weathers tripped or sealed	doors not weathers tripped or sealed

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
LoadDockSeal			Code	doors weatherstripped and sealed	doors weatherstripped and sealed	doors weatherstripped and sealed		doors weathers tripped and sealed	doors weathers tripped and sealed	doors weathers tripped and sealed
			Best	NA	NA	NA		NA	NA	NA
5083	Building entrances shall be protected with an enclosed vestibule	30	Worst	NA	No vestibule	No vestibule	door infiltration rate, cfm with off-peak fraction	NA	2210 cfm; 0.144 off-peak	2210 cfm; 0.144 off-peak
Vestibule			Code	NA	Yes vestibule	Yes vestibule		NA	1438 cfm; 0.131 Off-peak	1438 cfm; 0.131 Off-peak
			Best	NA	NA	NA		NA	NA	NA
5089	Fenestration orientation	30	Worst	All windows on E/W orientation	All windows on E/W orientation	All windows on E/W orientation	ft2 of E windows exceeding S windows + ft2 of W windows exceeding S windows	6,387	6,387	6,387
FenOrient			Code	Separate baseline, average of the base building EUI from facing 4 orientations	Separate baseline, average of the base building EUI from facing 4 orientations	Separate baseline, average of the base building EUI from facing 4 orientations		0	0	0
			Best	NA	NA	NA		NA	NA	NA
6004A	Equipment sizing requirement for PkgAC	15	Worst	250% for heating and 230% for cooling	250% for heating and 230% for cooling	250% for heating and 230% for cooling	Cooling size as % of load	230%	230%	230%
EqpSizPkgAC			Code	125% for heating and 115% for cooling	125% for heating and 115% for cooling	125% for heating and 115% for cooling		115%	115%	115%
			Best	NA	NA	NA		NA	NA	NA
6004B	Equipment sizing requirement for PkgVAV-RH	15	Worst	250% for heating and 230% for cooling	250% for heating and 230% for cooling	250% for heating and 230% for cooling	Cooling size as % of load	230%	230%	230%
EqpSizPvavRH			Code	125% for heating and 115% for cooling	125% for heating and 115% for cooling	125% for heating and 115% for cooling		115%	115%	115%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	NA	NA	NA		NA	NA	NA
6005A	Packaged air conditioner efficiency	15	Worst	94% of code efficiency	94% of code efficiency	94% of code efficiency	EER	10.3	10.3	10.3
ACCoolingEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		11	11	11
			Best	113% of code efficiency	113% of code efficiency	113% of code efficiency		12.4	12.4	12.4
6005B	Packaged heat pump efficiency	15	Worst	Code efficiency when high performance tradeoff is used	NA	NA	Rated Heating COP	NA	NA	NA
HPEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		3.29	3.29	3.29
			Best	116% of code heating efficiency	116% of code heating efficiency	116% of code heating efficiency		3.8	3.8	3.8
6005C	Gas furnace efficiency	15	Worst	Code efficiency when high performance tradeoff is used	NA	NA	AFUE	NA	NA	NA
FurnaceEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		78%	78%	78%
			Best	124% of code heating efficiency	124% of code heating efficiency	124% of code heating efficiency		97%	97%	97%
6005D	Boiler efficiency	15	Worst	Code efficiency when high performance tradeoff is used	NA	NA	ET	NA	NA	NA
BoilerEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		80%	80%	80%
			Best	121% of code heating efficiency	121% of code heating efficiency	121% of code heating efficiency		97%	97%	97%
6005E	WSHP efficiency	15	Worst	Code efficiency when high performance tradeoff is used	NA	NA	Heating COP (cooling EER is a match)	NA	NA	NA
WSHPEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		3.7	3.7	3.7
			Best	159% of code heating efficiency	159% of code heating efficiency	159% of code heating efficiency		5.9	5.9	5.9

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6007A	Air-cooled Chiller efficiency	15	Worst	80% of code efficiency	80% of code efficiency	80% of code efficiency	EER	7.65	7.65	7.65
AirChillerEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		9.562	9.562	9.562
			Best	120% of code efficiency	120% of code efficiency	120% of code efficiency		11.47	11.47	11.47
6007B	Water-cooled Chiller efficiency	23	Worst	120% of code kW/ton	120% of code kW/ton	120% of code kW/ton	kW/Ton	0.816	0.816	0.816
WatrChillerEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		0.68	0.68	0.68
			Best	84% of code kW/ton	84% of code kW/ton	84% of code kW/ton		0.57	0.57	0.57
6014	Thermostatic control is used for individual zones	15	Worst	1 Tstat per floor	1 Tstat per floor	1 Tstat per floor	Thermostats for each	Floor	Floor	Floor
TstatZone			Code	1 Tstat per zone	1 Tstat per zone	1 Tstat per zone		Zone	Zone	Zone
			Best	NA	NA	NA		NA	NA	NA
6016	Humidity control device for each humidity system	15	Worst	No humidistat. Constant subcooling and reheat. SAT of 52 F	No humidistat. Constant subcooling and reheat. SAT of 52 F	No humidistat. Constant subcooling and reheat. SAT of 52 F	Max SAT reset	52 F	52 F	52 F
ActiveRHCtrl			Code	60% RH control. SAT down to 52F when dehumidification, OA-based SAT reset to 60F	60% RH control. SAT down to 52F when dehumidification, OA-based SAT reset to 60F	60% RH control. SAT down to 52F when dehumidification, OA-based SAT reset to 60F		60% RH control. SAT up to 60F	60% RH control. SAT up to 60F	60% RH control. SAT up to 60F
			Best	NA	NA	NA		NA	NA	NA
6017	Heat pump supplementary heat control	15	Worst	OA lockout 70°F. Compressor lockout 35°F	OA lockout 70°F. Compressor lockout 35°F	OA lockout 70°F. Compressor lockout 35°F	Score	-10	-10	-10
HPSuppHeatCtrl			Code	OA lockout 40°F. Compressor lockout 10°F	OA lockout 40°F. Compressor lockout 10°F	OA lockout 40°F. Compressor lockout 10°F		0	0	0
			Best	OA lockout 30°F Compressor lockout -4°F	OA lockout 30°F Compressor lockout -4°F	OA lockout 30°F Compressor lockout -4°F		2.3	2.3	2.3
6018	Thermostat deadband requirement	15	Worst	Heating 72F, Cooling 73F	Heating 72F, Cooling 73F	Heating 72F, Cooling 73F	°F difference between heat & cool	1	1	1

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
TempDeadband			Code	Heating 70F, Cooling 75F	Heating 70F, Cooling 75F	Heating 70F, Cooling 75F		5	5	5
			Best	Heating 67F, Cooling 76F	Heating 67F, Cooling 76F	Heating 67F, Cooling 76F		9	9	9
6019A	Thermostat heating setback	15	Worst	No heat setback; Heating 70F, Cooling 85F	No heat setback; Heating 70F, Cooling 85F	No heat setback; Heating 70F, Cooling 85F	°F setpoint for heating setback	70	70	70
SetbackCtrl			Code	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F		60	60	60
			Best	Setback: Heating 50F, Cooling 85F	Setback: Heating 50F, Cooling 85F	Setback: Heating 50F, Cooling 85F		50	50	50
6019B	Thermostat cooling setback	15	Worst	No cooling setback; Heating 60F, Cooling 75F	No cooling setback; Heating 60F, Cooling 75F	No cooling setback; Heating 60F, Cooling 75F	°F setpoint for cooling setback	75	75	75
SetCoolCtrl			Code	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F		85	85	85
			Best	Setback: Heating 60F, Cooling 90F	Setback: Heating 60F, Cooling 90F	Setback: Heating 60F, Cooling 90F		90	90	90
6019C	Night fan control	15	Worst	Fan runs during unoccupied hours	Fan runs during unoccupied hours	Fan runs during unoccupied hours	Fan operation during unoccupied hours	Runs continuous	Runs continuous	Runs continuous
NightFanCtrlIECC			Code	Fan cycles during unoccupied hours	Fan cycles during unoccupied hours	Fan cycles during unoccupied hours		cycles	cycles	cycles
			Best	NA	NA	NA		NA	NA	NA
6023	Optimal start controls	15	Worst	No optimal start	No optimal start	No optimal start	Optimal Start?	No	No	No
OptStart			Code	Optimal start as required	Optimal start as required	Optimal start as required		Yes	Yes	Yes
			Best	NA	NA	NA		NA	NA	NA
6025	Damper control when space is unoccupied	15	Worst	NA	NA	Gravity damper open during night cycle and optimum start	Damper type; operation	NA	NA	Gravity; open night cycle and warmup

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
OADamperCtrl			Code	Gravity damper open during night cycle and optimum start	Gravity damper open during night cycle and optimum start	Motorized damper closed during warmup and night cycle hours		Gravity; open night cycle and warmup	Gravity; open night cycle and warmup	Motorized; closed night cycle and warmup
			Best	NA	NA	NA		NA	NA	NA
6026p	Snow and ice-melting system control	15	Worst	NA	Manual Seasonal shutoff	Manual Seasonal shutoff	Score	NA	-10	-10
SnowIceCtrl			Code	NA	Automatic off at >40F OA or >50F pavement temp	Automatic off at >40F OA or >50F pavement temp		NA	0	0
			Best	NA	Automatic off at >35F OA or >35F pavement temp	Automatic off at >40F OA or >50F pavement temp		NA	7.34	7.34
6029	Demand control ventilation	15	Worst	No DCV	No DCV	No DCV	Actual condition	No DCV	No DCV	No DCV
DCV			Code	DCV in conference room	DCV in conference room	DCV in conference room		DCV in conference room	DCV in conference room	DCV in conference room
			Best	NA	NA	NA		NA	NA	NA
6030	Energy recovery requirement	15	Worst	No energy recovery system	No energy recovery system	No energy recovery system	ERV system	No	No	No
ERVUse			Code	Yes, for all AC except for conference room with DCV	Yes, for all AC except for conference room with DCV	Yes, for all AC except for conference room with DCV		Yes, except for DCV	Yes, except for DCV	Yes, except for DCV
			Best	NA	NA	NA		NA	NA	NA
6033p	Exterior (outside building) Duct insulation	30	Worst	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff =1/(0.17*2)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff =1/(0.17*2)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff= 1/(0.17*2)*5.678263	% required Insul R-value	0%	0%	0%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
DuctInsul			Code	Ignore the inside heat/cool loss, only calculate the exterior ducts R8 insulation i.e., OutDuctLossCoeffDiff =1/(0.17*2+8)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts R8 insulation i.e., OutDuctLossCoeffDiff =1/(0.17*2+8)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts R8 insulation i.e., OutDuctLossCoeffDiff= 1/(0.17*2+8)*5.678263		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
6035	Duct leakage requirement	20	Worst	Duct leakage is 30% of the supply airflow	Duct leakage is 30% of the supply airflow	Duct leakage is 30% of the supply airflow	Duct Leakage of SA cfm	30%	30%	30%
DuctLeakage			Code	Duct leakage is 10% of the supply airflow for all the RTUs	Duct leakage is 10% of the supply airflow for all the RTUs	Duct leakage is 10% of the supply airflow for all the RTUs		10%	10%	10%
			Best	NA	NA	NA		NA	NA	NA
6042A	Hydronic Piping CHW Insulation Requirement	20	Worst	No insulation	No insulation	No insulation	Insulation R-value	No insulation	No insulation	No insulation
HydPipeInsCHW			Code	Insulated to code	Insulated to code	Insulated to code		Insulated to code	Insulated to code	Insulated to code
			Best	postponed	postponed	postponed		postponed	postponed	postponed
6042B	Hydronic Piping HW Insulation Requirement	20	Worst	No insulation	No insulation	No insulation	% Req'd Insul Thickness	0%	0%	0%
HydPipeInsHW			Code	Insulated as required	Insulated as required	Insulated as required		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
6045p	Mechanical Commissioning	15	Worst	No commissioning	No commissioning	No commissioning	Score	-10	-10	-10
MechCx			Code	Commissioning per code; satisfactory	Commissioning per code; satisfactory	Commissioning per code; satisfactory		0	0	0
			Best	Commissioning above code; excellent	Commissioning above code; excellent	Commissioning above code; excellent		3	3	3
6046A	Fan power limit requirement for PkgAC	15	Worst	150% of limit	150% of limit	150% of limit	bHP (not SP)	35.5		37.7

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
FanPowPkgAC			Code	Fan power as required	Fan power as required	Fan power as required		23.7		25.1
			Best	40% below limit or 60% of limit	40% below limit or 60% of limit	40% below limit or 60% of limit		14.4		15.1
6046B	Fan power limit requirement for VAV	15	Worst	150% of limit	150% of limit	150% of limit	bHP (not SP)	72	73.5	75
FanPowVAV			Code	Fan power as required	Fan power as required	Fan power as required		48	49	50
			Best	40% below limit or 60% of limit	40% below limit or 60% of limit	40% below limit or 60% of limit		28.8	29.4	30
6051	Outdoor heating: radiant and controlled	15	Worst	NA	NA	NA	NA	NA	NA	NA
OutdoorHeat			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6056	Economizer supplies 100% design supply air	15	Worst	No economizer	No economizer	No economizer	OA fraction max observed; 100% = 0.7 OA fraction	0%	0%	0%
Econ100Pct			Code	Economizer as required	Economizer as required	Economizer as required		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
6058	Economizers should have appropriate high-limit shutoff control and be integrated	15	Worst	High limit Tdb of 55F	High limit Tdb of 55F	High limit Tdb of 55F	Economizer high limit cutoff temp	55F	55F	55F
EconHiLimit			Code	Separate baseline to use fixed dry bulb. High limit Tdb of 65F	Separate baseline to use fixed dry bulb. High limit Tdb of 75F	Separate baseline to use fixed dry bulb. High limit Tdb of 65F		65F	75F	65F
			Best	postponed	postponed	postponed		postponed	postponed	postponed
6066p	Water economizer capacity meets requirements	15	Worst	50% required size	50% required size	50% required size	% Cooling tons of required	50%	50%	50%
WaterEconCap			Code	100% load @ 50FDB/45FWB	100% load @ 50FDB/45FWB	100% load @ 50FDB/45FWB		100%	100%	100%
			Best	NA - low occurrence measure	NA - low occurrence measure	NA - low occurrence measure		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6067p WaterEconDP	Pre-cooling coils have low pressure drop	15	Worst Code Best	25 ft coil max 15 ft water side coil max pressure drop NA	25 ft coil max 15 ft water side coil max pressure drop NA	25 ft coil max 15 ft water side coil max pressure drop NA	Feet of pressure drop in coil	25 15 NA	25 15 NA	25 15 NA
6070 FanVSD	Multi-zone systems shall be VAV and fans with motors ≥threshold hp shall have variable speed, variable pitch axial, or fan demand reduction	15	Worst Code Best	Inlet vane control Fan curve for VSD with static pressure reset NA	Inlet vane control Fan curve for VSD with static pressure reset NA	Inlet vane control Fan curve for VSD with static pressure reset NA	Fan curve type	Inlet vane VSD; SP reset NA	Inlet vane VSD; SP reset NA	Inlet vane VSD; SP reset NA
6071 FanPresReset	Static pressure reset for multi-zone VAV fans	15	Worst Code Best	No reset Fan curve for VSD with static pressure reset NA	No reset Fan curve for VSD with static pressure reset NA	No reset Fan curve for VSD with static pressure reset NA	Fan curve type	No reset VSD static pressure reset NA	No reset VSD static pressure reset NA	No reset VSD static pressure reset NA
6075p BoilerLoadDistr	Multiple boiler systems must include sequencing controls	20	Worst Code Best	Uniform loading Sequenced with base loss when the boiler is in use Postponed	Uniform loading Sequenced with base loss when the boiler is in use Postponed	Uniform loading Sequenced with base loss when the boiler is in use Postponed	Boiler Loading	Uniform Sequenced Postponed	Uniform Sequenced Postponed	Uniform Sequenced Postponed
6082 WSHPDeadband	WSHP shall have a deadband between heat rejection and addition	15	Worst Code Best	79.5/74.5, 5°F deadband 87/67, 20°F deadband per code Postponed	79.5/74.5 87/67, 20°F deadband per code Postponed	79.5/74.5 87/67, 20°F deadband per code Postponed	°F	79.5/74.5 87/67 Postponed	79.5/74.5 87/67 Postponed	79.5/74.5 87/67 Postponed

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	15	Worst	Constant flow	Constant flow	Constant flow	Score relative to code and worst condition	-10	-10	-10
			Below	Variable flow pump - pump ride on the curve	Variable flow pump - pump ride on the curve	Variable flow pump - pump ride on the curve		-2	-2	-2
WSHPvalve			Code	Variable flow pump - VSD without pressure reset curve	Variable flow pump - VSD without pressure reset curve	Variable flow pump - VSD without pressure reset curve		0	0	0
			Best	NA	NA	NA		NA	NA	NA
6090	Hydronic systems > 300 MBH shall reset supply water temp or reduce system flow	15	Worst	Constant flow, no reset	Constant flow, no reset	Constant flow, no reset	Minimum Pump Speed	100%	100%	100%
HydRstTmpFlow			Code	variable flow pump for chilled water and hot water. This should be the primary baseline.	variable flow pump for chilled water and hot water. This should be the primary baseline.	variable flow pump for chilled water and hot water. This should be the primary baseline.		50%	50%	50%
			Best	NA	NA	NA		NA	NA	NA
6091p	Multiple chillers shall reduce flow when a chiller is shut down	20	Worst	No isolation	No isolation	No isolation	NA	No isolation	No isolation	No isolation
ChillerIsol			Code	Isolation	Isolation	Isolation		Isolation	Isolation	Isolation
			Best	NA	NA	NA		NA	NA	NA
6093p	Multiple boilers shall reduce flow when a boiler is shut down	20	Worst	No isolation	No isolation	No isolation	NA	No isolation	No isolation	No isolation
BoilerIsol			Code	Sequenced with base loss when the boiler is in use	Sequenced with base loss when the boiler is in use	Sequenced with base loss when the boiler is in use	Boiler staging control	Sequenti al	Sequenti al	Sequenti al
			Best	NA	NA	NA		NA	NA	NA
6094	Tower Fans ≥ 75 hp shall have variable speed control	20	Worst	Constant speed	Constant speed	Constant speed	NA	Constant speed	Constant speed	Constant speed

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
TwrFanVSD			Code	Variable speed cooling tower	Variable speed cooling tower	Variable speed cooling tower		Variable speed	Variable speed	Variable speed
			Best							
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	15	Worst	Fixed SA setpoint	Fixed SA setpoint	Fixed SA setpoint	Score	-10	-10	-10
SATreset			Code	OA Based SAT Reset	OA Based SAT Reset	OA Based SAT Reset		0	0	0
			Best	NA	NA	NA		NA	NA	NA
6105p	Hot gas bypass only allowed with multiple steps of unloading or capacity modulation	15	Worst	Single compressor no staging	Single compressor no staging	Single compressor no staging	% waste of modeled cooling load	10.9%	10.9%	10.9%
HotGasBypass			Code	Multistage Compressor	Multistage Compressor	Multistage Compressor		0%	0%	0%
			Best	NA	NA	NA		NA	NA	NA
6106AS	VAV ventilation optimization	15	Worst	No reset of outdoor air intake flow	No reset of outdoor air intake flow	No reset of outdoor air intake flow	Sys OSA Optimization	No reset	No reset	No reset
DynVentReset			Code	Separate baseline to include reset for three VAV systems	Separate baseline to include reset for three VAV systems	Separate baseline to include reset for three VAV systems		OA reset for VAV systems	OA reset for VAV systems	OA reset for VAV systems
			Best	NA	NA	NA		NA	NA	NA
6108AS	Single zone VAV	15	Worst	Constant Volume fan	Constant Volume fan	Constant Volume fan	Min VAV or multi-speed fan%	100%	100%	100%
SZVAV			Code	SZVAV or two speed fan; code minimum speed	SZVAV or two speed fan; code minimum speed	SZVAV or two speed fan; code minimum speed		67%	67%	67%
			Best	SZVAV or two speed fan; low minimum speed	SZVAV or two speed fan; low minimum speed	SZVAV or two speed fan; low minimum speed		25%	25%	25%
6109pAS	Parking garage fan controls	15	Worst	Fans run full during occupied hours	Fans run full during occupied hours	Fans run full during occupied hours	Minimum fan speed	100%	100%	100%
GarageFanCtrl			Code	Controlled by CO sensors, 50% minimum fan speed	Controlled by CO sensors, 50% minimum fan speed	Controlled by CO sensors, 50% minimum fan speed		50%	50%	50%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	Controlled by CO sensors, 33% minimum fan speed	Controlled by CO sensors, 33% minimum fan speed	Controlled by CO sensors, 33% minimum fan speed		33%	33%	33%
6110pAS	Zone Isolation	15	Worst	No isolation, 1/3 of building has minimum damper position of 30% during unoccupied	No isolation, 1/3 of building has minimum damper position of 30% during unoccupied	No isolation, 1/3 of building has minimum damper position of 30% during unoccupied	Percent of building area operating unnecessarily	23.90%	23.90%	23.90%
ZoneIsolate			Code	Core zone on the top floor runs 24/7. Other zones have night setback and reduced minimum damper position.	Core zone on the top floor runs 24/7. Other zones have night setback and reduced minimum damper position.	Core zone on the top floor runs 24/7. Other zones have night setback and reduced minimum damper position.		0.00%	0.00%	0.00%
			Best	NA	NA	NA		NA	NA	NA
7002A	Water heater efficiency, Gas	18	Worst	No worst case	No worst case	No worst case		NA	NA	NA
SwhGasEff			Code	Code efficiency	Code efficiency	Code efficiency	Thermal Efficiency, Et	78%Et	78%Et	78%Et
			Best	Enhanced efficiency	Enhanced efficiency	Enhanced efficiency		92% Et	92% Et	92% Et
7002B	Water heater efficiency, Electric	18	Worst	2009 IECC efficiency	2009 IECC efficiency	2009 IECC efficiency	Efficiency factor, EF	EF= 0.8772	EF= 0.8772	EF= 0.8772
SwhEleEff			Code	Code efficiency	Code efficiency	Code efficiency		EF = 0.9172	EF = 0.9172	EF = 0.9172
			Best	NA	NA	NA		NA	NA	NA
7004	Outlet temperature of lavatories in public facility rest rooms is limited to 110°F (43°C)	15	Worst	Higher outlet temperature	Higher outlet temperature	Higher outlet temperature	°F, Lavatory Outlet temp	120°F	120°F	120°F
LavTempLmt			Code	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110		110°F	110°F	110°F
			Best	NA	NA	NA		NA	NA	NA
7005p	SWH Heat Trap	15	Worst	No heat trap	No heat trap	No heat trap	NA	No heat trap	No heat trap	No heat trap
SwhHeatTrap			Code	Heat trap as required	Heat trap as required	Heat trap as required		Heat trap as required	Heat trap as required	Heat trap as required
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
7006	SWH Pipe Insulation - Recirculated	15	Worst	No pipe insulation	No pipe insulation	No pipe insulation	Insulation level	0%	0%	0%
SwhRecPipIns			Code	Insulate as required	Insulate as required	Insulate as required		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
7007	SWH Pipe Insulation - Non-recirculated	15	Worst	NA	NA	NA	NA	NA	NA	NA
SwhNonPipIns			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
7008	Circulating hot water system pumps and heat trace must have readily-accessible controls to turn them off when not needed	15	Worst	Pumps run continuously	Pumps run continuously	Pumps run continuously	Pipe Heat Loss, W	1732 W	1732 W	1732 W
SwhRecCtrl			Code	Pumps run intermittently	Pumps run intermittently	Pumps run intermittently		1301 W	1301 W	1301 W
			Best	NA	NA	NA		NA	NA	NA
9003	Manual lighting control	20	Worst	Lights full on during all occupied hours	Lights full on during all occupied hours	Lights full on during all occupied hours	Score	-10	-10	-10
ManLtCtl			Code	Original lighting schedule in IECC 2012	Original lighting schedule in IECC 2012	Original lighting schedule in IECC 2012		0	0	0
			Best	NA	NA	NA		NA	NA	NA
9009	Automatic time switch control	15	Worst	All lights on all night	All lights on all night	All lights on all night	Lights on unoccupied	Yes	Yes	Yes
AutoLtCtrl			Code	Original lighting schedule in IECC 2012	Original lighting schedule in IECC 2012	Original lighting schedule in IECC 2012		No	No	No
			Best	NA	NA	NA		NA	NA	NA
9011	Occupancy sensor control	15	Worst	No occupancy sensors where required	No occupancy sensors where required	No occupancy sensors where required	Score	-5	-5	-5
OccSens			Code	Occupancy sensors installed where required per code	Occupancy sensors installed where required per code	Occupancy sensors installed where required per code		0	0	0
			Best	More savings than code baseline	More savings than code baseline	More savings than code baseline		10	10	10

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9014A	Daylighting control	15	Worst	No automatic daylighting controls	No automatic daylighting controls	No automatic daylighting controls	Score	-10	-10	-10
DLCtrlReqd			Code	Separate baseline: 40% WWR, 3% SRR, DL control to 50% of total floor	Separate baseline: 40% WWR, 3% SRR, DL control to 50% of total floor	Separate baseline: 40% WWR, 3% SRR, DL control to 50% of total floor		0	0	0
			Best	40% WWR, 3% SSR, DL control to 60% of total floor. All daylightable area is controlled.	40% WWR, 3% SSR, DL control to 60% of total floor. All daylightable area is controlled.	40% WWR, 3% SSR, DL control to 60% of total floor. All daylightable area is controlled.		2.8	2.8	2.8
9014B	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	15	Worst	No automatic daylighting controls	No automatic daylighting controls	No automatic daylighting controls	% Skylit area controlled	0%	0%	0%
DLCtrlHiBay			Code	50% of DL area with automatic daylighting controls	50% of DL area with automatic daylighting controls	50% of DL area with automatic daylighting controls		50%	50%	50%
			Best	All daylightable area is controlled.	All daylightable area is controlled.	All daylightable area is controlled.		100%	100%	100%
9025	Display lighting control	15	Worst	NA	NA	NA	NA	NA	NA	NA
DispLtCtrl			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
9028	Task lighting control	15	Worst	No manual task lighting controls where required. All task lighting is on.	No manual task lighting controls where required. All task lighting is on.	No manual task lighting controls where required. All task lighting is on.	$task_ltg_ctrl_multiplier	1.0719	1.0719	1.0719
TskLtCtrl			Code	Task lighting controls where required.	Task lighting controls where required.	Task lighting controls where required.		1	1	1
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9029	Lighting for nonvisual applications shall be controlled separately	15	Worst	NA	NA	NA	NA	NA	NA	NA
NonVisLtCtrl			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
9031	Exterior lighting control	15	Worst	Exterior lighting is always on	Exterior lighting is always on	Exterior lighting is always on	Score	-10	-10	-10
ExtLtCtrl			Code	Astronomical clock	Astronomical clock	Astronomical clock		0	0	0
			Best	Photocell plus all lights reduced 30% after midnight to 6 am	Photocell plus all lights reduced 30% after midnight to 6 am	Photocell plus all lights reduced 30% after midnight to 6 am		1.5	1.5	1.5
9034	Tandem wiring	20	Worst	2 ballasts per fixture	2 ballasts per fixture	2 ballasts per fixture	Lamps per ballast	1.5	1.5	1.5
TandWire			Code	1.5 ballasts per fixture	1.5 ballasts per fixture	1.5 ballasts per fixture		2	2	2
			Best	NA	NA	NA		NA	NA	NA
9035	Exit sign maximum power	15	Worst	10 W per side of the exit sign (Each sign has two sides)	10 W per side of the exit sign (Each sign has two sides)	10 W per side of the exit sign (Each sign has two sides)	Watts per each of two sides of exit sign	10	10	10
ExitSign			Code	5 W per side of the exit sign (Each sign has two sides)	5 W per side of the exit sign (Each sign has two sides)	5 W per side of the exit sign (Each sign has two sides)		5	5	5
			Best	2.5 W per side of the exit sign (Each sign has two sides)	2.5 W per side of the exit sign (Each sign has two sides)	2.5 W per side of the exit sign (Each sign has two sides)		2.5	2.5	2.5
9037	Interior lighting power allowance	15	Worst	200% code requirement	200% code requirement	200% code requirement	LPD, W/sf	1.8	1.8	1.8
IntLPD			Code	Code requirement	Code requirement	Code requirement		0.9	0.9	0.9
			Best	50% code requirement	50% code requirement	50% code requirement		0.45	0.45	0.45

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9047	Additional retail lighting power allowance	15	Worst	NA	NA	NA	NA	NA	NA	NA
AddRtlLPD			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
9048	Exterior lighting power allowance	15	Worst	200% of allowance	200% of allowance	200% of allowance	Watts exterior lighting	16,199	16,199	16,199
ExtLPD			Code	100% of allowance	100% of allowance	100% of allowance		8,099	8,099	8,099
			Best	50% of allowance	50% of allowance	50% of allowance		4,050	4,050	4,050
9049pAS	Electric feeder and branch circuit maximum voltage drop	15	Worst	7% voltage drop	7% voltage drop	7% voltage drop	Voltage drop	7%	7%	7%
MaxVoltDrop			Code	Assume total 5% (2% feeder + 3% branch circuit) already included in baseline	Assume total 5% (2% feeder + 3% branch circuit) already included in baseline	Assume total 5% (2% feeder + 3% branch circuit) already included in baseline		5%	5%	5%
			Best	NA	NA	NA		NA	NA	NA
9054AS	Occupant based parking garage light control	15	Worst	Lighting on 100%	Lighting on 100%	Lighting on 100%	% lights on	100%	100%	100%
GarageLtCtrl			Code	85% on all hours	85% on all hours	85% on all hours		85%	85%	85%
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case conditions by climate zones			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9055pAS	Plug load controls	15	Worst	No plug load control	No plug load control	No plug load control	NA	No plug load control	No plug load control	No plug load control
PlugLdCtrl			Code	Plug load control per code	Plug load control per code	Plug load control per code		Plug load control per code	Plug load control per code	Plug load control per code
			Best	NA	NA	NA		NA	NA	NA
9099p	Lighting Testing or Commissioning	15	Worst	No commissioning	No commissioning	No commissioning	Score	-10	-10	-10
LightCx			Code	General commissioning and functional testing as required	General commissioning and functional testing as required	General commissioning and functional testing as required		0	0	0
			Best	High quality comprehensive commissioning	High quality comprehensive commissioning	High quality comprehensive commissioning		3	3	3

Table B.2. Code Measures, Conditions, and Input Parameters – Retail Building

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
15007	Optional onsite renewable	15	Worst	No option installed	No option installed	No option installed	Peak design W/sf	0	0	0
OptRenewbl			Code	Min requirement for renewable energy option	Min requirement for renewable energy option	Min requirement for renewable energy option		0.5	0.5	0.5
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		1	1	1
5012	Roofs shall be insulated to meet CZ requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.89	0.89	0.89
RoofIns			Code	Insulated per code	Insulated per code	Insulated per code		0.048	0.048	0.039
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		0.024	0.024	0.0195
5013	Skylight curbs shall be insulated	30	Worst	No insulation	No insulation	No insulation	Insulation R-value	R-0	R-0	R-0
SkylCurbIns			Code	Insulated per code	Insulated per code	Insulated per code		R-5	R-5	R-5
			Best	Insulated to 75% of roof U	Insulated to 75% of roof U	Insulated to 75% of roof U		R-28	R-28	R-28
5014	Low slope roofs in CZ 1-3 shall be cool roofs	30	Worst	Asphalt roof	Asphalt roof	NA	Solar Reflectance	0.1	0.1	NA
CoolRoof			Code	Code reflective roof	Code reflective roof	NA		0.55	0.55	NA
			Best	Highly reflective roof membrane, clean	Highly reflective roof membrane, clean	NA		0.87	0.87	NA
5018A	Above grade frame walls shall be insulated to meet CZ requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.459	0.459	0.459
FrameWallIns			Code	Insulated per code	Insulated per code	Insulated per code		0.077	0.064	0.064
			Best	Insulated to 2.4 times code requirement	Insulated to 2.4 times code requirement	Insulated to 2.4 times code requirement		0.032	0.026	0.026

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	30	Worst	No insulation	No insulation	No insulation	U-factor	0.555	0.555	0.555
MassWallIns			Code	Insulated per code	Insulated per code	Insulated per code		0.142	0.11	0.078
			Best	Double the minimum requirement	Double the minimum requirement	Double the minimum requirement		0.071	0.055	0.039
5021p	Below grade wall insulation requirements and protection	30	Worst	No insulation	No insulation	No insulation	Wall C-Factor	1.140	1.140	0.119
BelowGradeIns			Code	No insulation (per code)	No insulation (per code)	Insulated per code		1.140	1.140	0.119
			Best	NA	NA	NA		NA	NA	NA
5023A	Exterior frame floors shall meet the insulation requirements	30	Worst	NA	NA	NA	U-factor	NA	NA	NA
FrameFloorIns			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
5023B	Exterior mass floors shall meet the minimum R-value or U-value by assembly type	30	Worst	NA	NA	NA	U-factor	NA	NA	NA
MassFloorIns			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
5025	Slab-on-grade floors shall meet insulation requirements and be protected	30	Worst	NA	NA	No insulation	F-factor	NA	NA	0.73

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
SlabIns			Code	NA	NA	Insulated per code		NA	NA	0.54
			Best	NA	NA	Insulated to 1.3 times code requirement		NA	NA	0.419
5029A	Opaque swing doors shall meet U-factor requirements	30	Worst	Uninsulated double layer metal door	Uninsulated double layer metal door	Uninsulated double layer metal door	U-factor	0.7	0.7	0.7
SwingDoorU			Code	Code insulated door	Code insulated door	Code insulated door		0.61	0.61	0.37
			Best	200% of code requirement	200% of code requirement	200% of code requirement		0.305	0.305	0.185
5029B	Opaque rollup doors shall meet U-factor requirements	30	Worst	Uninsulated single layer metal door	Uninsulated single layer metal door	Uninsulated single layer metal door	U-factor	1.45	1.45	1.45
RollupDoorU			Code	Code insulated door	Code insulated door	Code insulated door		0.21	0.21	0.21
			Best	Insulated to 4.6 times code requirement	Insulated to 4.6 times code requirement	Insulated to 4.6 times code requirement		0.045	0.045	0.045
5034	Window-to-wall ratio shall meet maximum limits	30	Worst	2.9 times max code limit	2.9 times max code limit	2.9 times max code limit	WWR	87.70%	87.70%	87.70%
MaxWWR			Code	Max WWR per code	Max WWR per code	Max WWR per code		30%	30%	30%
			Best	NA	NA	NA		NA	NA	NA
5035	Skylight to roof ratio shall meet maximum limits	30	Worst	2.3 times max code limit	2.3 times max code limit	2.3 times max code limit	SRR	6.93%	6.93%	6.93%
MaxSkyLtRoofR			Code	Max per code	Max per code	Max per code		2.95%	2.95%	2.95%
			Best	NA	NA	NA		NA	NA	NA
5042A	Windows shall meet U-factor requirements	30	Worst	Single pane, fixed, thermally unbroken metal frame	Single pane, fixed, thermally unbroken metal frame	Single pane, fixed, thermally unbroken metal frame	U-factor	1.25	1.25	1.25
WinUFactor			Code	Code U-factor	Code U-factor	Code U-factor		0.5	0.46	0.38

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	250% of code requirement	250% of code requirement	250% of code requirement		0.2	0.2	0.2
5042B	Windows shall meet SHGC requirements	30	Worst	Single pane, clear	Single pane, clear	Single pane, clear	SHGC	0.82	0.82	0.82
WinSHGC			Code	Code SHGC	Code SHGC	Code SHGC		0.25	0.25	0.4
			Best	Low-e coating on tint	Low-e coating on tint	Low-e coating on tint		0.2	0.2	0.2
5043A	Skylights shall meet U-factor requirements	30	Worst	Single pane clear, w/metal thermally unbroken frame	Single pane clear, w/metal thermally unbroken frame	Single pane clear, w/metal thermally unbroken frame	U-factor	1.98	1.98	1.98
SkyLtUFactor			Code	Code U-factor	Code U-factor	Code U-factor		0.65	0.55	0.5
			Best	210% of code requirement	210% of code requirement	210% of code requirement		0.31	0.31	0.31
5043B	Skylights shall meet SHGC requirements	30	Worst	Clear, 1/8" glass, metal frame w/o thermal break	Clear, 1/8" glass, metal frame w/o thermal break	Clear, 1/8" glass, metal frame w/o thermal break	SHGC	0.82	0.82	0.82
SkyLtSHGC			Code	Code SHGC	Code SHGC	Code SHGC		0.35	0.35	0.4
			Best	Low-e coating on tint	Low-e coating on tint	Low-e coating on tint		0.2	0.2	0.2
5056	Building shall meet continuous air barrier requirements	30	Worst	3 x base leakage	3 x base leakage	3 x base leakage	cfm/ft2 exterior surface at 75Pa	3.00	3.00	3.00
ContAirBar			Code	equivalent to a CAB as required	equivalent to a CAB as required	equivalent to a CAB as required		1.00	1.00	1.00
			Best	1/4 x code leakage	1/4 x code leakage	1/4 x code leakage		0.25	0.25	0.25
5063	Recessed lighting shall be sealed, rated and labeled	15	Worst	30 cfm at 75 Pa per fixture, Unsealed recessed lights	30 cfm at 75 Pa per fixture, Unsealed recessed lights	30 cfm at 75 Pa per fixture, Unsealed recessed lights	cfm per fixture @ 4 Pa	30	30	30
RecsLtgLeak			Code	2 cfm at 75 Pa per fixture	2 cfm at 75 Pa per fixture	2 cfm at 75 Pa per fixture		2	2	2
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
5075	Fenestration assemblies shall meet air leakage requirements	30	Worst	Leaky windows 5x code requirement	Leaky windows 5x code requirement	Leaky windows 5x code requirement		1.5	1.5	1.5
WindowLeak			Code	Code requirement for window leakage	Code requirement for window leakage	Code requirement for window leakage		0.3	0.3	0.3
			Best	66% less leakage for windows	66% less leakage for windows	66% less leakage for windows		0.1	0.1	0.1
5077	Stair and shaft vent leakage	30	Worst	Open damper, leaky door	Open damper, leaky door	Open damper, leaky door	Leakage	High	High	High
StairShaftLeak			Code	Damper closed, doors sealed	Damper closed, doors sealed	Damper closed, doors sealed		Low	Low	Low
			Best	NA	NA	NA		NA	NA	NA
5082	Loading dock doors shall be equipped with weather seals	15	Worst	doors not weatherstripped or sealed	doors not weatherstripped or sealed	doors not weatherstripped or sealed	Actual condition	doors not weathers tripped or sealed	doors not weather stripped or sealed	doors not weather stripped or sealed
LoadDockSeal			Code	doors weatherstripped and sealed	doors weatherstripped and sealed	doors weatherstripped and sealed		doors weathers tripped and sealed	doors weather stripped and sealed	doors weather stripped and sealed
			Best	NA	NA	NA		NA	NA	NA
5083	Building entrances shall be protected with an enclosed vestibule	30	Worst	NA	No vestibule	No vestibule	Added door infiltration rate, cfm	NA	1020 cfm	1020 cfm
Vestibule			Code	NA	Has vestibule	Has vestibule		NA	0 cfm	0 cfm
			Best	NA	NA	NA		NA	NA	NA
5089	Fenestration orientation	30	Worst	All windows on E/W orientation	All windows on E/W orientation	All windows on E/W orientation	ft2 of E windows	3,801	3,801	3,801

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
FenOrient			Code	Separate baseline with 30% WWR, average of the base building EUI from facing 4 orientations	Separate baseline with 30% WWR, average of the base building EUI from facing 4 orientations	Separate baseline with 30% WWR, average of the base building EUI from facing 4 orientations	exceeding S windows + ft2 of W windows exceeding S windows	0	0	0
			Best	NA	NA	NA		NA	NA	NA
6004A	Equipment sizing requirement for PkgAC	15	Worst	250% for heating and 230% for cooling	250% for heating and 230% for cooling	250% for heating and 230% for cooling	Cooling size as % of load	230%	230%	230%
EqpSizPkgAC			Code	125% for heating and 115% for cooling	125% for heating and 115% for cooling	125% for heating and 115% for cooling		115%	115%	115%
			Best	NA	NA	NA		NA	NA	NA
6004B	Equipment sizing requirement for PkgVAV-RH	15	Worst	NA	NA	NA	NA	NA	NA	NA
EqpSizPvavRH			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6005A	Packaged air conditioner efficiency	15	Worst	94% of code efficiency	94% of code efficiency	94% of code efficiency	EER	10.3	10.3	10.3
ACCoolingEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		11	11	11
			Best	113% of code efficiency	113% of code efficiency	113% of code efficiency		12.4	12.4	12.4
6005B	Packaged heat pump efficiency	15	Worst	NA	NA	NA	Rated Heating COP	NA	NA	NA
HPEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		3.3	3.3	3.3
			Best	115% of code heating efficiency	115% of code heating efficiency	115% of code heating efficiency		3.8	3.8	3.8
6005C	Gas furnace efficiency	15	Worst	NA	NA	NA	AFUE	NA	NA	NA
FurnaceEff			Code	Code minimum required efficiency	Code minimum required efficiency	Code minimum required efficiency		78%	78%	78%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	124% of code heating efficiency	124% of code heating efficiency	124% of code heating efficiency		97%	97%	97%
6005D	Boiler efficiency	15	Worst	NA	NA	NA	ET	NA	NA	NA
BoilerEff			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6005E	WSHP efficiency	15	Worst	NA	NA	NA	Heating COP (cooling EER is a match)	NA	NA	NA
WSHPEff			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6007A	Air-cooled Chiller efficiency	15	Worst	NA	NA	NA	EER	NA	NA	NA
AirChillerEff			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6007B	Water-cooled Chiller efficiency	23	Worst	NA	NA	NA	kW/Ton	NA	NA	NA
WatrChillerEff			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6014	Thermostatic control is used for individual zones	15	Worst	1 Tstat per floor or per building	1 Tstat per floor or per building	1 Tstat per floor or per building	Thermostat s for each	Floor	Floor	Floor
TstatZone			Code	One thermostat per zone	One thermostat per zone	One thermostat per zone		Zone	Zone	Zone
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6016	Humidity control device for each humidity system	15	Worst	73 F cooling setpoint during occupied hours all year	73 F cooling setpoint during occupied hours all year	73 F cooling setpoint during occupied hours all year	Occupied Cooling Setpoint	73 F	73 F	73 F
ActiveRHCtrl			Code	73F RH>60%, 75F RH<=60% (occupied hours RH control only)	73F RH>60%, 75F RH<=60% (occupied hours RH control only)	73F RH>60%, 75F RH<=60% (occupied hours RH control only)		73F RH>60% , 75F RH<=60 %	73F RH>60 %, 75F RH<=60 %	73F RH>60 %, 75F RH<=6 0%
			Best	NA	NA	NA		NA	NA	NA
6017	Heat pump supplementary heat control	15	Worst	OA lockout 70°F. Compressor lockout 35°F	OA lockout 70°F. Compressor lockout 35°F	OA lockout 70°F. Compressor lockout 35°F	Score	-10	-10	-10
HPSuppHeatCtrl			Code	OA lockout 40°F. Compressor lockout 10°F	OA lockout 40°F. Compressor lockout 10°F	OA lockout 40°F. Compressor lockout 10°F		0	0	0
			Best	OA lockout 30°F. Compressor lockout -4°F	OA lockout 30°F. Compressor lockout -4°F	OA lockout 30°F. Compressor lockout -4°F		1.3	1.3	1.3
6018	Thermostat deadband requirement	15	Worst	Heating 72F, Cooling 73F	Heating 72F, Cooling 73F	Heating 72F, Cooling 73F	°F difference between heat & cool	1	1	1
TempDeadband			Code	Heating 70F, Cooling 75F	Heating 70F, Cooling 75F	Heating 70F, Cooling 75F		5	5	5
			Best	Heating 67F, Cooling 76F	Heating 67F, Cooling 76F	Heating 67F, Cooling 76F		9	9	9
6019A	Thermostat heating setback	15	Worst	No heat setback; Heating 70F, Cooling 85F	No heat setback; Heating 70F, Cooling 85F	No heat setback; Heating 70F, Cooling 85F	°F setpoint for heating setback	70	70	70
SetbackCtrl			Code	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F		60	60	60
			Best	Setback: Heating 50F, Cooling 90F	Setback: Heating 50F, Cooling 90F	Setback: Heating 50F, Cooling 90F		50	50	50
6019B	Thermostat cooling setback	15	Worst	No setback	No setback	No setback	°F setpoint for cooling setback	75	75	75
SetCoolCtrl			Code	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F	Setback: Heating 60F, Cooling 85F		85	85	85
			Best	Setback: Heating 50F, Cooling 90F	Setback: Heating 50F, Cooling 90F	Setback: Heating 50F, Cooling 90F		90	90	90

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6019C	Night fan control	15	Worst	Fan runs during unoccupied hours	Fan runs during unoccupied hours	Fan runs during unoccupied hours	Fan operation during unoccupied hours	Runs continuous	Runs continuous	Runs continuous
NightFanCtrlIECC			Code	Fan cycles during unoccupied hours	Fan cycles during unoccupied hours	Fan cycles during unoccupied hours		cycles	cycles	cycles
			Best	NA	NA	NA		NA	NA	NA
6023	Optimal start controls	15	Worst	No optimal start	No optimal start	No optimal start	Optimal Start?	No	No	No
OptStart			Code	Optimal start as required	Optimal start as required	Optimal start as required		Yes	Yes	Yes
			Best	NA	NA	NA		NA	NA	NA
6025	Damper control when space is unoccupied	15	Worst	NA	NA	Gravity damper open during night cycle and optimum start	Damper type; operation	NA	NA	Gravity; open night cycle and warmup
OADamperCtrl			Code	Gravity damper open during night cycle and optimum start	Gravity damper open during night cycle and optimum start	Motorized damper closed during warmup and night cycle hours		Gravity; open night cycle and warmup	Gravity; open night cycle and warmup	Motorized; closed night cycle and warmup
			Best	NA	NA	NA		NA	NA	NA
6026p	Snow and ice-melting system control	15	Worst	NA	Manual Seasonal shutoff	Manual Seasonal shutoff	Score	NA	-10	-10
SnowIceCtrl			Code	NA	Automatic off at >40F OA or >50F pavement temp	Automatic off at >40F OA or >50F pavement temp		NA	0	0
			Best	NA	Automatic off at >35F OA or >35F pavement temp	Automatic off at >40F OA or >50F pavement temp		NA	7.34	7.34
6029	Demand control ventilation	15	Worst	Manual Calc from prior	Manual Calc from prior	Manual Calc from prior	Actual condition	Manual Calc from prior	Manual Calc from prior	Manual Calc from prior
DCV			Code	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	NA	NA	NA		NA	NA	NA
6030	Energy recovery requirement	15	Worst	No energy recovery system	No energy recovery system	No energy recovery system	ERV system	No	No	No
ERVUse			Code	Yes, core retail only	Yes, core retail only	Yes, core retail only		Yes, core retail only	Yes, core retail only	Yes, core retail only
			Best	NA	NA	NA		NA	NA	NA
6033p	Exterior (outside building) Duct insulation	30	Worst	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff= 1/(0.17*2)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff= 1/(0.17*2)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. Non-insulation , i.e., OutDuctLossCoeffDiff= 1/(0.17*2)*5.678263	% required Insul R-value	0%	0%	0%
DuctInsul			Code	Ignore the inside heat/cool loss, only calculate the exterior ducts. R8 insulation i.e., OutDuctLossCoeffDiff= 1/(0.17*2+8)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. R8 insulation i.e., OutDuctLossCoeffDiff= 1/(0.17*2+8)*5.678263	Ignore the inside heat/cool loss, only calculate the exterior ducts. R8 insulation i.e., OutDuctLossCoeffDiff= 1/(0.17*2+8)*5.678263		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
6035	Duct leakage requirement	20	Worst	Duct leakage is 30% of the supply airflow	Duct leakage is 30% of the supply airflow	Duct leakage is 30% of the supply airflow	Duct Leakage of SA cfm	30%	30%	30%
DuctLeakage			Code	Duct leakage is 10% of the supply airflow for all the RTUs	Duct leakage is 10% of the supply airflow for all the RTUs	Duct leakage is 10% of the supply airflow for all the RTUs		10%	10%	10%
			Best	NA	NA	NA		NA	NA	NA
6042A	Hydronic Piping CHW Insulation Requirement	20	Worst	NA	NA	NA	NA	NA	NA	NA
HydPipeInsCHW			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6042B HydPipeInsHW	Hydronic Piping HW Insulation Requirement	20	Worst	NA	NA	NA	% Req'd Insul Thickness	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6045p MechCx	Mechanical Commissioning	15	Worst	No commissioning	No commissioning	No commissioning	Score	-10	-10	-10
			Code	Commissioning per code; satisfactory	Commissioning per code; satisfactory	Commissioning per code; satisfactory		0	0	0
			Best	Commissioning above code; excellent	Commissioning above code; excellent	Commissioning above code; excellent		3	3	3
6046A FanPowPkgAC	Fan power limit requirement for PkgAC	15	Worst	150% of limit	150% of limit	150% of limit	bHP (not SP)	17.9		18.1
			Code	Fan power as required	Fan power as required	Fan power as required		12		12.1
			Best	40% below limit or 60% of limit	40% below limit or 60% of limit	40% below limit or 60% of limit		7.2		7.2
6046B FanPowVAV	Fan power limit requirement for VAV	15	Worst	NA	NA	NA	bHP (not SP)	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6051 OutdoorHeat	Outdoor heating: radiant and controlled	15	Worst	24/7 during Winter months, 5 kW design power	24/7 during Winter months, 5 kW design power	24/7 during Winter months, 5 kW design power	Heat Schedule; Average output	24/7 during Winter; 100%	24/7 during Winter; 100%	24/7 during Winter; 100%
			Code	Schedule based on building occupancy schedule, 2.5 kW design power	Schedule based on building occupancy schedule, 2.5 kW design power	Schedule based on building occupancy schedule, 2.5 kW design power		Match occupancy; 50%	Match occupancy; 50%	Match occupancy; 50%
			Best	NA	NA	NA		NA	NA	NA
6056 Econ100Pct	Economizer supplies 100% design supply air	15	Worst	No economizer	No economizer	No economizer	OA fraction max observed; 100% = 0.7 OA fraction	0%	0%	0%
			Code	Economizer as required	Economizer as required	Economizer as required		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6058 EconHiLimit	Economizers should have appropriate high-limit shutoff control and be integrated	15	Worst	High limit Tdb of 55F	High limit Tdb of 55F	High limit Tdb of 55F	Economizer high limit cutoff temp	55F	55F	55F
			Code	Separate baseline to use fixed dry bulb. High limit Tdb of 65F.	Separate baseline to use fixed dry bulb. High limit Tdb of 75F.	Separate baseline to use fixed dry bulb. High limit Tdb of 65F.		65F	75F	65F
			Best	NA	NA	NA		NA	NA	NA
6066p WaterEconCap	Water economizer capacity meets requirements	15	Worst	NA	NA	NA	% Cooling tons of required	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6067p WaterEconDP	Pre-cooling coils have low pressure drop	15	Worst	NA	NA	NA	ft	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6070 FanVSD	Multi-zone systems shall be VAV and fans with motors ≥threshold hp shall have variable speed, variable pitch axial, or fan demand reduction	15	Worst	NA	NA	NA	NA	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6071 FanPresReset	Static pressure reset for multi-zone VAV fans	15	Worst	NA	NA	NA	NA	NA	NA	NA
			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6075p	Multiple boiler systems must	20	Worst	NA	NA	NA	NA	NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
BoilerLoadDistr	include sequencing controls		Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6082	WSHP shall have a deadband between heat rejection and addition	15	Worst	NA	NA	NA	°F	NA	NA	NA
WSHPDeadband			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	15	Worst	NA	NA	NA	NA	NA	NA	NA
			Below	NA	NA	NA		NA	NA	NA
WSHPvalve			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6090	Hydronic systems > 300 MBH shall reset supply water temp or reduce system flow	15	Worst	NA	NA	NA	NA	NA	NA	NA
HydRstTmpFlow			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6091p	Multiple chiller shall reduce flow when a chiller is shut down	20	Worst	NA	NA	NA	NA	NA	NA	NA
ChillerIsol			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
6093p	Multiple Boilers plants shall reduce flow when a boiler is shut down	20	Worst	NA	NA	NA	NA	NA	NA	NA
BoilerIsol			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6094	Tower Fans ≥ 75 hp shall have variable speed control	20	Worst	NA	NA	NA	NA	NA	NA	NA
TwrFanVSD			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	15	Worst	NA	NA	NA	NA	NA	NA	NA
SATreset			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6105p	Hot gas bypass only allowed with multiple steps of unloading or capacity modulation	15	Worst	Single compressor no staging	Single compressor no staging	Single compressor no staging	% waste of modeled cooling load	10.9%	10.9%	10.9%
HotGasBypass			Code	Multistage Compressor	Multistage Compressor	Multistage Compressor		0%	0%	0%
			Best							
6106AS	VAV ventilation optimization	15	Worst	NA	NA	NA	NA	NA	NA	NA
DynVentReset			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
6108AS	Single zone VAV	15	Worst	Constant Volume fan	Constant Volume fan	Constant Volume fan	Min VAV or multi-speed fan%	100%	100%	100%
SZVAV			Code	SZVAV or two speed fan; code minimum speed	SZVAV or two speed fan; code minimum speed	SZVAV or two speed fan; code minimum speed		67%	67%	67%

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	SZVAVor two speed fan; low minimum speed	SZVAVor two speed fan; low minimum speed	SZVAVor two speed fan; low minimum speed		25%	25%	25%
6109pAS	Parking garage fan controls	15	Worst	Fans run full during occupied hours	Fans run full during occupied hours	Fans run full during occupied hours	Minimum fan speed	100%	100%	100%
GarageFanCtrl			Code	Controlled by CO sensors, 50% minimum fan speed	Controlled by CO sensors, 50% minimum fan speed	Controlled by CO sensors, 50% minimum fan speed		50%	50%	50%
			Best	Controlled by CO sensors, 33% minimum fan speed	Controlled by CO sensors, 33% minimum fan speed	Controlled by CO sensors, 33% minimum fan speed		33%	33%	33%
6110pAS	Zone Isolation	15	Worst	NA	NA	NA	NA	NA	NA	NA
ZoneIsolate			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
7002A	Water heater efficiency, Gas	18	Worst	No worst case	No worst case	No worst case		No worst case	No worst case	No worst case
SwhGasEff			Code	Code efficiency	Code efficiency	Code efficiency	Thermal Efficiency, Et	78%Et	78%Et	78%Et
			Best	Enhanced efficiency	Enhanced efficiency	Enhanced efficiency		92% Et	92% Et	92% Et
7002B	Water heater efficiency, Electric	18	Worst	2009 IECC efficiency	2009 IECC efficiency	2009 IECC efficiency	Efficiency factor, EF	EF= 0.8772	EF= 0.8772	EF= 0.8772
SwhEleEff			Code	Code efficiency	Code efficiency	Code efficiency		EF = 0.9172	EF = 0.9172	EF = 0.9172
			Best	postponed	postponed	postponed		postponed	postponed	postponed
7004	Outlet temperature of lavatories in public facility rest rooms is limited to 110°F (43°C)	15	Worst	Higher outlet temperature	Higher outlet temperature	Higher outlet temperature	Lavatory outlet temp, °F	120°F	120°F	120°F
LavTempLmt			Code	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110	SWH Tank temperature setpoint 130F, restroom outlet temperature at 110		110°F	110°F	110°F

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
			Best	NA	NA	NA		NA	NA	NA
7005p SwhHeatTrap	SWH Heat Trap	15	Worst Code Best	No heat trap Heat trap as required NA	No heat trap Heat trap as required NA	No heat trap Heat trap as required NA	NA	No heat trap Heat trap as required NA	No heat trap Heat trap as required NA	No heat trap Heat trap as require d NA
7006 SwhRecPipIns	SWH Pipe Insulation - Recirculated	15	Worst Code Best	NA NA NA	NA NA NA	NA NA NA	Insulation level	NA NA NA	NA NA NA	NA NA NA
7007 SwhNonPipIns	SWH Pipe Insulation - Non-recirculated	15	Worst Code Best	No pipe insulation Non-recirculation pipe insulated NA	No pipe insulation Non-recirculation pipe insulated NA	No pipe insulation Non-recirculation pipe insulated NA	Pipe heat loss (W)	1879 1862 NA	1879 1862 NA	1879 1862 NA
7008 SwhRecCtrl	Circulating hot water system pumps and heat trace must have readily-accessible controls to turn them off when not needed	15	Worst Code Best	NA NA NA	NA NA NA	NA NA NA	NA	NA NA NA	NA NA NA	NA NA NA
9003 ManLtCtl	Manual lighting control	20	Worst Code Best	NA NA NA	NA NA NA	NA NA NA	NA	NA NA NA	NA NA NA	NA NA NA
9009 AutoLtCtrl	Automatic time switch control	15	Worst Code Best	All lights on all night Original lighting schedule in IECC 2012 NA	All lights on all night Original lighting schedule in IECC 2012 NA	All lights on all night Original lighting schedule in IECC 2012 NA	Lights on unoccupied	Yes No NA	Yes No NA	Yes No NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9011	Occupancy sensor control	15	Worst	No occupancy sensors where required	No occupancy sensors where required	No occupancy sensors where required	Score	-10	-10	-10
OccSens			Code	Occupancy sensors installed where required per code	Occupancy sensors installed where required per code	Occupancy sensors installed where required per code		0	0	0
			Best	More savings than code baseline	More savings than code baseline	More savings than code baseline		5	5	5
9014A	Daylighting control	15	Worst	No automatic daylighting controls	No automatic daylighting controls	No automatic daylighting controls	Score	-10	-10	-10
DLCtrlReqd			Code	Required automatic daylight controls in all daylight zones	Required automatic daylight controls in all daylight zones	Required automatic daylight controls in all daylight zones		0	0	0
			Best	All daylightable area is controlled.	All daylightable area is controlled.	All daylightable area is controlled.		2.8	2.8	2.8
9014B	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	15	Worst	No automatic daylighting controls	No automatic daylighting controls	No automatic daylighting controls	% Skylit area controlled	0%	0%	0%
DLCtrlHiBay			Code	50% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls.	50% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls.	50% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls.		50%	50%	50%
			Best	100% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls	100% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls	100% of high bay space in daylight zone. 100% of DL area with automatic daylighting controls		100%	100%	100%
9025	Display lighting control	15	Worst	No separate controls. On during occupancy	No separate controls. On during occupancy	No separate controls. On during occupancy	% of display lighting controlled	0%	0%	0%
DispLtCtrl			Code	Display lighting controlled based on a fraction schedule during the day.	Display lighting controlled based on a fraction schedule during the day.	Display lighting controlled based on a fraction schedule during the day.		100%	100%	100%
			Best	NA	NA	NA		NA	NA	NA
9028	Task lighting control	15	Worst	No manual task lighting controls where required. All task lighting is on.	No manual task lighting controls where required. All task lighting is on.	No manual task lighting controls where required. All task lighting is on.	$task_ltg_ctrl_multiplier	1.0206	1.0206	1.0206

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
TskLtCtrl			Code	Task lighting controls where required.	Task lighting controls where required.	Task lighting controls where required.		1	1	1
			Best	NA	NA	NA		NA	NA	NA
9029	Lighting for nonvisual applications shall be controlled separately	15	Worst	Lighting is on continuously (24/7)	Lighting is on continuously (24/7)	Lighting is on continuously (24/7)	Operating hours per day	24	24	24
NonVisLtCtrl			Code	Model 1000 W controlled to be on 4hr per day.	Model 1000 W controlled to be on 4hr per day.	Model 1000 W controlled to be on 4hr per day.		4	4	4
			Best	NA	NA	NA		NA	NA	NA
9031	Exterior lighting control	15	Worst	Exterior lighting is always on	Exterior lighting is always on	Exterior lighting is always on	Score	-10	-10	-10
ExtLtCtrl			Code	Astronomical clock	Astronomical clock	Astronomical clock		0	0	0
			Best	Photocell plus all lights reduced 30% after midnight to 6 am	Photocell plus all lights reduced 30% after midnight to 6 am	Photocell plus all lights reduced 30% after midnight to 6 am		1.5	1.5	1.5
9034	Tandem wiring	20	Worst	2 ballasts per fixture	2 ballasts per fixture	2 ballasts per fixture	Lamps per ballast	1.5	1.5	1.5
TandWire			Code	1.5 ballasts per fixture	1.5 ballasts per fixture	1.5 ballasts per fixture		2	2	2
			Best	NA	NA	NA		NA	NA	NA
9035	Exit sign maximum power	15	Worst	10 W per side of the exit sign (Each sign has two sides)	10 W per side of the exit sign (Each sign has two sides)	10 W per side of the exit sign (Each sign has two sides)	Watts per each of two sides of exit sign	10	10	10
ExitSign			Code	5 W per side of the exit sign (Each sign has two sides)	5 W per side of the exit sign (Each sign has two sides)	5 W per side of the exit sign (Each sign has two sides)		5	5	5
			Best	2.5 W per side of the exit sign (Each sign has two sides)	2.5 W per side of the exit sign (Each sign has two sides)	2.5 W per side of the exit sign (Each sign has two sides)		2.5	2.5	2.5
9037	Interior lighting power allowance	15	Worst	200% code requirement	200% code requirement	200% code requirement	LPD, W/sf	2.8	2.8	2.8
IntLPD			Code	Code requirement	Code requirement	Code requirement		1.4	1.4	1.4
			Best	50% code requirement	50% code requirement	50% code requirement		0.7	0.7	0.7

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	3B	5A		2A	3B	5A
9047	Additional retail lighting power allowance	15	Worst	~3x code allowed extra lighting = 1.29 w/sf for core zone adder = 22,173 W	~3x code allowed extra lighting = 1.29 w/sf for core zone adder = 22,173 W	~3x code allowed extra lighting = 1.29 w/sf for core zone adder = 22,173 W	Watts of added retail lighting	22,173	22,173	22,173
AddRtlLPD			Code	40% core space; 0.6 & 1.4 average; 1w/sf + 500W = 7,391W ~ 0.429 W/sf; 0.43 w/sf for core zone adder on 17,227 sf	40% core space; 0.6 & 1.4 average; 1w/sf + 500W = 7,391W ~ 0.429 W/sf; 0.43 w/sf for core zone adder on 17,227 sf	40% core space; 0.6 & 1.4 average; 1w/sf + 500W = 7,391W ~ 0.429 W/sf; 0.43 w/sf for core zone adder on 17,227 sf		7,391	7,391	7,391
			Best	10% of 0.6 & 1.4 average; 1w/sf + 500W; 0.043 for core zone adder on 17,227 sf = 739 W	10% of 0.6 & 1.4 average; 1w/sf + 500W; 0.043 for core zone adder on 17,227 sf = 739 W	10% of 0.6 & 1.4 average; 1w/sf + 500W; 0.043 for core zone adder on 17,227 sf = 739 W		739	739	739
9048	Exterior lighting power allowance	15	Worst	200% of allowance	200% of allowance	200% of allowance	Watts exterior lighting	9,489	9,489	9,489
ExtLPD			Code	100% of allowance	100% of allowance	100% of allowance		4,745	4,745	4,745
			Best	25% of allowance	25% of allowance	25% of allowance		1,186	1,186	1,186
9049pAS	Electric feeder and branch circuit maximum voltage drop	15	Worst	7% voltage drop	7% voltage drop	7% voltage drop	Voltage drop	7%	7%	7%
MaxVoltDrop			Code	Total 5% included in baseline	Total 5% included in baseline	Total 5% included in baseline		5%	5%	5%
			Best	NA	NA	NA		NA	NA	NA
9054AS	Occupant based parking garage light control	15	Worst	Lighting on 100%	Lighting on 100%	Lighting on 100%	% lights on	100%	100%	100%
GarageLtCtrl			Code	85% on all hours	85% on all hours	85% on all hours		85%	85%	85%
			Best	NA	NA	NA		NA	NA	NA

Measure ID Abbrev.	Measure Name	Life (yr)	Case	Case Conditions by Climate Zone			Input Units (modeled)	Case Input Parameters		
				2A	**3B**	**5A**		**2A**	**3B**	**5A**
9055pAS	Plug load controls	15	Worst	NA	NA	NA		NA	NA	NA
PlugLdCtrl			Code	NA	NA	NA		NA	NA	NA
			Best	NA	NA	NA		NA	NA	NA
9099p	Lighting Testing or Commissioning	15	Worst	No commissioning	No commissioning	No commissioning	NA	-10	-10	-10
LightCx			Code	General commissioning and functional testing as required	General commissioning and functional testing as required	General commissioning and functional testing as required		0	0	0
			Best	High quality comprehensive commissioning	High quality comprehensive commissioning	High quality comprehensive commissioning		3	3	3

Appendix C

Code Measures Ranked by LCC Energy Cost Impact

Appendix C

Code Measures Ranked by LCC Cost Impact

Graphs are shown on the following pages, ranking the measures by simulated or calculated present value life-cycle cost (LCC) energy savings. Separate graphs are provided by building type and climate zone. Measure abbreviations and numbers can be found in Appendix B. The values used in the graphs can be found in Table 4.4, sorted by measure reference number.

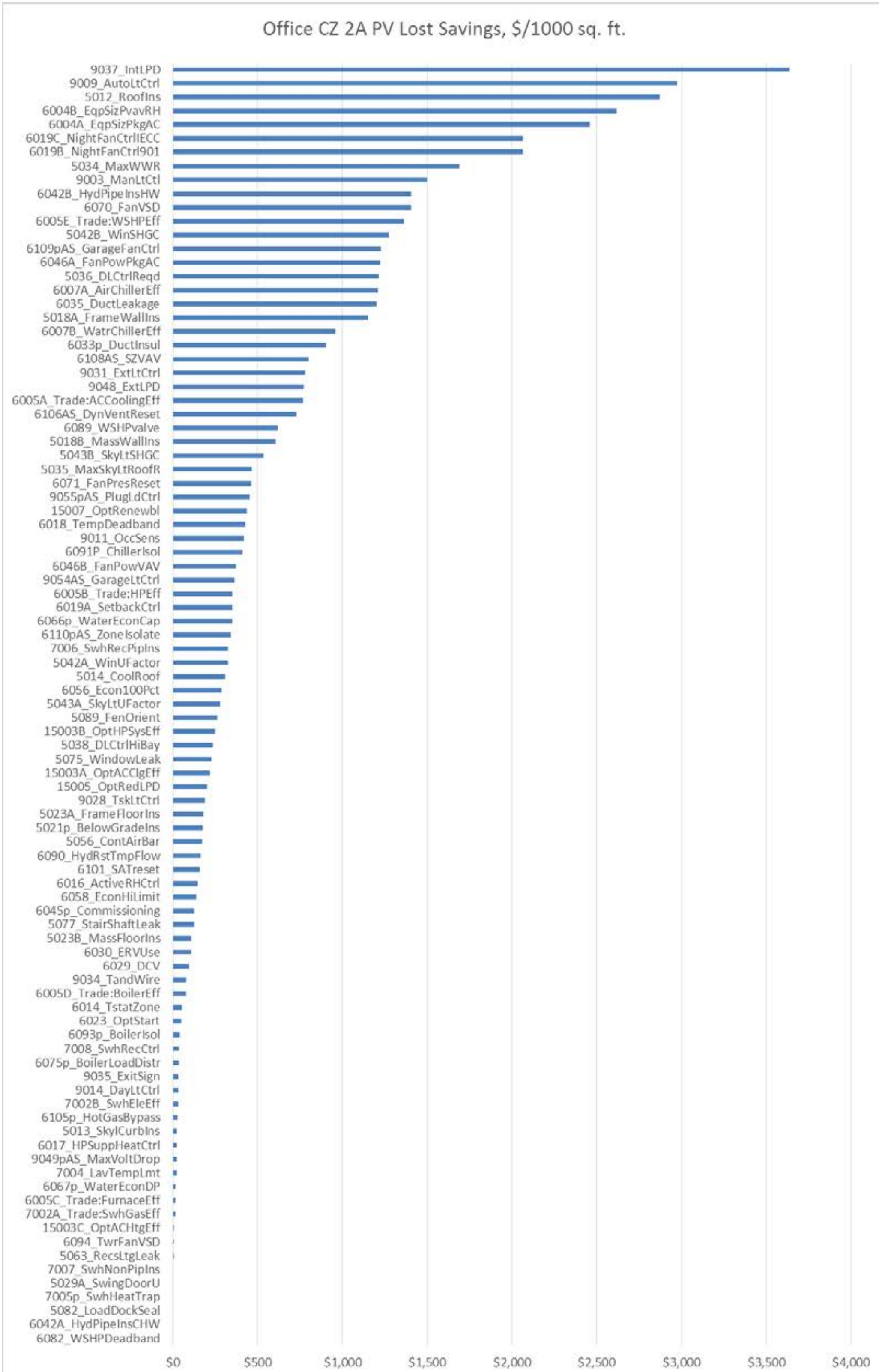

Figure C.1. Ranked Code Measures by LCC: Office Climate Zone 2A

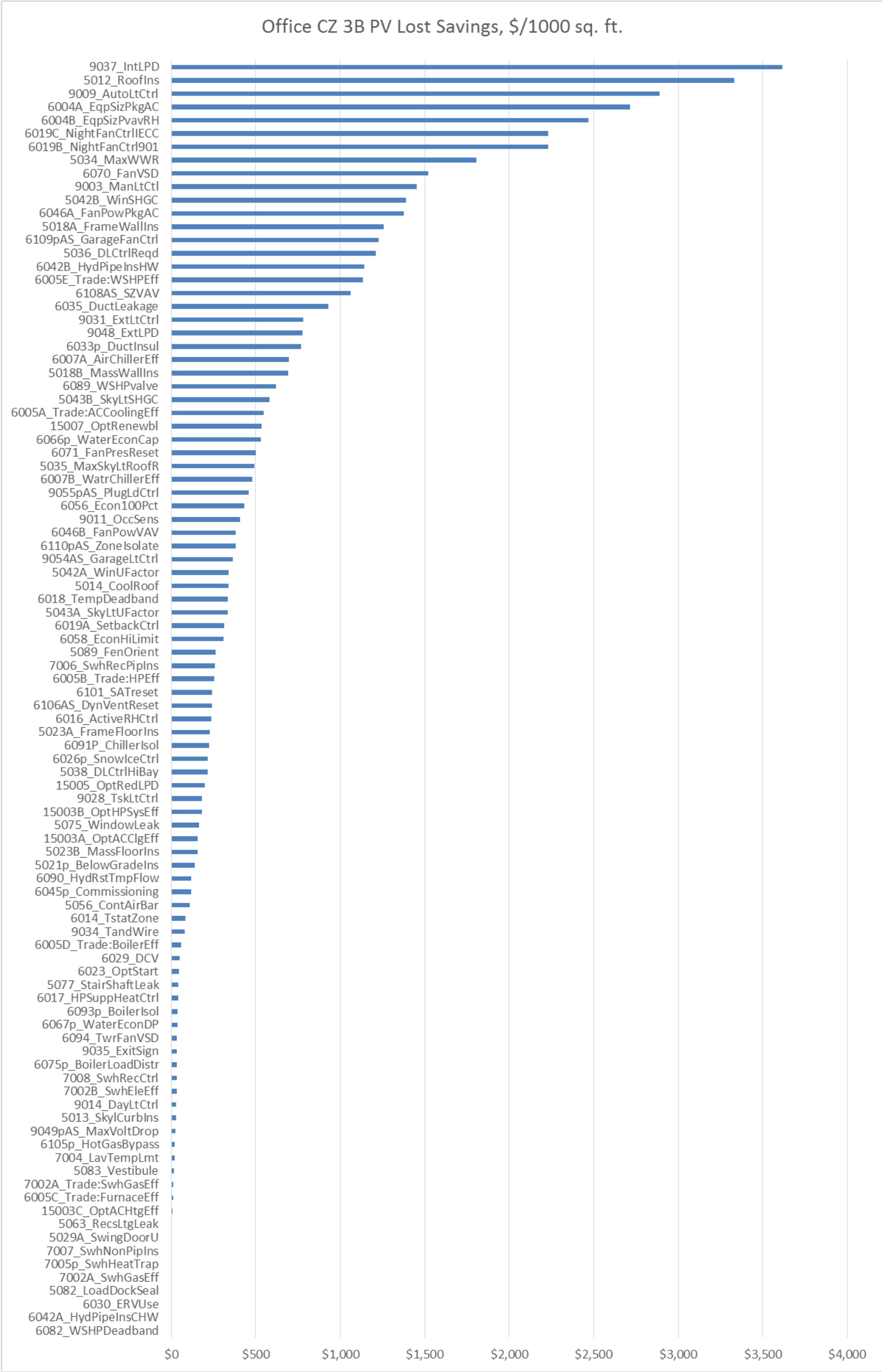

Figure C.2. Ranked Code Measures by LCC: Office Climate Zone 3B

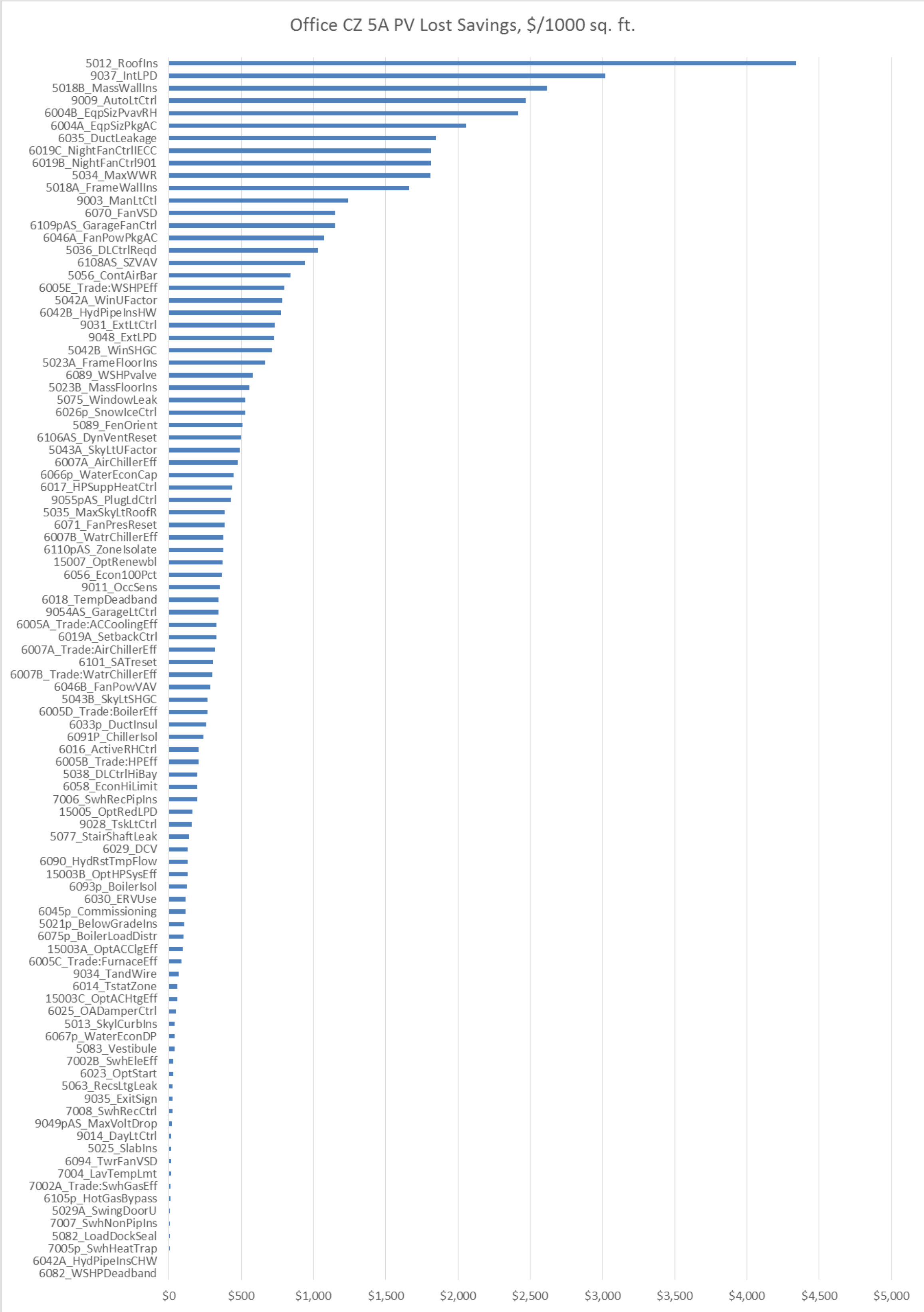

Figure C.3. Ranked Code Measures by LCC: Office Climate Zone 5A

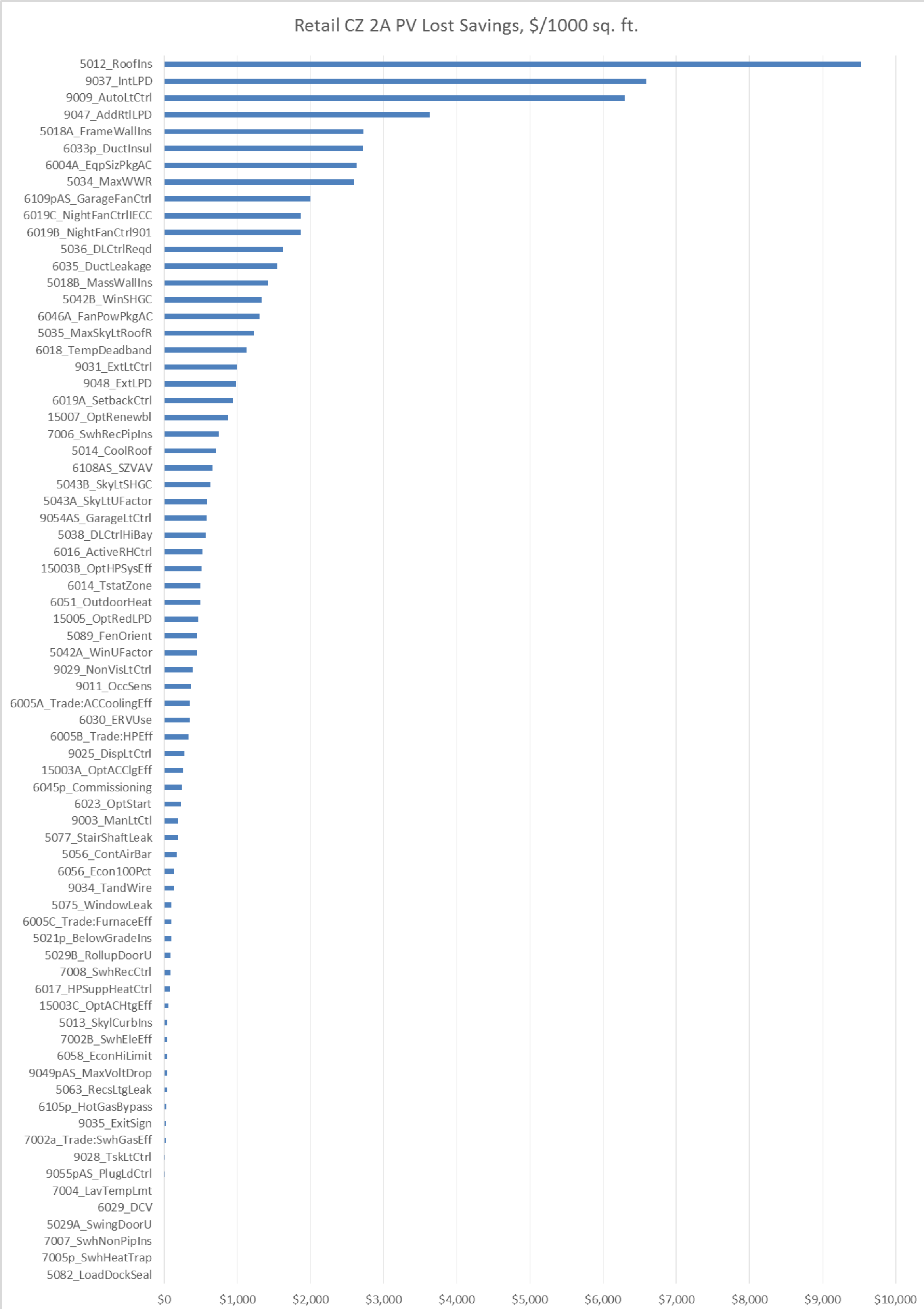

Figure C.4. Ranked Code Measures by LCC: Retail Climate Zone 2A

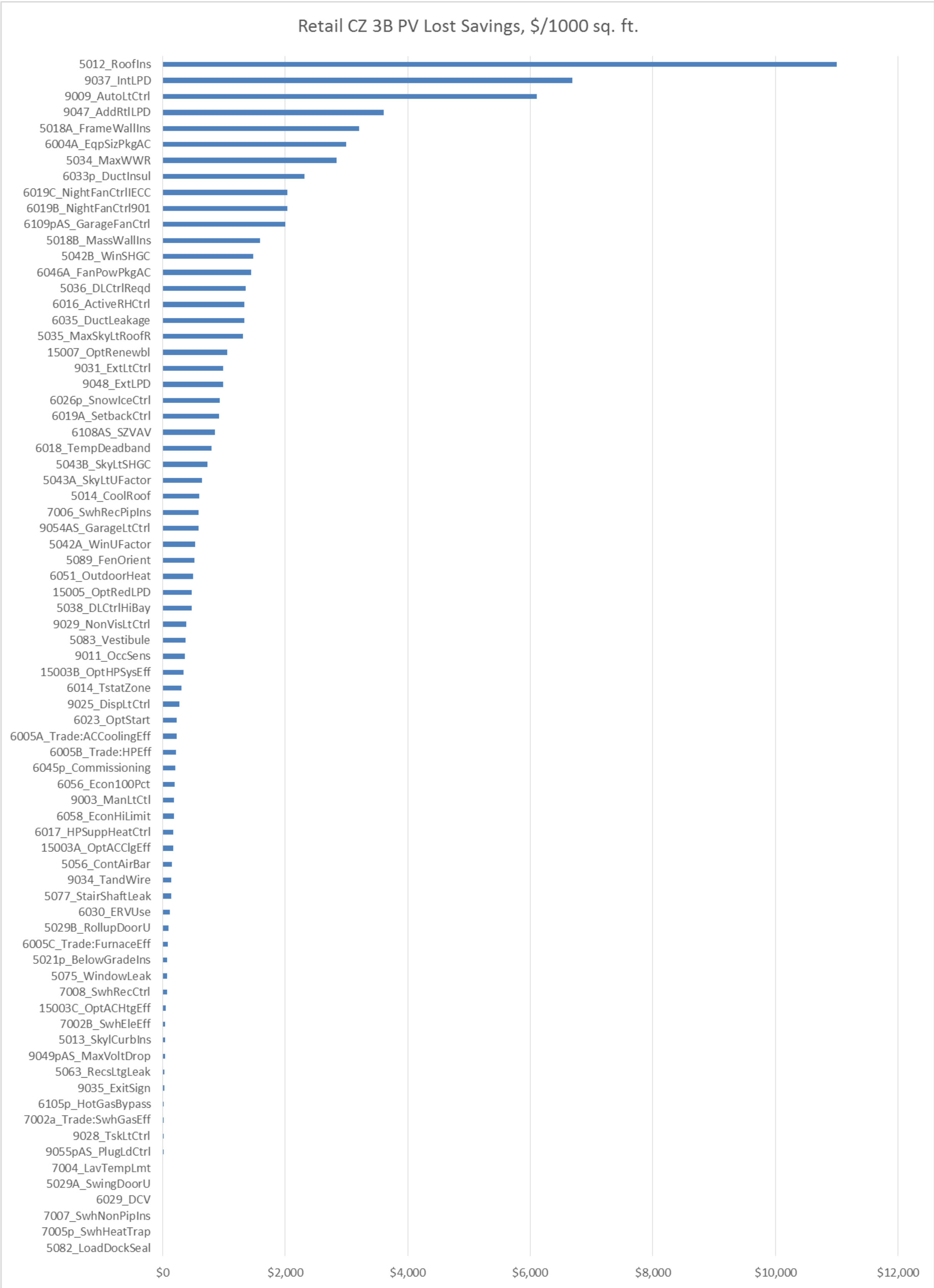

Figure C.5. Ranked Code Measures by LCC: Retail Climate Zone 3B

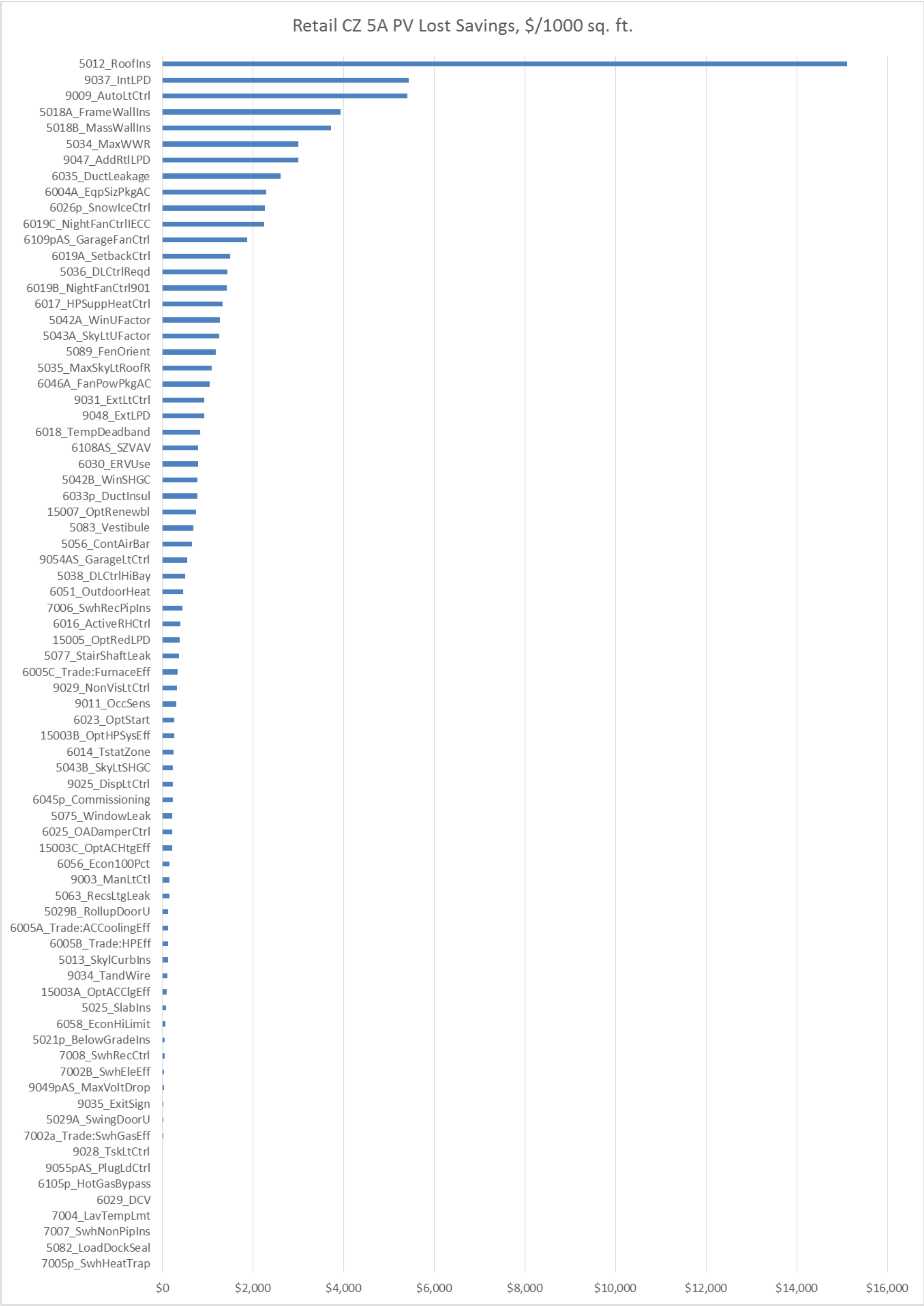

Figure C.6. Ranked Code Measures by LCC: Retail Climate Zone 5A

Appendix D

Sample Field Audit Form

Table D.1. Sample Data Collection Form

Building Code Verification Record

Copy row: Select any cell on row, then hit this button. Copy rows when measures apply differently to parts of building.

Delete Dup Row

Code Required Factors or conditions must match actual code, option path chosen, or performance baseline.

Building Information

Conditioned Floor Area	8,827	sq ft
Building Type	Retail	
ASHRAE Climate Zone	2A	
Number of stories	1	
Scope	Full Bldg	
Which option path?	NA-Perf	
Compliance Path?	Performance	

Initialize applicability after Equip, CZ or Bldg type is changed

crete code indicators (see comme

IECC: ^ 2009; * 2012; ** 2015

90.1: - 2007; + 2010; ++ 2013

Building Identifier	FL_SM_R_015	
City/St	Gainesville	FL
Actual code	2009 IECC	
System Type	DX cool/Furnace; Packaged (incl	VRF or
Occupancy	Retail	100%
Occ'pcy 2		
Occ'pcy 3		0%

Building comments:

Accessed during retail hours. Unable to access office, receiving area, or mechanical closet. Main body and bathrooms all accessible.

Equipment in Building:

8

4

12

Y	DX cooling
N	Gas Furnace
N	Air-to-Air Heat Pump
N	WSHP
N	VAV Reheat System
N	Gas/Oil Boiler
N	Air-Cooled Chiller
N	Water-cooled Chiller

FL State Energy Prices

Elec $0.0950

Nat Gas $1.0530

Source: EIA 2015 average commercia

"Applicable floor area" is typically full building conditioned area; however, input for tenant infill, split measures, or multiple HVAC system types

Total measure time: ***19.00***

				Code or Performance Requirement		***Plan Takeoff Condition***		***As Found Condition***								
Measure #	**Measure name** (see requirements tab for items included)	**Apply to Bldg**	**Factor Units**	**Factor**	**Discrete Condition**	**Factor**	**Discrete Condition or Quality**	**Verif Lvl**	**Factor**	**Discrete Condition or Quality**	**Affected quantity**	**Applicabile units**	**Measure specific Comments**	**Measure Time, hr**	**Surveyed Floor Area**	**Complies**
5012	Roofs shall be insulated to meet CZ requirements	Y	U-factor	0.490		0.045		inf	0.045	Fair Installation = Gaps over 2.5% area	9,026	ft2 net roof area	Inferred from Plans. Not sure if good or fair insulation.	0.75	8,827	OK
5014	Low slope roofs in CZ 1-3 shall be cool roofs	Y	Reflectance	0.550		0.550		ver	0.550		9,026	ft2 of net roof area	White Roof Verified.	0.25	8,827	OK
5018A	Above grade frame walls shall be insulated to meet CZ requirements	Y	U-Factor	0.084		0.053		inf	0.053	Fair Installation = Gaps over 2.5% area	1,680	ft2 net opaque wall area	Inferred from plans. Plans specify "wood framed and others" value (0.084) found in IECC with this specifications. Plans and report show only walls North and South.	0.5	8,827	OK
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	Y	U-factor	0.092		0.048		inf	0.048	Fair Installation = Gaps over 2.5% area	3,120	ft2 net opaque wall area	Inferred from plans.	0.5	8,827	OK
5023A	Exterior frame floors shall meet the insulation requirements	x	U-factor							Select Condition		ft2 exterior floor			0	NA
5023B	Exterior mass floors shall meet the minimum R-value or U-value by assembly type	x	U-factor							Select Condition		ft2 exterior floor			0	NA
5029B	Opaque rollup doors shall meet U-factor requirements	x	Door U-factor									ft2 doors			0	NA
5034	Window-to-wall ratio shall meet maximum limits	Y	% window area	10.5%		10.5%		ver	10.9%		4,800	ft2 Gross Wall Area		0.5	8,827	**Not**
5035	Skylight to roof ratio shall meet maximum limits	N	% skylight area									ft2 Gross Roof Area	No Skylights.		8,827	NA
5042A	Windows shall meet U-factor requirements	Y	U-Factor	0.450		1.100		ver	1.100		524	ft2 window affected	Estimated with IECC table for observed materials: Single Pane, Metal, Tinted. Not specified on plans	1	8,827	**Not**
5042B	Windows shall meet SHGC requirements	Y	SHGC	0.340		0.700		ver	0.700		524	ft2 window affected	Estimated with IECC table for observed materials: Single Pane, Metal, Tinted. Not specified on plans	1	8,827	**Not**
5043A	Skylights shall meet U-factor requirements	N	U-Factor									ft2 skylight affected	No Skylights.		8,827	NA
5043B	Skylights shall meet SHGC requirements	N	SHGC									ft2 skylight affected	No Skylights.		8,827	NA
5056	Building shall meet continuous air barrier requirements	x					Select Condition			Select Condition		ft2 thermal envelope, excluding slab floor/UG walls			0	NA
5077	Stair and shaft vent leakage	x					Select Condition			Select Condition		# of shafts and stairwells			0	NA

*Cells colored in ivory are user inputs. When Measures are not applicable or not included for the building type, rows are greyed out.

Table D.2. Sample Data Collection Form, Continued

baseline.				*Code or Performance Requirement*		*Plan Takeoff Condition*		*As Found Condition*					*Total measure time:*	*19.00*		
Measure #	Measure name (see requirements tab for items included)	Apply to Bldg	Factor Units	Factor	Discrete Condition	Factor	Discrete Condition or Quality	Verif Lvl	Factor	Discrete Condition or Quality	Affected quantity	Applicable units	Measure specific Comments	Measure Time, hr	Surveyed Floor Area	Complies
5083	Building entrances shall be protected with an enclosed vestibule	x					Select Condition			Select Condition		# of Entrances			0	NA
5089	Fenestration orientation	x	ft2 of excess E + W window area	0		332		ver	332		524	ft2 of total window area	Single window entered in model. South orientation.	0.5	0	NA
6005A	Packaged air conditioner efficiency	Y	SEER	13		13		inf	13		8	Tons cooling			8,827	OK
6005B	Packaged heat pump efficiency	x	HSPF									MBh heating			0	NA
6005C	Gas furnace efficiency	x	Ec									MBh heating			0	NA
6005D	Boiler efficiency	x	Ec									MBh heating			0	NA
6005E	WSHP efficiency	x	COP									Tons cooling			0	NA
6007A	Air-cooled Chiller efficiency	x	EER									Tons cooling		0.75	0	NA
6007B	Water-cooled Chiller efficiency	x	kW/ton									Tons cooling			0	NA
6017	Heat pump supplementary heat control	x					Select Condition			Select Condition		MBh heating (HP only, exclude			0	NA
6018	Thermostat deadband requirement	Y	deg.F					unk			8,827	ft2 floor area affected	Unable to observed. Not written on the plans.	0.25	8,827	OK
6019A	Thermostat heating setback	Y	deg.F					unk			8,827	ft2 floor area affected	Not on plans. Not able to access on site.	1	8,827	OK
6019B	Thermostat cooling setback	Y	deg.F					unk			8,827	ft2 floor area affected	Not on plans. Not able to access on site.	0.5	8,827	OK
6019C	Night fan control	Y			(^) Fan Cycles during Unoccp by Schedule; but fan "ON" during warmup		(^) Fan Cycles during Unoccp by Schedule; but fan "ON" during warmup	inf		(^) Fan Cycles during Unoccp by Schedule; but fan "ON" during warmup	2,400	Total supply fan CFM	Inferred from plans.	0.75	8,827	OK
6023	Optimal start controls	x					Select Condition			Select Condition		ft2 floor area affected			0	NA
6026p	Snow and ice-melting system control	x					Select Condition			Select Condition		ft2 of heated surface area			0	NA
6029	Demand control ventilation	Y			(^ * ** - + ++) DCV installed		(^ * ** - + ++) DCV installed	inf		(^ * ** - + ++) DCV installed	8,482	ft2 space area qualified for	From Plans. Excluded Restrooms in ft^2.	0.5	8,827	NA
6030	Energy recovery requirement	x					Select Condition			Select Condition		cfm OA			0	NA
6033p	Exterior (outside building) Duct insulation	N	R-value of duct insulation									ft2 exterior duct surface	No Exterior duct.		8,827	NA
												SA cfm affected				

*Cells colored in ivory are user inputs. When Measures are not applicable or not included for the building type, rows are greyed out.

Table D.3. Sample Data Collection Form, Continued

baseline.				*Code or Performance Requirement*		*Plan Takeoff Condition*		*As Found Condition*					*Total measure time:*	*19.00*		
Measure #	**Measure name (see requirements tab for items included)**	**Apply to Bldg**	**Factor Units**	**Factor**	**Discrete Condition**	**Factor**	**Discrete Condition or Quality**	**Verif Lvl**	**Factor**	**Discrete Condition or Quality**	**Affected quantity**	**Applicabile units**	**Measure specific Comments**	**Measure Time, hr**	**Surveyed Floor Area**	**Complies**
6035	Duct leakage requirement	N			(^ * ** - + ++) Sealed As Required		Select Condition			Select Condition		SA cfm affected (only applies to ductwork outside conditioned	No Exterior duct.		8,827	NA
6042B	Hydronic Piping HW Insulation Requirement	N	R-value of pipe insulation									Total pipe length (Lin ft) HWS + HWR	Not Hydronic.	0.25	8,827	NA
6045p	Mechanical Commissioning	x			(^) Cx Not completed or specified		(* ** - + ++) Commissioned; Satisfactory Quality	inf		(* ** - + ++) Commissioned; Satisfactory Quality	8,827	ft2 floor area	Changed "Applied to building" to an x since not required under 2009 IECC. Plans state testing of HVAC units.		0	NA
6046A	Fan power limit requirement for PkgAC	N	nhp or bhp									Total supply fan CFM	It doesn't exceed 5hp.		8,827	NA
6046B	Fan power limit requirement for VAV	x	nhp or bhp	5		1.5		ver	1.5		2,400	Total supply fan CFM		0.5	0	NA
6051	Outdoor heating: radiant and controlled	x					Select Condition			Select Condition		MBh heating			0	NA
6056	Economizer supplies 100% design supply air	x	OA% available for econo.	20%		2%		inf	2%		6	Tons mechanical cooling	Inferred from Plans "Economizer with Barometric relief" IECC does not require economizer based on climate zone.	0.5	0	NA
6066p	Water economizer capacity meets requirements	x	Water Econo Cooling tons output								0.0	Tons cooling not covered at given conditions	IECC does not require economizer based on climate zone.	0.25	0	NA
6070	Multi-zone reheat systems shall be VAV with appropriate zone minimums, and fans with motors ≥threshold hp shall be variable speed or pitch	N	sum of zone reheat min cfm		(^ * ** - + ++) Variable speed fan with VSD; or vari-pitch axial fan		Select Condition			Select Condition		Total fan CFM	Doesn't apply. Fan hp = 1.5.	0.25	8,827	NA
6071	Static pressure reset for multi-zone VAV fans	N			(** ++) Static pressure reset at least 0.5" w.c.; with max setpoint 1.2" w.c.		Select Condition			Select Condition		Total fan CFM	Doesn't apply. Fan hp = 1.5.	0.25	8,827	NA
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	x					Select Condition			Select Condition		pump nameplate HP			0	NA
6091p	Multiple chiller shall reduce flow when a chiller is shut down	x			(^ * ** - + ++) Individual chiller valves; and separate pumps for each chiller or VSD on common pump		Select Condition	unk		Select Condition	6	Tons cooling		0.5	0	NA

*Cells colored in ivory are user inputs. When Measures are not applicable or not included for the building type, rows are greyed out.

Table D.4. Sample Data Collection Form, Continued

baseline.				*Code or Performance Requirement*		*Plan Takeoff Condition*			*As Found Condition*				*Total measure time:*	*19.00*		
Measure #	**Measure name** (see requirements tab for items included)	**Apply to Bldg**	**Factor Units**	**Factor**	**Discrete Condition**	**Factor**	**Discrete Condition or Quality**	**Verif Lvl**	**Factor**	**Discrete Condition or Quality**	**Affected quantity**	**Applicabile units**	**Measure specific Comments**	**Measure Time, hr**	**Surveyed Floor Area**	**Complies**
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	N			(^ * ** - + ++) SAT is reset; ≥ 25% des SA to Space reset		(^ * ** - + ++) SAT is reset; ≥ 25% des SA to Space reset	inf		(^ * ** - + ++) SAT is reset; ≥ 25% des SA to Space reset	110	Total fan CFM	No multizone	0.5	8,827	NA
6106AS	VAV ventilation optimization	x			(^ * -) No VAV ventilation optimization		(^ * -) No VAV ventilation optimization	inf		(** + ++) VAV ventilation optimization	2,056	OA cfm	Not required by code.	1	0	NA
6108AS	Single zone VAV	x	% min fan speed									Supply cfm			0	NA
6109pAS	Parking garage fan controls	x			(^ * -) Constant volume parking garage exhaust		Select Condition			Select Condition		Fan hp	Ashrae Only		0	NA
6110pAS	Zone Isolation	x			(^ *) Zones with different schedule not isolated; or zone area exceeds 25 ksf or 1 floor		Zone air shut off Unoccp by Sensor; and zone areas are < 5 ksf			Select Condition		ft2 spaces not isolated and running during off hours	Ashrae Only	0.5	0	NA
7006	SWH Pipe Insulation - Recirculated	N	R-value of pipe insulation									LF SHW Pipe		0.5	8,827	NA
9003	Manual lighting control	Y			(^ * **) Manual 2-step controls; w/reduction to ≤50% in each room		(-) Manual 1-step room controls for 100% off only	inf		(-) Manual 1-step room controls for 100% off only	8,827	ft2 floor area affected.	Inferred from plans.	0.5	8,827	NA
9009	Automatic time switch control	Y			(^ *) Automatic time controls ; Control zones ≤25k ft2/1 floor; and override limited to 5000 sf & 2 hours		Automatic time controls ; Control zones >25k ft2/1 floor; or override >5000 sf or > 2 hours	inf		Automatic time controls ; Control zones >25k ft2/1 floor; or override >5000 sf or > 2 hours	8,482	ft2 floor area affected	Inferred from plans. Time control referenced, but not to the details identified in these options.	1	8,827	**Not**
9011	Occupancy sensor control	Y			(^ * ** - + ++) Occupancy sensors ; Auto on 100%; time off ≤ req'd		Occupancy sensors ; Auto on 100%; time off > req'd	inf		(^ * ** - + ++) Occupancy sensors ; Auto on 100%; time off ≤ req'd	345	ft2 floor area required to have occupancy sensors	Only found in Restrooms. Store Operating at time of the site visit. Could not verified time to off.	1.5	8,827	OK
9014A	Daylighting control	Y			(^ * **) Daylight zone w/; separate manual control; zones ≤ ft2 req'd		(-) Daylight zone not controlled separately	ver		(-) Daylight zone not controlled separately	300	ft2 of floor area where DL controls req'd	Represents front entry area. All other windows were blocked by partitions. No separate control observed in building, though it is very crowded with goods. No indication on plans of separate control for this zone.		8,827	**Not**
9014B	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	N			(^ -) Daylight zone not controlled separately; or no skylights		Select Condition			Select Condition		ft2 of floor area where DL controls req'd	No High Bay.		8,827	NA
9025	Display lighting control	N					Select Condition			Select Condition		Display Watts (W)	No speical lighting observed on site or in plans		8,827	NA

*Cells colored in ivory are user inputs. When Measures are not applicable or not included for the building type, rows are greyed out.

Table D.5. Sample Data Collection Form, Continued

baseline.				Code or Performance Requirement		Plan Takeoff Condition		As Found Condition						Total measure time: 19.00		
Measure #	Measure name (see requirements tab for items included)	Apply to Bldg	Factor Units	Factor	Discrete Condition	Factor	Discrete Condition or Quality	Verif Lvl	Factor	Discrete Condition or Quality	Affected quantity	Applicabile units	Measure specific Comments	Measure Time, hr	Surveyed Floor Area	Complies
9029	Lighting for nonvisual applications shall be controlled separately	N					Select Condition			Select Condition		Uncontrolled Watt	No speical lighting observed on site or in plans		8,827	NA
9031	Exterior lighting control	Y			(^ * ** -) Photocell or Astro time switch		No exterior lighting controls	ver		(^ * ** -) Photocell or Astro time switch	1,400	Exterior Watts Affected	No indicaiton on plans, but lights were off when we arrived.	0.5	8,827	OK
9037	Interior lighting power allowance	Y	Watts interior lighting except retail display	1,400		7,919		ver	7,919		8,827	ft2 floor area	Count and lamp tpy on plans aligned well with observation. We could observd all	0.5	8,827	Not
9047	Additional retail lighting power allowance	N	Watts retail display lighting								1				8,827	NA
9048	Exterior lighting power allowance	Y	Exterior Total Watts	2,800		2,374		ver	2,374				Lighting count matched plans. Plans bulb wattage seemed plausible.	0.5	8,827	OK
9054AS	Occupant based parking garage light control	N			(^ * ** -) Schedule based lighting controls		Select Condition			Select Condition		W Parking garage lighting	No garage.		8,827	NA
9055pAS	Receptacle controls	x			(^ * ** -) No automatic plug load controls		Select Condition			Select Condition		Floor area subject to		0.25	0	NA
9099p	Lighting Testing or Commissioning	x			(^ -) Cx Not completed or specified		(^ -) Cx Not completed or specified	inf		(^ -) Cx Not completed or specified	8,827	ft2 floor area	Cx not completed/specified	0.5	0	NA
15007	Optional onsite renewable	x	Annual kWh								1		No renewables.		0	NA

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Pacific Northwest
NATIONAL LABORATORY

www.pnnl.gov

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

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