PNNL-23977

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

2015 IECC: Energy Savings Analysis

May 2015

VV Mendon
ZT Taylor
SU Rao
YL Xie

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov

This document was printed on recycled paper.
(8/2010)

PNNL-23977

2015 IECC: Energy Savings Analysis

VV Mendon
ZT Taylor
SU Rao
YL Xie

May 2015

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Section 304(a) of the Energy Conservation and Production Act, as amended, requires the Secretary of Energy to make a determination each time a revised edition of the 1992 Model Energy Code (MEC), or any successor thereof, is published with respect to whether the revised code would improve energy efficiency in residential buildings. The International Energy Conservation Code (IECC), as administered by the International Code Council (ICC), establishes the national model code for energy efficiency requirements for residential buildings.[1] The latest edition of the IECC, the 2015 IECC, was published on June 3, 2014 and forms the basis of this analysis.

To meet these statutory requirements, as well as to assist states and adopting entities in understanding associated savings, the DOE Building Energy Codes Program and Pacific Northwest National Laboratory (PNNL) conduct analyses to evaluate the differences between the latest edition of the IECC and its immediate predecessor. A qualitative analysis is conducted, identifying all changes made to the previous edition of the IECC, and characterizing these changes in terms of their anticipated impact on residential building energy consumption. A quantitative analysis is then modeled through building energy simulation to estimate the resulting energy impacts.

This report documents the technical analysis used to evaluate whether residential buildings constructed to meet the requirements of the 2015 IECC would result in energy efficiency improvements over residential buildings constructed to meet the requirements of the previous edition, the 2012 IECC. PNNL considered all code change proposals approved for inclusion in the 2015 IECC during the ICC code development cycle[2], and evaluated their combined impact on a suite of prototypical residential building energy models across all U.S. climate zones.

Many of the code change proposals approved for inclusion in the 2015 IECC were deemed, within the context of the current analysis, to not have a direct impact on residential energy efficiency. Of the 76 code change proposals approved for inclusion in the 2015 IECC:

- 6 were considered beneficial,
- 62 were considered neutral,
- 5 were considered negligible,
- 2 were considered detrimental, and
- 1 was considered to have an unquantifiable impact at this time.

The present analysis builds on previous work conducted by PNNL to assess the energy performance of the 2009 and 2012 IECC (Mendon et al 2013). A suite of 480 residential prototype building models—a combination of the 32 residential prototype buildings and 15 climate zones—complying with the 2012

[1] In 1997, the Council of American Building Officials was incorporated into the ICC and the MEC was renamed to the IECC.
[2] More information on the ICC code development and consensus process is described at http://www.iccsafe.org/cs/codes/Pages/procedures.aspx

IECC was developed using *DOE EnergyPlus version 8.0* (DOE 2013). A second set of prototype building models was then created from the baseline set that incorporated the requirements of the six approved code change proposals with quantifiable energy impacts. Annual energy use for the end uses regulated by the IECC—heating, cooling, fans, domestic water heating, and lighting—was extracted from the simulation output files and converted to an energy use intensity (EUI) based on source and site energy using the prototype building model conditioned floor area. The energy use was also converted to energy cost based on national average fuel prices. The EUIs and energy costs per residence were then aggregated to the national level using weighting factors based on construction shares by foundation and heating system type and new housing permits for single- and multifamily buildings. The development of these weighting factors is described in detail in Mendon et al. (2013). The resulting national energy cost and EUIs indicate that the prototype buildings used less energy under the 2015 IECC than the 2012 edition.

On a national basis, the analysis estimated that buildings built to the 2015 IECC, as compared with buildings built to the 2012 IECC, would result in national source energy savings of approximately 0.87 percent, site energy savings of approximately 0.98 percent, , and energy cost savings of approximately 0.73 percent of residential building energy consumption, as regulated by the IECC. These can be considered conservative estimates based on the assumptions used in modeling the code changes approved for inclusion in the 2015 IECC. These assumptions are discussed in more detail in this report. Site and source EUIs, energy costs and national savings results by climate-zone are shown in Table E.1 through Table E.3.

Table E.1. Estimated Regulated Annual Site and Source Energy Use Intensities (EUI), and Energy Costs by Climate-Zone (2012 IECC)

Climate-Zone	Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	Energy Costs ($/residence-yr)
1	13.96	38.57	845
2	16.99	43.24	1104
3	16.90	40.43	988
4	19.52	44.00	1069
5	27.62	47.49	1162
6	29.28	49.21	1195
7	36.18	63.25	1501
8	50.28	89.49	2320
National Weighted Average	**20.82**	**44.17**	**1086**

Table E.2. Estimated Regulated Annual Site and Source Energy Use Intensities (EUI), and Energy Costs by Climate-Zone (2015 IECC)

Climate-Zone	Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	Energy Costs ($/residence-yr)
1	13.85	38.33	841
2	16.84	42.90	1096
3	16.71	40.03	980
4	19.31	43.56	1060
5	27.38	47.14	1155
6	29.03	48.84	1187
7	35.86	62.72	1490
8	49.80	88.65	2299
National Weighted Average	**20.61**	**43.78**	**1078**

Table E.3. Regulated Annual Energy Savings Estimated between the 2012 and 2015 Editions of the IECC

Climate-Zone	Site EUI[(a)]	Source EUI[(a)]	Energy Costs[(a)]
1	0.78%	0.61%	0.43%
2	0.88%	0.79%	0.68%
3	1.13%	0.99%	0.83%
4	1.08%	0.99%	0.82%
5	0.87%	0.74%	0.63%
6	0.85%	0.75%	0.61%
7	0.88%	0.84%	0.71%
8	0.95%	0.94%	0.94%
National Weighted Average	**0.98%**	**0.87%**	**0.73%**

(a) Percentages are calculated before rounding and may not exactly match percentages calculated directly from Table E.1 and Table E.2.

Acronyms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CASE	California Codes and Standards Enhancement (Initiative)
CEC	California Energy Commission
cfm	cubic feet per minute
CSA	Canadian Standards Association
DHW	domestic hot water
DOE	U.S. Department of Energy
ECPA	Energy Conservation and Production Act
ERI	energy rating index
EUI	energy use intensity
HERS	Home Energy Rating System
HVAC	heating, ventilating, and air-conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IMC	International Mechanical Code
IPC	International Plumbing Code
IRC	International Residential Code
MEC	Model Energy Code
PEX	cross-linked polyethylene
PNNL	Pacific Northwest National Laboratory
SHGC	solar heat gain coefficient

Contents

Tables

Figures

1.0 Introduction

Title III of the Energy Conservation and Production Act, as amended (ECPA), establishes requirements for building energy conservation standards, administered by the U.S. Department of Energy (DOE) Building Energy Codes Program (BECP). (42 U.S.C. 6831 *et seq.*) Section 304(a), as amended, of ECPA provides that whenever the 1992 Model Energy Code (MEC), or any successor to that code, is revised, the Secretary of Energy (Secretary) must make a determination, not later than 12 months after such revision, whether the revised code would improve energy efficiency in residential buildings and must publish notice of such determination in the *Federal Register*. (42 U.S.C. 6833(a)(5)(A)) The Secretary may determine that the revision of the 1992 MEC, or any successor thereof, improves the level of energy efficiency in residential buildings. If so, then not later than 2 years after the date of the publication of such affirmative determination, each State is required to certify that it has reviewed its residential building code regarding energy efficiency and made a determination whether it is appropriate to revise its code to meet or exceed the provisions of the successor code. (42 U.S.C. 6833(a)(5)(B)) DOE announced the Secretary's determination that the 2012 IECC was a substantial improvement over its predecessor in May 2012 (77 FR 29322). Consequently, the 2012 IECC forms the baseline for the current analysis of the 2015 IECC (ICC 2014), which was published by the International Code Council (ICC) on June 3, 2014.

In support of DOE's determination of energy savings of the 2015 IECC, as well as to assist states and adopting entities in understanding associated savings, PNNL evaluated the energy use of residential buildings designed to meet requirements of the 2015 IECC relative to meeting requirements of the 2012 edition. A qualitative assessment of the code change proposals approved for inclusion in the 2015 IECC was undertaken to approximate and characterize the nature of the energy impact of each code change, and evaluate the potential for capturing the energy impact through building energy simulation or other analytical methods. A quantitative analysis was then modeled through building energy simulation to estimate the resulting energy impacts, in which PNNL relied on the set of residential prototype building models and analysis methodologies established in the previous IECC determinations (BECP 2012a, Taylor et al. 2012) for evaluating the energy impact of code change proposals that were deemed quantifiable.

The building energy simulations are carried out using prototype building models constructed to the prescriptive and mandatory requirements of the 2012 IECC and 2015 IECC across the range of U.S. climates. A set of prototype building models were first developed to minimally comply with the prescriptive and mandatory requirements of the 2012 IECC. This set was then modified to create a set of prototype building models minimally compliant with the prescriptive and mandatory requirements of the 2015 IECC. Annual site energy use for the end uses regulated by the IECC—heating, cooling, fans, domestic water heating and lighting—was extracted from the simulation output files and converted to a site and a source energy use intensity (EUI) based on prototype building model conditioned floor area and site-source energy conversion factors discussed in Section 5.0. Energy use was also converted to energy cost based on national average fuel prices to reflect the homeowner's perspective. The energy costs and EUI metrics for each climate zone were then weighted using foundation shares, heating system shares, and construction starts to yield national energy costs and EUIs for the 2012 and the 2015 editions of the IECC.

The ensuing sections of this document describe the

- characterization of the code change proposals approved for inclusion in the 2015 IECC,
- characterization of the residential prototype building models,
- simulation methodology,
- translation of the modeled code change proposals into modeling inputs used in the computer simulations,
- use of building construction weights to aggregate results from simulations across building types and locations into national results, and
- results of the analysis with regard to the regulated EUIs and energy costs for buildings under both codes, and the energy and energy cost savings for the 2015 IECC over the 2012 IECC.

Review under the Information Quality Act

This report is being disseminated by DOE. The document was thus prepared in compliance with Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) and information quality guidelines issued by DOE. Though this report does not constitute "influential" information, as that term is defined in DOE's information quality guidelines or the Office of Management and Budget's Information Quality Bulletin for Peer Review, the current report builds upon methods of analysis that have been subjected to peer review and public dissemination. In addition, this work has been subjected to internal peer review and external review through the public comment process as part of the DOE determination for the 2015 IECC.

2.0 Qualitative Analysis of the 2015 IECC

In developing the residential provisions of the 2015 edition of the IECC, the ICC approved 76 code change proposals through the ICC code development cycle in 2013. The final results of the 2013 ICC code development cycle are published on the ICC website (ICC 2013), with the 2015 edition of the IECC published in June 2014 (ICC 2014). A qualitative discussion of each approved code change proposal with an impact on residential building energy is included in Table 2.1 and summarized in Table 2.2. Further details are discussed in the subsections below.

2.1 Approved Proposals Having Neutral Impact on Residential Energy Efficiency

A significant majority of approved residential proposals have no direct impact on residential energy efficiency. Most such proposals involve clarifications to the code, improvements in the code's usability and/or consistency with itself or other ICC codes, corrections to inadvertent errors in the code text or wording, addition of options or minor extensions to existing options that increase flexibility for users, updates to references, or requirements for additional documentation in compliance submittals by builders. Although many of these arguably improve the code and could enhance compliance and enforcement in the field, they are considered neutral within the current analysis because any such impact depends on code users' actions rather than on the specific requirements of the code. A few of the neutral-impact proposals represent changes that are outside the scope of residential efficiency, either because they impact only non-residential buildings or they primarily impact indoor air quality or another non-energy factor.

2.1.1 Proposals Not Applicable to Residential Building Energy

The residential portion of the IECC has occasional provisions that relate more to non-residential buildings and spaces than residential. Similarly, the ICC occasionally includes proposed code changes in the residential portion of the IECC code development process that primarily impact non-residential buildings. Finally, some code provisions, although applicable to residential buildings, impact something other than energy efficiency, such as indoor air quality.

- RE1-13 deletes an exception for vestibules in the provisions pertaining to additions, alterations, renovations, and repairs. The residential code has no requirement for vestibules, so the exception was deemed superfluous.
- RE3-13 deletes text relating to commercial building components in "Information on Construction Documents." This is an editorial change.
- RE5-13 deletes a definition of "entrance door" that applied only to non-residential buildings.
- RE193-13 adds requirements for testing of combustion venting systems, a change affecting indoor air quality rather than having a direct impact on home energy usage.
- CE177-13 requires open combustion appliances to be outside conditioned space or in a room isolated from conditioned space and ducted to the outside. Although the change does discourage bad practices that could affect energy (e.g., allowing a leaky envelope to ensure sufficient

combustion air), other code provisions prevent such things, so this change has little direct energy impact.

2.1.2 Proposals with Negligible Impacts

Five proposals may have an impact on energy efficiency, but that impact is considered too small to quantify for the purposes of this analysis:

- RE45-13 slightly increases frame wall U-factor in climate zones 1 and 2. The associated requirements in the R-value table remain unchanged. The proposal was intended to correct a perceived misalignment between the code's R-value-based requirements and the alternative U-factor-based requirements. The changes are very small and unlikely to change wall insulation levels in most homes.
- RE50-13 slightly increases frame wall U-factor in climate zones 1 through 5 but reduces it in climate zones 6 through 8. The associated requirements in the R-value table remain unchanged. The proposal was intended to correct a perceived misalignment between the code's R-value-based requirements and the alternative U-factor-based requirements. The changes are very small and unlikely to change wall insulation levels in most homes because the available R-values tend to be discrete and the minor U-factor changes would only rarely result in a real change to a home.
- CE161-13 allows dynamic glazing to satisfy the solar heat gain coefficient (SHGC) requirements provided the ratio of upper to lower SHGC is 2.4 or greater and is automatically controlled to modulate the amount of solar gain into the space. It is difficult to quantify the direct impact of this change because there is no definition of "controlled to modulate." However, dynamic glazing is generally considered a useful energy management feature and its relatively high cost makes it unlikely to be used without careful consideration of its energy efficiency effects, so there is little reason to expect any detrimental impact.
- CE179-13 exempts fire sprinklers from air sealing requirements. However, all homes still must comply with a maximum overall leakage rate based on a blower-door test, so overall efficiency will likely not be reduced.
- CE283-13 requires drain water heat recovery systems to comply with Canadian Standards Association (CSA) Standard 55 and adds references to CSA Standard 55 to Chapter 5. This enables developers to take credit for efficiency improvements due to the use of drain water heat recovery devices, but only in the context of a performance tradeoff, so overall efficiency should not be affected.

2.1.3 Proposals with Impacts That Cannot Be Estimated

Approved proposal RE-188 adds a new alternative compliance path in the 2015 IECC based on an Energy Rating Index (ERI). While this change does not directly alter stringency of the code, it does provide an additional compliance path as an alternative to the IECC prescriptive and performance paths. Similar past analyses have primarily focused on the prescriptive compliance path, as these requirements are generally considered the predominant path. In addition, performance pathways effectively allow a limitless numbers of ways to comply with the code, and the impact of the ERI path on national residential energy consumption is dependent on the number of homes that use this new path, and the unique characteristics of those homes. No accepted methodology or supporting data sources currently exist to adequately document how buildings meet the performance path criteria. In the absence of such data, an analysis of the performance path would have no empirical basis. Therefore, within the context of the current analysis, the immediate impact of this change on residential energy efficiency is considered not estimable.

2.1.4 Non-mandatory Proposals

RE9-13 adds an appendix (Appendix RB in the 2015 IECC) with informative provisions to ensure homes are "solar-ready." Because the appendix is non-mandatory, there is no direct impact on residential energy efficiency.

2.2 Approved Proposals Having Beneficial Impact on Residential Energy Efficiency

Six approved proposals have been preliminarily identified as having a direct and beneficial impact on the energy efficiency of residential buildings, five of which have been subjected to a quantitative analysis. The remaining proposal, CE8-13, is deemed unquantifiable, due to a lack of sufficient data to characterize historic buildings. The reasons for their categorization as beneficial are discussed briefly here.

- RE107-13 increases insulation requirements for return ducts in attics from R-6 to R-8. Attics are generally the most hostile environment in which air ducts can be located, so the increase in required duct insulation will undoubtedly be beneficial. However, the increase applies only to return ducts (supply ducts are already required to have R-8), which carry air at moderate temperatures, so the impact is likely to be modest.
- RE125-13 adds new requirements for heated water circulation systems and heat trace systems. This change makes the IECC consistent with the International Residential Code (IRC) and the International Plumbing Code (IPC), and clarifies requirements for these systems when present in a home. The change requires such systems to be controlled by demand-activated circulation systems that can be expected to significantly reduce heat losses from pipes and energy consumed by circulation pumps.
- RE132-13 deletes a requirement for insulation on hot water pipes to kitchen spaces and deletes a generic requirement for insulation on long and large-diameter pipes. These changes lower overall efficiency. However, the code change adds a requirement for pipe insulation on all 3/4-inch pipes that previously applied only to pipes with diameter greater than 3/4-inch. Because 3/4-inch is the most common size for the long trunk lines in typical residences, this improvement is likely to compensate for the code change's efficiency losses.
- RE136-13 adds demand control requirements for recirculating systems that use a cold water supply pipe to return water to the tank. Although this change affects relatively few systems, the requirement for demand control is likely to significantly reduce the energy consumption of those systems.
- CE8-13 requires historic buildings, which are generally exempted from the code, to comply with any of the code's provisions for which there is no "compromise to the historic nature and

function of the building." This change will bring a few more buildings under the code's scope and hence improve overall residential efficiency.

- CE362-13 adds a requirement for outdoor reset control for hot water boilers. Requiring that boiler water temperature be lower when outdoor temperature is higher will result in more efficient heating of buildings with hot water boilers.

2.3 Approved Proposals Having Detrimental Impact on Residential Energy Efficiency

Two approved proposals are expected to reduce overall residential energy efficiency. Of the two, only CE66-13 has been subjected to a quantitative analysis because there are not enough data available to characterize sunrooms for RE68-13. The justification behind the categorization of each proposal is discussed briefly here.

- RE68-13 slightly reduces the required efficiency (in terms of U-factor) of glazing in sunrooms. Because the change affects only climate zones 2 and 3, the U-factor change is expected to have minimal impact. Also, the change modifies requirements that apply only to sunrooms that are isolated from the conditioned space; somewhat attenuating the potential detrimental impacts of the U-factor changes. Nonetheless, the change represents a small detrimental impact on residential efficiency.
- CE66-13 defines a new "tropical" climate zone and adds an optional compliance path for semi-conditioned residential buildings having certain defined criteria to be deemed as code compliant in this climate zone. The new climate zone includes locations with relatively low construction rates, and the compliance path only applies to those homes that are semi-conditioned and match the defined criteria; hence, the change impacts relatively few homes. Although the criteria required for qualification under the new compliance path are often beneficial from an energy efficiency standpoint, analysis of individual homes may be required to reach a confident conclusion. Also, because the new path eliminates many of the code's existing requirements for semi-conditioned homes, there is risk that homes originally semi-conditioned will be made conditioned later by occupants (e.g., by adding inefficient window units for air conditioning).

2.4 Qualitative Analysis Findings

Table 2.1 presents the findings resulting from the qualitative analysis, along with a description of the change, as well as an assessment of the anticipated impact on energy savings in residential buildings.

Table 2.1. Qualitative Analysis Findings

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE1-13	R101.4.3 (IRC N1101.3)	Deletes the exception for vestibules in the provisions pertaining to additions, alterations, renovations, and repairs.	Neutral	The residential code has no requirements for vestibules
RE3-13	R103.2 (IRC N1101.8)	Deletes text relating to commercial building components in "Information on Construction Documents."	Neutral	Editorial change
RE5-13	R202 (IRC N1101.9)	Deletes the definition of "entrance door."	Neutral	The definition applied to nonresidential buildings only
RE6 -13	R202 (NEW) (IRC N1101.9 (NEW))	Adds definition of "Insulating Siding" and notes that the insulation level of this siding must be R-2 or greater.	Neutral	Addition of definition
RE9-13	R202 (NEW) (IRC N1101.9 (NEW)), R304 (NEW) (IRC N1101.16 (NEW))	Adds an appendix with non-mandatory provisions for homes to be "solar-ready." Designed to be readily referenced by adopting authorities as needed.	Neutral	No direct impact, but has the potential to increase efficiency in the future
RE12-13	R401.2 (IRC N1101.15)	Minor clarification that the code's mandatory requirements should be met in all compliance paths.	Neutral	Clarification of code requirements
RE14-13	R401.3 (IRC N1101.16)	Adds more options for the allowable locations for posting the certificate of occupancy.	Neutral	Not energy related but does eliminate a small enforcement hindrance
RE16-13	R401.3 (IRC N1101.16)	Similar to RE14-13. Allows more options for the allowable locations for posting the certificate of occupancy.	Neutral	Not energy related but does eliminate a small enforcement hindrance
RE18-13	R402.1 (IRC N1102.1), R402.1.1 (NEW) (IRC N1102.1.1 (NEW))	Cross-references vapor barrier requirements by referencing IRC R702.7.	Neutral	Adds consistency and clarifies code requirements
RE30-13	Table R402.1.1, (IRC Table N1102.1.1)	Modifies footnote h to these tables to allow combined sheathing/siding.	Neutral	Adds an option for combined insulated sheathing/siding that meets code requirements
RE43-13	R402.1.2 (IRC N1102.1.2)	Adds use of term "continuous insulation" instead of "insulating sheathing."	Neutral	Minor clarification of terminology

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE45-13	Table R402.1.3 (IRC N1102.1.3)	Slightly increases frame wall U-factor in climate zones 1 and 2. The R-value table remains unchanged.	Negligible	Intended to correct a perceived misalignment between the code's R-value-based requirements and the alternative U-factor-based requirements. The changes are very small and unlikely to change wall insulation levels in most homes.
RE50-13	Table R402.1.3 (IRC Table N1102.1.3)	Slightly increases frame wall U-factor in climate zones 1-5 but reduces it in climate zones 6-8. The R-value table remains unchanged.	Negligible	Intended to correct a perceived misalignment between the code's R-value-based requirements and the alternative U-factor-based requirements. The changes are very small and unlikely to change wall insulation levels in most homes.
RE53-13	R402.2.1 (IRC N1102.2.1)	Clarifies decreased ceiling insulation allowance for ceilings with attic spaces only.	Neutral	Clarification of the code requirement
RE58-13	R402.2.4 (IRC N1102.2.4)	Clarifies that vertical doors are not "access doors" in R402.2.4 and shall be permitted to meet the fenestration requirements of Table 402.1.1.	Neutral	Clarification of the code requirement
RE60-13	R402.2.7 (IRC N1102.2.7), Table R402.4.1.1 (IRC Table N1102.4.1.1)	Allows the floor cavity insulation to not be in contact with the underside of the subfloor decking if it is in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing.	Neutral	Allows a combination of cavity and continuous insulation to meet the floor R-value requirement
RE63-13	Table R402.1.1 (IRC Table N1102.1.1), R402.2.13 (NNEW) (IRC N1102.2.13 (NEW))	Clarifies footnote h text by rewording it and moving it to new section R402.2.13.	Neutral	Clarification of code requirements

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE68-13	R402.3.5 (IRC N1102.3.5)	Slightly increases sunroom U-factor .	Detrimental	Applies to only climate zones 2 and 3; impacts only thermally isolated sunrooms
RE83-13	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Clarifies requirements for wall corner and headers to have insulation that has at least R-3 per inch, and clarifies that it is the cavities in such components that require the insulation.	Neutral	Minor addition and clarification of code requirements
RE84-13	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Allows a combination of cavity and continuous insulation to meet the floor R-value requirement.	Neutral	Subset of RE60-13; makes minor clarifying revisions to wording.
RE85-13	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Reorganizes Table 402.4.1.1 by adding an additional column and separating "air barrier criteria" from "insulation installation criteria," for clarity.	Neutral	Clarification of code requirements
RE86-13	Table R402.4.1.1 (IRC Table N1102.4.1.1), R402.4.2 (IRC N1102.4.2)	Clarifies language relating to fireplace sealing/door requirements.	Neutral	Clarification of code requirements
RE91-13	R402.4.1.2 (IRC N1102.4.1.2), Chapter 5	Adds references to the American Society for Testing and Materials (ASTM) standards E779 and E1827 for blower door testing.	Neutral	Adds more detailed references for procedures
RE103-13	R403.1.1 (IRC N1103.1.1)	Adds requirements for the thermostat to be pre-programmed by the manufacturer.	Neutral	Clarifies that the requirement is the manufacturer's responsibility
RE105-13	R403.1.1 (IRC N1103.1.1)	Makes the programmable thermostat requirement apply to any heating/cooling system.	Neutral	No direct impact on energy
RE107-13	R403.2.1 (IRC N1103.2.1)	Increases insulation requirements for return ducts in attics from R-6 to R-8.	Beneficial	Modestly reduces conduction losses from return ducts in attics

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE109-13	R403.2 (IRC N1103.2), R403.2.2 (IRC N1103.2.2), R403.2.3 (NEW) (IRC N1103.2.3 (NEW)), R403.2.4 (NEW) (IRC N1103.2.4 (NEW))	Makes the maximum allowable duct leakage rates prescriptive, allowing performance path trade-offs.	Neutral	Zero-sum tradeoff within IECC performance path rules; applies only to compliance via performance path
RE111-13	R403.2.2 (IRC N1103.2.2)	Aligns the IECC with the International Mechanical Code (IMC) by removing exception from duct sealing for low-pressure continuously welded ducts.	Neutral	Requires sealing of additional locking joints for consistency between the IECC and IMC. Impact is negligible because the mandatory duct pressure test governs duct leakage regardless of specific sealing strategies.
RE117-13	R403.2.2 (IRC N1103.2.2)	Deletes exception relating to partially inaccessible duct connections.	Neutral	Editorial change to eliminate irrelevant text
RE118-13	R403.2.2 (IRC N1103.2.2)	Reverses the order of how the two duct testing options are presented.	Neutral	Rearrangement of text

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE125-13, Part I	R403.4.1 (IRC N1103.4.1), R403.4.1.1 (NEW) (IRC N1103.4.1.1 (NEW)), R403.4.1.2 (NEW) (IRC N1103.4.1.2 (NEW)), Chapter 5, IPC [E] 607.2.1, [E] 607.2.1.1 (NEW), [E] 607.2.1.1.1 (NEW), [E] 607.2.1.1.2 (NEW), IPC Chapter 14, IRC P2905 (NEW), IRC P2905.1 (NEW)	Adds requirements for demand-activated control on hot water circulation systems and heat trace systems. Makes IECC, IRC, and IPC consistent and clarifies requirements for these systems.	Beneficial	Demand activated control reduces the runtime of circulation pumps
RE132-13	R403.4.2 (IRC N1103.4.2), Table R403.4.2 (IRC Table N1103.4.2)	Deletes requirement for domestic hot water (DHW) pipe insulation to kitchen and the generic requirement on long/large-diameter pipes. However, adds DHW pipe insulation for 3/4-inch pipes.	Beneficial	Energy lost due to the elimination of hot water pipe insulation on the kitchen pipe is typically more than made up by added insulation requirements for pipes 3/4 inches in diameter, the most common size for trunk lines
RE136-13, Part I	R403.4.2 (NEW) (IRC N1103.4.2 (NEW)), IPC 202, IPC [E]607.2.1.1 (NEW), IRC P2905 (NEW), IRC P2905.1 (NEW)	Adds demand control requirements for recirculating systems that use a cold water supply pipe to return water to the tank.	Beneficial	Demand activated control reduces the runtime of circulation pumps

Proposal Number	Code Section(s) Affected[a]	Description of Changes	Impact on Energy Efficiency	Reason
RE142-13	R403.6 (IRC N1103.6)	Requires heating, ventilation, and air-conditioning equipment to meet Federal efficiency standards.	Neutral	DOE's Appliances and Commercial Equipment Standards Program regulates the minimum efficiency of units produced by equipment manufacturers
RE163-13	R405.4.2 (IRC N1105.4.2), R405.4.2.1 (NEW) (IRC N1105.4.2.1 (NEW)), R405.2.2 (NEW) (IRC N1105.4.2.2 (NEW))	Specifies details of a compliance report for the performance approach.	Neutral	No direct impact on energy
RE167-13	Table R405.5.2(1) (IRC Table B1105.5.2(1))	Fixes missing standard reference design specifications for thermal distribution systems.	Neutral	Adds details for modeling the standard reference design in the performance path
RE173-13	Table R405.5.2(1) (IRC Table N1105.5.2(1))	Adjusts Table R405.5.2(1) (the performance path) terminology for doors and fenestration.	Neutral	Simple clarification of the intent of the code
RE184-13	R101.4.3, R202, R406 (NEW), (IRC N1101. 3, N1101.9, N1106(NEW))	Revamps alterations language and moves it from chapter 1 to section R406.	Neutral	Trade-offs between weakened and strengthened requirements possible but there is no feasible method for quantifying the energy impact of these trade-offs.
RE188-13	R202 (NEW) (IRC N1101.9 (NEW)), R401.2 (IRC N1101.15), R406 (NEW) (IRC N1106 NEW)	Optional new approach in section 406 requiring an ERI with a tradeoff limitation on the thermal envelope requirements.	Not quantifiable at this time	New alternative compliance path—no data is currently available to adequately estimate the number of homes that may be constructed using this compliance path.
RE193-13	R202 (IRC N1101.9), 403.10 (New) (IRC N1103.10 (New))	Adds requirements for testing of combustion venting systems.	Neutral	Impacts air quality; no direct impact on home energy usage

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
RE195-13	R402.1.2	Subtracts out R-0.6 for insulating siding from R-value table to prevent double counting of siding.	Neutral	Adds consistency in R-value calculations
RB96-13, Part I	Table R402.4.1.1	Specifies that air sealing shall be provided in fire separation assemblies.	Neutral	Minor clarification of code requirements
RB100-13	R303.4	Corrects the air infiltration threshold in R303.4 to be 5 air changes per hour or less to align it with the infiltration limits set by the code.	Neutral	Consistency change
SP19-13, Part III	303.1; IECC C404.7; IECC R403.9	Makes numerous wording changes to pool and spa requirements. Doesn't appear to make substantive changes.	Neutral	No direct impact on home energy usage
ADM22-13, Part III	IECC: R108.2	Revises "owner's agent" to "owner's authorized agent" in R108.2.	Neutral	Simple language change
ADM30-13, Part III	IECC: R103.4	Adds "work shall be installed in accordance with the approved construction documents" to R103.4.	Neutral	Simple language change
ADM40-13, Part III	IECC: R103.1	Adds "technical reports" as acceptable data for submittal with a permit application.	Neutral	Simple language change
ADM51-13, Part III	IECC: R202 (IRC N1101.9)	Adds "retrofit" and other terms to definition of "alteration."	Neutral	Simple language change
ADM57-13, Part III	IECC: R202 (IRC N1101.9)(New)	Adds definition of "approved agency."	Neutral	Simple language change
ADM60-13, Part III	IECC: R202 (IRC N1101.9)	Revises definition of "repairs."	Neutral	Simple language change
CE4-13, Part II	R101.4, R202 (IRC N1101.9); R402.3.6 (IRC N1102.3.6), Chapter 5 (RE) (NEW) (IRC N1106 (NEW))	Editorial relocation of code text pertaining to "existing buildings" to a separate chapter.	Neutral	Editorial change
CE8-13, Part II	R101.4.2, R202 (NEW) (IRC N1101.9 (NEW))	Revises language requiring the code to apply to historic buildings if no "compromise to the historic nature and function of the building" occurs.	Beneficial	Additional buildings must meet the code requirements

Proposal Number	Code Section(s) Affected[a]	Description of Changes	Impact on Energy Efficiency	Reason
CE11-13, Part II	R101.4.3, (IRC N1101.3)	Adds existing single-pane fenestration with surface films to the list of exceptions in R101.4.3.	Neutral	Exceptions are allowed only if energy use is not increased
CE15-13, Part II	R101.4.3 (IRC N1101.3), R202 (NEW) (IRC N1101.9 (NEW))	Revises exemption for roofing replacement.	Neutral	Editorial change
CE23-13, Part II	R101.5.2 (IRC N1101.6), R402.1 (IRC N1102.1)	Relocates exception for "low energy" buildings from R101.5.2 to R402.1.	Neutral	Editorial change
CE33-13, Part II	R102, R102.1.1 (NEW)	Changes title of section R102 to "Applicability - Duties and powers of the Code Official" and revises language on "alternative materials, design and methods of construction and equipment."	Neutral	Editorial change
CE37-13, Part II	R103.2.1 (NEW)	Requires the building's thermal envelope to be represented on construction documents.	Neutral	Simple documentation requirement
CE38-13, Part II	R103.3, R104.1, R104.2 (NEW), R104.3, R104.3.1 (NEW), R014.3.2 (NEW), R104.3.3 (NEW), R104.3.4 (NEW), R104.3.5 (NEW), R104.3.6 (NEW), R104.5	Revises a number of administrative requirements to enhance the ability to ensure compliance with the code and improve the usability of the code.	Neutral	No direct impact on energy
CE43-13, Part II	R106.2	Deletes R106.2 "Conflicting requirements" because it is redundant with "Conflicts" in R106.1.1.	Neutral	Editorial change
CE44-13, Part II	R108.4	Revises language pertaining to "fines" in section R108.4.	Neutral	Editorial change
CE49-13, Part III	R202 (NEW) (IRC N1101.9 (NEW))	Adds definition of a "circulating hot water system."	Neutral	Editorial change

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
CE50-13, Part II	R202 (NEW) (IRC N1101.9 (NEW))	Add definition of "climate zone."	Neutral	Editorial change
CE51-13, part II	R202 (IRC N1101.9)	Revises the definition of "conditioned space."	Neutral	Revision of definition
CE52-13, Part II	R202 (NEW) (IRC N1101.9 (NEW))	Adds definition of "continuous insulation."	Neutral	Definition addition
CE59-13, Part II	R202 (IRC N1101.9)	Revises the definition of "vertical glazing."	Neutral	Revision of definition
CE61-13, Part II	Table R301.1	Adds "Broomfield County" to Table C301.1 and R301.1.	Neutral	Editorial change
CE62-13, Part II	Figure R301.1 (IRC Figure N1101.10), Table R301.1 (IRC Table N1101.10)	Eliminates the "warm humid" designation for counties in the "dry" moisture regime in Southwest Texas.	Neutral	No efficiency requirements depend on the warm-humid designation in Climate Zone 2/Dry
CE63-13, Part II	R303.1.1 (IRC N1101.12.1)	Requires labelling R-value on packaging of insulated siding and listing of same on the certification.	Neutral	Labeling requirement
CE65-13, Part II	R303.1.3 (IRC N1101.12.3), Chapter 5	Adds the American National Standards Institute (ANSI)/Door and Access Systems Manufacturers Association (DASMA) standard 105 as an alternative to National Fenestration and Rating Council (NFRC) 100 for determining U-factors of garage doors, where required.	Neutral	Adds an option of using ANSI/DASMA 105 instead of NFRC 100
CE66-13, Part II	R301.4 (NEW) (IRC N1101.10.3 (NEW)), R406 (NEW) (IRC N1106 (NEW))	Defines a new "Tropical" climate zone and adds an optional compliance path for semi-conditioned residential buildings with a list of pre-defined criteria to be deemed as code compliant in this climate zone.	Detrimental	Exception to code requirements applicable to a small number of homes in tropical areas
CE67-13, Part II	R303.1.4.1 (N1101.12.4) (NEW), Chapter 5	Adds ASTM C1363 as the required test standard for determining the thermal resistance (R-value) of insulating siding.	Neutral	Addition of testing requirements

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes	Impact on Energy Efficiency	Reason
CE161-13, Part II	R402.3.2 (IRC N1102.3.2)	Allows dynamic glazing to satisfy the SHGC requirements provided the ratio of upper to lower SHGC is 2.4 or greater and is automatically controlled to modulate the amount of solar gain into the space.	Negligible	Similar energy impact to non-dynamic glazing
CE177-13, Part II	R402.1.2 (NEW), (IRC N1102.4.1.2 (NEW))	Requires open combustion appliances to be outside conditioned space or in a room isolated from conditioned space and ducted to the outside.	Neutral	Relates to indoor air quality and does not impact energy directly.
CE179-13, Part II	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Exempts fire sprinklers from air sealing requirements.	Negligible	The home/unit would still have to pass the blower door test
CE283-13, Part II	R403.4.3 (NEW) (N1103.5 (NEW)), Chapter 5, IRC P2903.11 (NEW)	Requires drain water heat recovery systems to comply with Canadian Standards Association (CSA) Standard 55 and adds references to CSA Standard 55 to chapter 5.	Negligible	Enables credit for efficiency improvements due to the use of drain water heat recovery devices
CE362-13, Part II	R403.2 (New) (IRC N1103.2 (New))	Adds requirement for outdoor setback control for hot water boilers that controls the boiler water temperature based on the outdoor temperature.	Beneficial	Lowering boiler water temperature during periods of moderate outdoor temperature reduces energy consumption of the boiler
(a) Code sections refer to the 2012 IECC.				

KEY: The following terms are used to characterize the effect of individual code change on energy efficiency (as contained in the above table): *Beneficial* indicates that a code change is anticipated to improve energy efficiency; *Detrimental* indicates a code change may increase energy use in certain applications; *Neutral* indicates that a code change is not anticipated to impact energy efficiency; *Negligible* indicates a code change may have energy impacts but too small to quantify; and *Not Quantifiable* indicates that a code change may have energy impacts but can't be quantified at this time.

Table 2.2 summarizes the overall impact of the code change proposals in the qualitative analysis. Overall, the sum of the beneficial code changes (6) is greater than the number of the detrimental code change proposals (3).

Table 2.2. Overall Summary of Code Change Proposal Impact in Qualitative Analysis

Detriment	Neutral	Benefit	Negligible Impact	Unquantifiable at this time	Total
2	62	6	5	1	76

3.0 Residential Prototype Buildings and Analysis Methodology

Quantifying the energy impact of the changes made to the residential provisions of the 2015 IECC over the 2012 IECC requires creating a reference set of residential building models representative of the national new residential building construction stock. Characteristics of residential buildings across the country vary by the climatic and regional construction practices and preferences. For example, residential buildings in the southern U.S. are more likely to have a slab-on-grade foundation, while residential buildings in the north more commonly have basements. Similarly, electric heating is more popular in the southern parts of the country, due to low heating requirements, while fuel oil is more popular in the northeastern parts of the country. Moreover, the residential provisions of the IECC apply to single-family as well as low-rise multifamily buildings, which have very different heating and cooling loads due to differences in the shape of the buildings, surface-to-volume ratios, typical glazing-to-opaque wall ratios, etc.

While the current analysis presents a national perspective, analyzing every unique residential building design across the country is not feasible. Through a public process, DOE previously developed a methodology for assessing the cost-effectiveness of residential codes and proposed changes (Taylor et al. 2012). The methodology, hereafter referred as the DOE methodology, proposed a suite of 32 representative residential prototype buildings for adequately capturing the entire new residential building construction stock. The current analysis is based on the DOE methodology and leverages the building energy models developed for the analysis of the 2012 IECC. These models are modified to create a second set of models that represent minimal compliance with the residential prescriptive and mandatory requirements of the 2015 IECC for each of the 15 climate zones and moisture regimes defined by the IECC.

Annual energy simulations are carried out for each of the 960 models (32 prototypes, 15 climate zones, and 2 code editions) using *EnergyPlus Version 8.0* (DOE 2013). The resulting energy data are converted to energy cost data using national fuel prices and the energy and energy cost results are weighted to the national level using weighting factors designed to complement the 32 prototype models to present a national perspective.

3.1 Building Types and Model Prototypes

The 32 residential prototype buildings developed during the 2012 IECC analysis are summarized in Table 3.1. The set consists of a single-family and a low-rise multifamily residential building with four different foundation types: slab on grade, vented crawlspace, heated basement, and unheated basement; and four different heating system types: gas furnace, electric resistance, heat pump, and a fuel oil furnace. The whole set is designed to present a national perspective on residential building construction and was created based on residential construction data from the U.S. Census (Census 2010) and the National Association of Home Builders (NAHB 2009). Detailed descriptions of the 32 prototype building models operational assumptions are documented in Mendon et al. 2013 and 2014.

Table 3.1. Residential Prototype Building Types

No.	Building Type	Foundation Type	Heating System Type
1	Single-family	Vented Crawlspace	Gas-fired Furnace
2	Single-family	Vented Crawlspace	Electric Furnace
3	Single-family	Vented Crawlspace	Oil-fired Furnace
4	Single-family	Vented Crawlspace	Heat Pump
5	Single-family	Slab-on-grade	Gas-fired Furnace
6	Single-family	Slab-on-grade	Electric Furnace
7	Single-family	Slab-on-grade	Oil-fired Furnace
8	Single-family	Slab-on-grade	Heat Pump
9	Single-family	Heated Basement	Gas-fired Furnace
10	Single-family	Heated Basement	Electric Furnace
11	Single-family	Heated Basement	Oil-fired Furnace
12	Single-family	Heated Basement	Heat Pump
13	Single-family	Unheated Basement	Gas-fired Furnace
14	Single-family	Unheated Basement	Electric Furnace
15	Single-family	Unheated Basement	Oil-fired Furnace
16	Single-family	Unheated Basement	Heat Pump
17	Multifamily	Vented Crawlspace	Gas-fired Furnace
18	Multifamily	Vented Crawlspace	Electric Furnace
19	Multifamily	Vented Crawlspace	Oil-fired Furnace
20	Multifamily	Vented Crawlspace	Heat Pump p
21	Multifamily	Slab-on-grade	Gas-fired Furnace
22	Multifamily	Slab-on-grade	Electric Furnace
23	Multifamily	Slab-on-grade	Oil-fired Furnace
24	Multifamily	Slab-on-grade	Heat Pump
25	Multifamily	Heated Basement	Gas-fired Furnace
26	Multifamily	Heated Basement	Electric Furnace
27	Multifamily	Heated Basement	Oil-fired Furnace
28	Multifamily	Heated Basement	Heat Pump
29	Multifamily	Unheated Basement	Gas-fired Furnace
30	Multifamily	Unheated Basement	Electric Furnace
31	Multifamily	Unheated Basement	Oil-fired Furnace
32	Multifamily	Unheated Basement	Heat Pump

3.2 Climate Zones

Standardized climate zones are used for the current analysis, and are consistent with those used by the ICC as well as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for both residential and commercial building applications. The common set of climate zones includes eight temperature-oriented zones covering the entire U.S., as shown in Figure 3.1 (Briggs et al. 2003). Climate zones are numbered from 1 to 8, with higher zone numbers representing colder climates. The thermal climate zones are further divided into moist (A), dry (B), and marine (C) regions. However, not all of the moisture regimes apply to all climate zones in the U.S. and some zones have no moisture designations at all, so only 15 of the theoretically possible 24 thermal-moisture zones exist in the IECC. For this analysis, a specific climate location (city) is selected as a representative of each of the 15 climate zones.

The 15 cities representing the climate zones are:

- 1A: Miami, Florida (very hot, moist)
- 2A: Houston, Texas (hot, moist)
- 2B: Phoenix, Arizona (hot, dry)
- 3A: Memphis, Tennessee (warm, moist)
- 3B: El Paso, Texas (warm, dry)
- 3C: San Francisco, California (warm, marine)
- 4A: Baltimore, Maryland (mixed, moist)
- 4B: Albuquerque, New Mexico (mixed, dry)
- 4C: Salem, Oregon (mixed, marine)
- 5A: Chicago, Illinois (cool, moist)
- 5B: Boise, Idaho (cool, dry)
- 6A: Burlington, Vermont (cold, moist)
- 6B: Helena, Montana (cold, dry)
- 7: Duluth, Minnesota (very cold)
- 8: Fairbanks, Alaska (subarctic)

The IECC further defines a warm-humid region in the southeastern U.S. This region is defined by humidity levels, whereas the moist (A) regime is more closely associated with rainfall. The warm-humid distinction is not used in the current analysis. The warm-humid designation affects only whether basement insulation is required in climate zone 3, where basements are relative rare. This requirement is not affected by any of the 2015 changes.

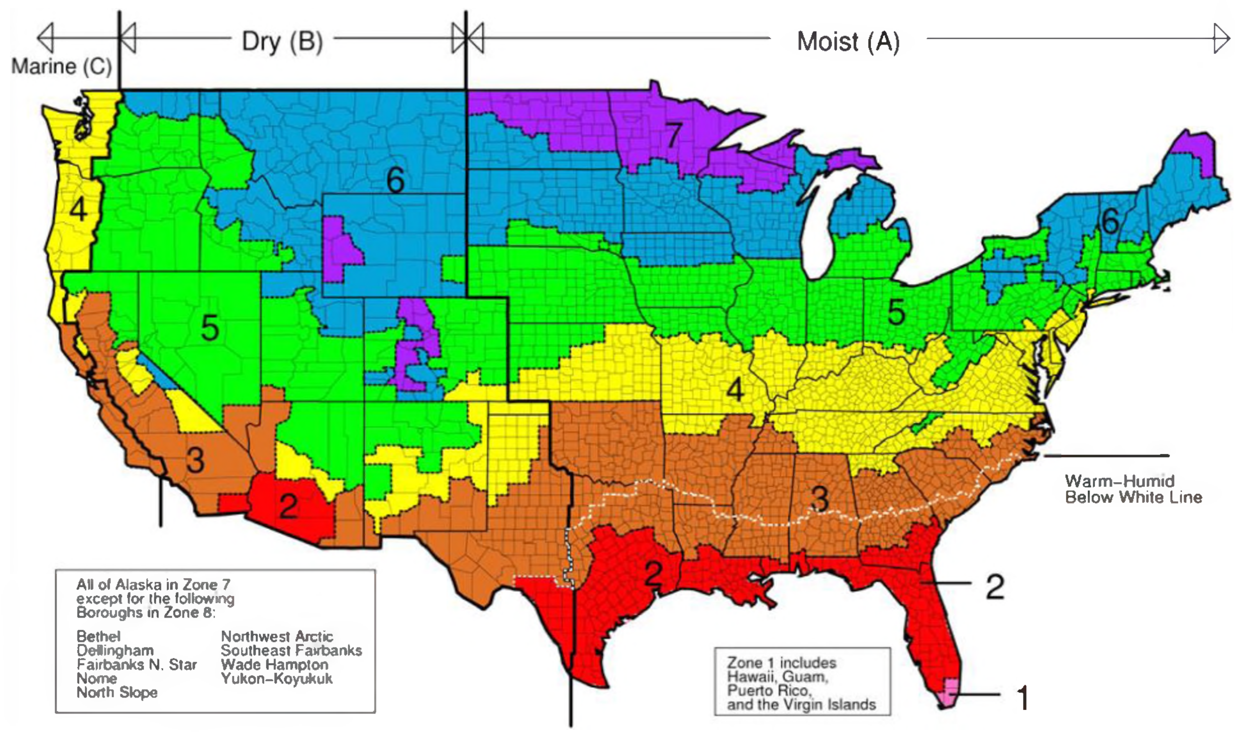

Figure 3.1. DOE-Developed Climate Zone Map

3.3 Development of Weighting Factors and National Savings Estimates

Weighting factors for each of the 32 prototype buildings were developed for each of the climate zones using new residential construction starts and residential construction details from the U.S. Census (Census

2010) and NAHB (NAHB 2009). Table 3.2 shows the weighting factors for the residential prototype buildings. Table 3.3 through Table 3.6 summarizes the weights aggregated to building type, foundation type, heating system, and climate zone levels.

Table 3.2. Weighting Factors for the Residential Prototype Building Models by Climate Zone (CZ)

Bldg. Type	Foundation	Heating System	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	Weights by Prototype
Single-family	Crawlspace	Gas-fired Furnace	0.14%	1.29%	2.69%	2.50%	2.58%	0.61%	0.14%	0.00%	9.95%
Single-family	Crawlspace	Electric Furnace	0.01%	0.33%	0.35%	0.16%	0.07%	0.02%	0.01%	0.00%	0.93%
Single-family	Crawlspace	Oil-fired Furnace	0.00%	0.00%	0.01%	0.02%	0.11%	0.04%	0.00%	0.00%	0.18%
Single-family	Crawlspace	Heat pump	0.11%	1.56%	4.20%	3.86%	0.94%	0.23%	0.07%	0.00%	10.97%
Single-family	Slab-on-grade	Gas-fired Furnace	0.16%	5.91%	5.66%	2.65%	3.25%	0.76%	0.15%	0.00%	18.55%
Single-family	Slab-on-grade	Electric Furnace	0.01%	1.25%	0.88%	0.18%	0.09%	0.02%	0.01%	0.00%	2.43%
Single-family	Slab-on-grade	Oil-fired Furnace	0.00%	0.01%	0.01%	0.03%	0.15%	0.05%	0.00%	0.00%	0.26%
Single-family	Slab-on-grade	Heat pump	0.31%	7.21%	5.91%	3.68%	1.14%	0.30%	0.08%	0.00%	18.64%
Single-family	Heated Basement	Gas-fired Furnace	0.02%	0.05%	0.21%	1.41%	3.45%	1.43%	0.26%	0.00%	6.83%
Single-family	Heated Basement	Electric Furnace	0.00%	0.01%	0.02%	0.07%	0.08%	0.05%	0.01%	0.00%	0.24%
Single-family	Heated Basement	Oil-fired Furnace	0.00%	0.00%	0.00%	0.02%	0.19%	0.07%	0.00%	0.00%	0.29%
Single-family	Heated Basement	Heat pump	0.01%	0.08%	0.36%	1.79%	1.20%	0.59%	0.13%	0.00%	4.17%
Single-family	Unheated Basement	Gas-fired Furnace	0.01%	0.11%	0.34%	1.08%	2.75%	0.94%	0.11%	0.00%	5.35%
Single-family	Unheated Basement	Electric Furnace	0.00%	0.02%	0.03%	0.05%	0.06%	0.02%	0.00%	0.00%	0.18%
Single-family	Unheated Basement	Oil-fired Furnace	0.00%	0.00%	0.00%	0.03%	0.36%	0.13%	0.00%	0.00%	0.53%
Single-family	Unheated Basement	Heat pump	0.01%	0.14%	0.57%	1.20%	0.89%	0.32%	0.05%	0.00%	3.18%
Multifamily	Crawlspace	Gas-fired Furnace	0.05%	0.10%	0.74%	0.58%	0.65%	0.17%	0.03%	0.00%	2.32%

Bldg. Type	Foundation	Heating System	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	Weights by Prototype
Multifamily	Crawlspace	Electric Furnace	0.00%	0.20%	0.25%	0.04%	0.01%	0.00%	0.00%	0.00%	0.51%
Multifamily	Crawlspace	Oil-fired Furnace	0.00%	0.00%	0.00%	0.01%	0.02%	0.01%	0.00%	0.00%	0.05%
Multifamily	Crawlspace	Heat pump	0.03%	0.16%	0.63%	0.80%	0.09%	0.02%	0.01%	0.00%	1.74%
Multifamily	Slab-on-grade	Gas-fired Furnace	0.10%	0.54%	1.37%	0.59%	0.75%	0.21%	0.04%	0.00%	3.60%
Multifamily	Slab-on-grade	Electric Furnace	0.00%	0.77%	0.79%	0.07%	0.01%	0.01%	0.00%	0.00%	1.66%
Multifamily	Slab-on-grade	Oil-fired Furnace	0.00%	0.00%	0.00%	0.02%	0.03%	0.01%	0.00%	0.00%	0.06%
Multifamily	Slab-on-grade	Heat pump	0.21%	0.73%	0.79%	0.76%	0.12%	0.03%	0.01%	0.00%	2.66%
Multifamily	Heated Basement	Gas-fired Furnace	0.01%	0.00%	0.03%	0.41%	0.86%	0.44%	0.07%	0.00%	1.83%
Multifamily	Heated Basement	Electric Furnace	0.00%	0.00%	0.01%	0.03%	0.01%	0.01%	0.00%	0.00%	0.06%
Multifamily	Heated Basement	Oil-fired Furnace	0.00%	0.00%	0.00%	0.02%	0.04%	0.01%	0.00%	0.00%	0.08%
Multifamily	Heated Basement	Heat pump	0.00%	0.01%	0.06%	0.40%	0.12%	0.07%	0.03%	0.00%	0.69%
Multifamily	Unheated Basement	Gas-fired Furnace	0.00%	0.01%	0.09%	0.33%	0.59%	0.23%	0.03%	0.00%	1.28%
Multifamily	Unheated Basement	Electric Furnace	0.00%	0.01%	0.01%	0.03%	0.01%	0.00%	0.00%	0.00%	0.07%
Multifamily	Unheated Basement	Oil-fired Furnace	0.00%	0.00%	0.00%	0.03%	0.08%	0.01%	0.00%	0.00%	0.12%
Multifamily	Unheated Basement	Heat pump	0.00%	0.02%	0.09%	0.35%	0.11%	0.03%	0.01%	0.00%	0.61%
Weights by Climate-zone			1.20%	20.52%	26.10%	23.22%	20.82%	6.87%	1.26%	0.01%	100.00%

Table 3.3. Weighting Factors by Building Type

Bldg. Type	Weight (%)
Single-family	82.7
Multifamily	17.3

Table 3.4. Weighting Factors by Foundation Type

Bldg. Type	Weight (%)
Crawlspace	26.6
Slab-on-grade	47.9
Heated Basement	14.2
Unheated Basement	11.3

Table 3.5. Weighting Factors by Heating System

Bldg. Type	Weight (%)
Gas-fired Furnace	49.7
Electric Furnace	6.1
Oil-fired Furnace	1.6
Heat Pump	42.7

Table 3.6. Weighting Factors by Climate Zone

Climate Zone	Weight (%)
1	1.2
2	20.5
3	26.1
4	23.2
5	20.8
6	6.9
7	1.3
8	0.0

4.0 Quantitative Analysis of the 2015 IECC

During the IECC code development cycle in 2013, the ICC approved a total of 76 code change proposals for inclusion in the 2015 edition of the IECC (ICC 2013). Details about each of these proposals are included in Table 2.1. From the qualitative analysis of the approved code change proposals impacting the prescriptive and mandatory provisions of the code, it was determined that most of the code changes had a neutral or an extremely small, unquantifiable energy impact. See Section 2.1 for a discussion of those changes. Of the changes with a quantifiable energy impact, it was determined that six would have a *beneficial* impact on energy efficiency, and two would likely have a *detrimental* impact on energy efficiency. After further consideration, it was determined that the energy impact of three of these eight proposals could be estimated using energy modeling, one could be estimated using independent heat transfer equations, and two could be estimated using extant research on the topic because they could not be directly modeled using the existing models and software. The impact of the remaining two could not be estimated because of the complications in energy modeling, lack of baseline data, and lack of external research studies. However, the three unquantified proposals are not expected to have a significant impact on energy efficiency.

4.1 Characterization of Approved Code Change Proposals

Table 4.1 lists the approved code change proposals that have a quantifiable energy impact and have been captured in the current analysis. Two of the six quantifiable code changes impact the building envelope, one impacts the heating, ventilating, and air-conditioning (HVAC) system, and the remaining three impact domestic hot water (DHW) systems.

Table 4.1. Approved Code Change Proposals with Quantified Energy Impacts

Proposal Number	Code Section(s) Affected[(a)]	Description of Changes
RE107-13	R403.2.1 (IRC N1103.2.1)	Increases insulation requirements for return ducts in attics from R-6 to R-8.
RE125-13, Part I	R403.4.1 (IRC N1103.4.1), R403.4.1.1 (NEW) (IRC N1103.4.1.1 (NEW)), R403.4.1.2 (NEW) (IRC N1103.4.1.2 (NEW)), Chapter 5, IPC [E] 607.2.1, [E] 607.2.1.1 (NEW), [E] 607.2.1.1.1 (NEW), [E] 607.2.1.1.2 (NEW), IPC Chapter 14, IRC P2905 (NEW), IRC P2905.1 (NEW)	Adds new language on heated water circulation systems and heat trace systems. Makes IECC, IRC, and IPC consistent and clarifies requirements for these systems only if they are installed.
RE132-13	R403.4.2 (IRC N1103.4.2), Table R403.4.2 (IRC Table N1103.4.2)	Deletes requirement for insulation on DHW pipes to kitchen and the generic requirement on long/large-diameter pipes. However, adds DHW pipe insulation for all 3/4-inch pipes.
RE136-13, Part I	R403.4.2 (NEW) (IRC N1103.4.2 (NEW)), IPC 202, IPC [E]607.2.1.1 (NEW), IRC P2905 (NEW), IRC P2905.1 (NEW)	Adds demand control requirements for recirculating systems that use a cold water supply pipe to return water to the tank.
CE66-13, Part II	R301.4 (NEW) (IRC N1101.10.3 (NEW)), R406 (NEW) (IRC N1106 (NEW))	Defines a new "Tropical" climate zone and adds an optional compliance path deeming semi-conditioned residential buildings having a list of pre-defined criteria as code compliant in this climate zone.

Proposal Number	Code Section(s) Affected[a]	Description of Changes
CE362-13, Part II	R403.2 (New) (IRC N1103.2 (New))	Adds requirement for outdoor setback control on hot water boilers that controls the boiler water temperature based on the outdoor temperature.

(a) Code sections refer to the 2012 IECC.

4.2 Implementation of Code Changes in Modeling

The building energy models developed during the 2012 IECC analysis are leveraged in the current analysis. The code changes to be implemented in modeling are added to the baseline 2012 IECC models to create a set of models minimally compliant with the requirements of the 2015 IECC. However, in some cases, the baseline 2012 IECC models do not have the characteristics to capture the differences in code requirements. In this case, the baseline model is enhanced to add the capability to address these changes by adding or modifying baseline building characteristics. In some cases, quantification of a code change is not feasible through energy modeling and/or more detailed research is available. The details of implementing each quantified code change proposal are included in this section. Where applicable, details of model enhancement or alternative impact calculations and methodologies are also included.

4.2.1 Building Envelope

The building envelope is the most important element of energy efficiency in residential buildings, especially in the context of the IECC, which excludes equipment efficiencies from its scope.[1] The 2012 IECC considerably improved the efficiency of building envelope components over the 2009 IECC. Efforts to increase the efficiency of building envelope components beyond the 2012 IECC levels were limited, and the 2013 code development cycle saw the incorporation of a number of code changes intended to simplify the code language and clarify the requirements set in the 2012 IECC. Among all the building envelope-related code changes approved for inclusion in the 2015 IECC, the one code change that impacts energy efficiency in a quantifiable way is CE66-13, Part II.

4.2.1.1 CE66-13, Part II: Definition of a New "Tropical" Climate Zone

Part I of this proposal targets the commercial provisions of the IECC, which are not the focus of the current analysis. Part II of the proposal applies to the residential provisions of the IECC. This approved code change added a new "tropical" climate zone to the IECC along with a set of requirements that if met would imply compliance with requirements set in Chapter 4 of the 2015 IECC *Residential Provisions*. The tropical climate zone includes Hawaii, Puerto Rico, Guam, American Samoa, U.S. Virgin Islands, Commonwealth of Northern Mariana Islands, and islands in the area between the Tropic of Cancer and the Tropic of Capricorn. The requirements to be met in order to demonstrate compliance with Chapter 4 (Residential Energy Efficiency) are as follows:

- Not more than one-half of the occupied space is air-conditioned.
- The occupied space is not heated.

[1] HVAC and appliance efficiencies are preemptively regulated at the Federal level. See http://energy.gov/node/773531/residential/pdfs/plmrul.pdf for details.

- Solar, wind, or other renewable energy source supplies are not less than 80 percent of the service water heating energy.
- Glazing in the conditioned space has a SHGC of less than or equal to 0.40, or has an overhang with a projection factor equal to or greater than 0.30.
- Permanently installed lighting is in accordance with the requirements of the 2015 IECC.
- The exterior roof surface complies with one of the options specified in the commercial provisions or the roof/ceiling has insulation with an R-value of R-15 or greater. If present, attics above the insulation are vented and attics below the insulation are unvented.
- Roof surfaces have a minimum slope of 1/4-inch per foot of run and the finished roof does not have water accumulation areas.
- Operable fenestration provides ventilation area equal to not less than 14 percent of the floor area in each room. Alternatively, equivalent ventilation is provided by a ventilation fan.
- Bedrooms with exterior walls facing two different directions have operable fenestration or exterior walls facing two directions.
- Interior doors to bedrooms are capable of being secured in an open position.
- A ceiling fan or ceiling fan rough-in is provided for the bedrooms and the largest space that is not used as a bedroom.

This code change applies to a portion of homes considered to be part of climate zone 1 in the 2012 IECC analysis. Based on new construction starts data compiled from the 2010 Census data in the 2012 analysis, approximately 50 percent of the single-family construction starts attributed to climate zone 1 were in Hawaii (Mendon et al. 2013). To estimate the energy impact of this code change in the present analysis, a new climate zone called "climate zone 1-tropical" is added to the existing list of 15 climate zones. This is done solely for the ease of post-processing and aggregation of results in a streamlined fashion. The IECC did not change the climate zone map to reflect a new climate zone for the tropical areas and hence this does not impact work done by Briggs et al. (2003) referenced in Section 3.2. The representative climate location selected for the energy simulation of the tropical climate zone is Honolulu, Hawaii, consistent with cost-effectiveness analysis conducted for the State of Hawaii (BECP 2012b, Mendon et al. 2013).

While not mentioned specifically, the requirements to demonstrate compliance will likely apply to single-family homes only. Thus, the current analysis assumes that new single-family homes built in climate zone 1-tropical, which represents approximately 50 percent of all new single-family homes built in climate-zone 1, would be eligible for this code change. No data are available to indicate how many eligible homes will use the tropical climate zone alternative. However, a building codes expert in Hawaii provided useful information for formulating a set of assumptions to quantify the energy impact of this code change[1]:

[1] Based on discussions with Mr. Howard Wiig, Department of Business, Economic Development and Tourism, State of Hawaii.

- Although the Hawaii state residential building code requires that all new single-family dwellings built in the State of Hawaii have a solar water heater, about 25 percent of new homes submit a "Request for Variance from Mandatory Solar Water Heater"; these are all accepted.
- No direct statistical data exist to arrive at an exact number of new homes that meet all the requirements listed in CE66-13 Part II. However, it is considered reasonable to assume that perhaps 35 percent of all new homes built in the State of Hawaii meet the prerequisites and hence can opt for the proposed tropical climate zone alternative.

Because Hawaii dominates the new residential construction shares in the tropical areas and data required to segregate these between the different islands are not available, the current analysis assumes that 35 percent of all single-family homes built in the tropical climate zone will opt for the proposed alternative. Modeling this code change involves a change to the baseline single-family prototype building to match its characteristics with the homes that already meet the prerequisites. Thus, the 2012 IECC single-family prototype building models are modified to be semi-conditioned homes with solar water heaters such that:

- Only the second story of the single-family home is considered to be conditioned while the first story is kept unconditioned.
- The conditioned space is not heated.
- The energy required by the domestic water heater is assumed to be provided by a solar water heater based on the Hawaii state residential code.

A second set of models, i.e., the 2015 IECC models, is then created to match the requirements listed in this code change proposal:

- Glazing in the conditioned space is assumed to have a SHGC of 0.40.
- The ceiling insulation level is assumed to be R-15.

The difference in energy between the 2012 IECC models and the modified prototype building models designed to imply compliance with the tropical climate zone alternative is aggregated with the other modeled code changes as described in chapter 3.0.

4.2.2 Heating, Ventilating, and Air-Conditioning

Residential HVAC efficiencies are preemptively regulated at the Federal level; hence, the IECC does not directly include those efficiencies in its scope. However, certain elements of HVAC controls, distribution systems, etc., are within the code's scope, and several approved code changes affect those elements in the 2015 IECC.

4.2.2.1 RE107-13: Insulation Requirements for Return Ducts in Attics

RE107-13 increases the required insulation on return ducts in attics to a minimum of R-8 (8 ft^2-hr-°F/Btu) where ducts are three inches or greater in diameter and to R-6 (6 ft^2-hr-°F/Btu) where they are less than 3 inches in diameter. This is an improvement over the 2012 IECC requirement that all ducts except supply ducts be insulated to R-6 (6 ft^2-hr-°F/Btu).

This code change impacts all the single-family prototype building models with slab-on-grade foundation because these models are assumed to have ducted air-distribution systems with return ducts located in the unconditioned attic. This assumption is based on the Building America House Simulation Protocols that characterize a "typical" code-compliant house built in 2010 (Wilson et al. 2014). The energy impact of duct insulation and leakage levels is calculated using the *EnergyPlus Airflownetwork*, which allows the creation of a detailed air-distribution system and the placement of ducts in various thermal zones. Due to compatibility issues between the *Airflownetwork* objects and the other *EnergyPlus* modules used in modeling the residential prototype buildings, this energy impact is calculated in isolation and incorporated through post-processing in the final energy results, which are calculated without the *Airflownetwork*.

RE107-13 is modeled by increasing the R-value of the main trunks of return ducts located in the attic for the single-family prototype building models with slab-on-grade foundation from R-6 to R-8 and calculating energy savings in isolation. The energy savings are then incorporated into the final 2015 IECC results during post-processing.

4.2.2.2 CE362-13, Part II: Outdoor Air Temperature Setback Control for Hot Water Boilers

Part II of CE362-13 adds a requirement that hot water boilers supplying heat to the building through one- or two-pipe heating systems be equipped with an outdoor setback control that lowers the temperature of the hot water based on outdoor air temperature.

This code change applies to hot water boilers used for space heating. The original set of 32 residential building prototypes used in the 2012 IECC analysis did not include a model with a hot water boiler used in a space heating application. However, many multifamily buildings in the northeast U.S. have hydronic heating systems. Because fuel oil is a more commonly used heating fuel in the northeast, the current analysis assumes that all multifamily buildings with oil as the primary heating fuel in the northeast are served by oil-fired hot water boilers. The original multifamily prototype models with individual oil-fired furnaces for each apartment from the 2012 IECC analysis are modified to have a central oil-fired hot water boiler that serves each apartment through a hydronic loop.

The code only requires an outdoor setback control to be added to the hot water boiler; it does not specify the control strategy or temperatures for the setback control. The energy savings from this control depends on the aggressiveness of the strategy. Dentz et al. (2013) report 10−15 percent savings from outdoor setback control. Because the code does not specify the temperatures to be used in the outdoor setback control, the current analysis employs a more conservative control strategy, illustrated in Figure 4.1. The updated 2012 IECC models with space heating provided by a central hot water boiler are modified to add an outdoor setback control illustrated in Figure 4.1 using the *EnergyPlus SetpointManager:OutdoorAirReset* object. The energy impact is aggregated with the other modeled code changes as described in Chapter 3.0.

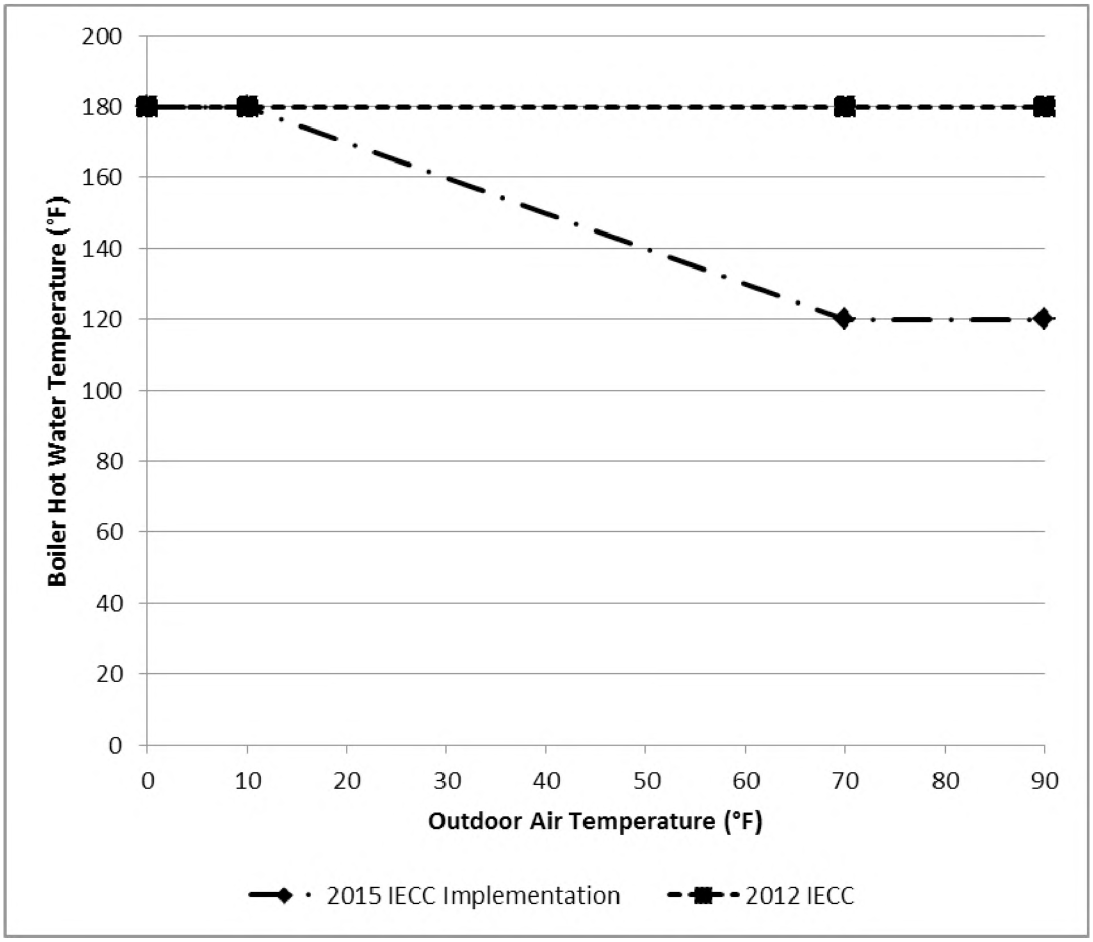

Figure 4.1. Outdoor Temperature Setback Control Strategy Used in Modeling CE362-13 Part II

4.2.3 Domestic Hot Water Systems

Because recent editions of the IECC have significantly improved the building envelope, water heating energy has emerged as a larger portion of home energy use regulated by the IECC than before. Several approved code change proposals modify DHW control and delivery systems.

4.2.3.1 RE125-13, Part I: New Requirements for Heated Water Circulation Systems and Heat Trace Systems and RE136-13, Part I: Demand-Activated Control for Recirculating Systems

RE125-13 Part I and RE136-13 Part I are discussed together because they both impact domestic hot water recirculating systems. RE125-13 adds new requirements for heated water circulation systems and heat trace systems to be controlled by demand-activated circulation systems, making the IECC consistent with the IRC and the IPC. RE136-13 adds demand control requirements for recirculating systems that use a cold water supply pipe to return water to the tank. These code changes do not require the addition of circulation systems to homes; the added requirements are applicable only when these systems are present in the home.

This change affects only homes that have a hot water recirculation system. There are no data available to identify how many new homes are built with these systems. Much of the existing research on hot water recirculation systems focuses on multifamily buildings (Zhang 2013; Zobrist 2012; NYSERDA 1999). Approximately half of the multifamily buildings within the IECC's residential scope use a centralized water heater (EIA 2009). Recirculation systems have been used for many years and many jurisdictions offer incentives for the purchase and installation of hot water recirculation systems (NACHI 2014). The current analysis assumes that all new multifamily buildings with centralized water heaters will have hot water recirculation systems and will need to comply with the new code requirements for demand-activated control.

The 2012 IECC does not include requirements for demand-activated control of hot water recirculation systems. The New York State Energy Research and Development Authority estimates water heater energy savings of approximately 11 percent from timer-controlled recirculating systems over the uncontrolled, continuously operating ones (NYSERDA 1999). Demand-activated controls are expected to save more energy than timer-based controls because they consider individual hot water demand as opposed to a timer-based control. Research conducted by the Lawrence Berkeley National Laboratory for the California Energy Commission (CEC) indicates that the use of demand-activated controls can save up to 27 percent of the total water heater energy in low-rise multifamily buildings (Lutz 2008). A more recent study conducted by the Heschong Mahone Group for CEC reports median measured hot water energy savings of 11.4 percent from demand-activated recirculation systems in multifamily buildings (Zhang 2013).

Because demand-activated control cannot be directly modeled using the hot water system in *EnergyPlus*, these two code changes are implemented in the multifamily prototype models through a work around solution, i.e., adding a savings factor to the hot water schedules. The current analysis conservatively assumes that demand-activated control on hot water recirculation systems in multifamily buildings results in hot water energy savings of 10 percent. This, combined with the earlier assumption that 50 percent of new multifamily buildings have a centralized water heater and will use a hot water recirculation system, results in a savings factor of 0.05 (10 percent × 50 percent). New hot water schedules that include this savings factor are created for the 2015 IECC and implemented in the multifamily prototype models.

4.2.3.2 RE132-13: DHW Pipe Insulation Requirements

RE132-13 deletes a requirement for insulation on hot water pipes to kitchen spaces and deletes a generic requirement for insulation on long and large-diameter pipes. These changes lower overall efficiency. However, the code change adds a requirement for pipe insulation on 3/4-inch pipes that previously applied only to pipes with diameter greater than 3/4-inch or 3/4-inch pipe lengths longer than 10 feet. Because 3/4-inch is the most common size for the long trunk lines in typical residences, this improvement is likely to compensate for the efficiency losses from the deletion of insulation requirements for kitchen and long and large-diameter pipes.

This code change is expected to affect only homes that have a non-recirculating DHW system because the 2012 IECC requires all piping for recirculating systems to be insulated (ICC 2011). Currently, the prototype building models do not include a detailed DHW piping layout. Thus, this code change is evaluated by separately computing energy savings from the requirements of this proposal and then applying them as a savings factor to the hot water schedule. Lengths of 3/4-inch pipes shorter than

10 feet and lengths of 1/2-inch pipes longer than 20 feet are extracted from the DHW pipe layout for a 2811 ft^2 two-story single-family prototype floor plan, a close match to the 2400 ft^2 single-family prototype used for the simulations in this analysis, from research conducted by the California Codes and Standards Enhancement (CASE) Initiative (CASE 2011). Similar data are also extracted from the DHW pipe layout for the 1357 ft^2 prototype floor plan to use in calculations for the 1200 ft^2 multifamily apartment units. These pipe lengths are summarized in Table 4.2.

Table 4.2. Pipe Lengths from the CASE Prototype Floor Plans

Pipe Diameter	Single-family Prototype Pipe Length (ft)	Multi-family Apartment Unit Pipe Length (ft)
3/4 inch runs shorter than 10 ft.	11	24.5
1/2 inch runs longer than 20 ft.	0	0
Kitchen Pipe (1/2 inch)	18	20

The difference between the reduced heat transfer from adding insulation to short 3/4-inch pipes and the increased heat transfer due to the elimination of pipe insulation on long 1/2-inch pipes is computed using the calculated pipe lengths and equations 1 and 2 below (ASHRAE 2013).

$$Heat\ Transfer\ Rate\ (q_r) = 2\pi kL(t_i - t_o)/\ln(\frac{r_o}{r_i}) \quad (1)$$

$$Thermal\ Resistance\ (R) = \ln(\frac{r_o}{r_i})/\ 2\pi kL \quad (2)$$

where,

k = pipe thermal conductivity (Btu/hr-ft^2-°F)

L = pipe length (ft)

t_i = internal fluid temperature (°F)

t_o = ambient temperature (°F)

r_i = pipe inside radius (ft)

r_o = pipe outside radius (ft)

Pipe heat losses are calculated for copper pipes and cross-linked polyethylene (PEX) tubing, more commonly used in homes now. Table 4.3 and Table 4.4 summarize the pipe parameters and heat transfer calculations for the 3/4-inch and 1/2-inch pipes. Pipe heat losses for the 2012 and the 2015 editions of the IECC are calculated using pipe heat transfer values and corresponding lengths of 3/4-inch and1/2-inch pipes from Table 4.4 and Table 4.2 respectively. Table 4.5 summarizes the average DHW pipe heat losses for the 2012 IECC and the 2015 IECC DHW pipe insulation requirements for the single-family house and multifamily apartment unit.

Table 4.3. Pipe and Insulation Properties Used in Calculations

	3/4-inch	1/2-inch	Kitchen Pipe (1/2-inch)
Hot Water Temp [°F]	110	110	110
Ambient Temp [°F]	75	75	75
Pipe Properties (Copper)			
Material		Copper	
ID [in]	0.063	0.042	0.042
OD [in]	0.073	0.052	0.052
k [BTU/hr-ft-°F]	232	232	232
Pipe Properties (PEX)			
Material		PEX	
ID [in]	0.063	0.042	0.042
OD [in]	0.073	0.052	0.052
k [BTU/hr-ft-°F]	2.43	2.43	2.43
Insulation Properties			
Type		Polyethylene Foam Pipe Insulation	
ID [in]	0.073	0.052	0.052
OD [in]	0.094	0.063	0.063
R [hr-F-ft^2/Btu]	3.800	3.000	3.000
k [hr-F-ft/Btu]	0.006	0.222	0.222

Table 4.4. Pipe Heat Transfer for 3/4-inch and 1/2-inch Pipes

	3/4-inch Copper	3/4-inch PEX	1/2-inch Copper	1/2-inch PEX
Heat transferred from uninsulated pipe [Btu/hr-ft]	39.60	39.16	28.26	27.94
Heat transferred from insulated pipe [Btu/hr-ft]	26.12	25.93	25.57	25.30

Table 4.5. Calculation of Heat Loss through Pipes for the 2012 and 2015 IECC

Scenario	Average Heat Loss through for the Single-Family Prototype Building (Btu/hr)	Average Heat Loss through Pipes for the Multi-Family Apartment Unit (Btu/hr)
2012 IECC[(a)] (Copper)	896	1,482
2015 IECC[(b)] (Copper)	796	1,205
2012 IECC[(a)] (PEX)	886	1,465
2015 IECC[(b)] (PEX)	788	1,194

(a) 2012 IECC allows 3/4-inch pipes shorter than 10 ft. to be uninsulated, but requires 1/2-inch pipes longer than 20 ft. and kitchen pipes to be insulated.
(b) 2015 IECC requires 3/4-inch pipes shorter than 10 ft. to be insulated but allows 1/2-inch pipes longer than 20 ft. and kitchen pipes to be uninsulated.

Sample Calculation 2012 IECC Single-family Building (Copper Pipes):
896 Btu/hr = (39.60 Btu/hr-ft x 11 ft) + (25.57 Btu/hr-ft x 18 ft)

The average hourly reduction in heat losses through the DHW pipes between the 2012 and the 2015 editions of the IECC is converted to annual Btu reduction by multiplying the hourly value with the annual average DHW load hours from the prototype model DHW use schedules. Table 4.6 summarizes the annual average reduction in heat losses through the DHW pipes from this code change.

Table 4.6. Average Reduction in DHW Pipe Heat Losses in the 2015 IECC

	Average Reduction in DHW Pipe Heat Losses in the 2015 IECC (Btu/year)
Single-family Building	21,630
Multifamily Apartment Unit	49,927

The energy savings from this code change are incorporated into the residential prototype building models as a reduction in the total DHW load in the 2015 IECC models. While this report presents only the total energy and costs for all end uses regulated by the IECC, detailed energy values by end use are generated through the analysis. Accordingly, the average reduction in DHW pipe heat losses for the 2015 IECC reported in Table 4.6 represents approximately 0.3 percent of the total 2012 IECC DHW load for the single-family prototype building and approximately 1.4 percent for the multifamily apartment unit. Because this code change applies to non-recirculating DHW systems and approximately half of the multifamily buildings are assumed to have a central water heater with recirculating controls as discussed previously in section 4.2.3.1, the savings from this code change for multifamily buildings are scaled down by 50 percent to 0.7 percent (1.4 percent x 50 percent) to account only for multifamily buildings with non-recirculating DHW systems. This code change is implemented by creating new hot water schedules that include a conservative average savings factor of 0.003 for the 2015 IECC single-family prototype models and 0.007 for the 2015 IECC multifamily prototype models.

5.0 Findings

The current analysis seeks to identify the energy impact of the 2015 IECC over the 2012 edition. The annual site energy results for the end uses regulated by the IECC—heating, cooling, fans, domestic water heating and lighting— from the simulation analysis of the residential prototype models that minimally comply with the prescriptive and mandatory requirements of the 2015 IECC are converted to annual site energy use intensities (EUI) based on the conditioned floor area of the residential prototype models. The site energy (or secondary energy) use is also converted to source energy. Source energy (or primary energy) accounts for the generation and losses involved in delivering energy to the site. The source-site conversion ratios for electricity and natural gas are calculated from energy values reported in Table 2 of the 2014 Annual Energy Outlook produced by the U.S. Energy Information Administration (EIA 2014a). Table 5.1 and Table 5.2 summarize the source-site conversion factor calculations for electricity and natural gas respectively. The EIA does not report similar losses associated with fuel oil. In absence of this data, a source-site conversion ratio of 1.01 is used for fuel oil based on ENERGY STAR (2013).

Table 5.1. Calculation of the Source-Site Ratio for Electricity

Electricity (quadrillion Btu)	Electricity-Related Losses (quadrillion Btu)	Source-Site Ratio[(a)]
4.685	9.703	3.071

(a) Source-Site ratio= (4.4685+9.703)/4.4685=3.071

Table 5.2. Calculation of the Source-Site Ratio for Natural Gas

Sum of Natural Gas Use, Pipeline, Lease and Plant Fuel (quadrillion Btu)	Delivered to Consumers (quadrillion Btu)	Source-Site Ratio[(a)]
25.757	23.585	1.092

(a) Source-Site ratio= 25.757/23.585= 1.092

Finally, the annual energy results from the simulation analysis of the residential prototype models that minimally comply with the prescriptive and mandatory requirements of the 2015 IECC are converted to annual energy costs using the 2014 national average fuel prices from the EIA. The price of natural gas is assumed to be $1.033/therm, the price of electricity is assumed to be $0.1226/kWh, and the price of fuel oil is assumed to be $23.7/MBtu (EIA 2014b, 2014c, 2014d). These energy costs are compared against similar energy costs derived for the residential prototype models that minimally comply with the prescriptive and mandatory requirements of the 2012 IECC.

Table 5.3 and Table 5.4 show the annual regulated site and source energy use intensities and energy costs for homes built to the 2012 and 2015 editions of the IECC, respectively, by climate zone and weighted using the weighting factors discussed in Section 3.3. Table 5.5 summarizes the annual weighted energy savings for the 2015 IECC over the 2012 IECC at the climate zone and national levels. Overall, the current analysis of the 2015 IECC indicates site energy, source energy and energy cost savings of 0.98 percent, 0.87 percent and 0.73 percent, respectively.

Table 5.3. Estimated Regulated Annual Site and Source Energy Use Intensities (EUI), and Energy Costs by Climate-Zone (2012 IECC)

Climate-Zone	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)	Energy Costs ($/residence-yr)
1	13.96	38.57	845
2	16.99	43.24	1104
3	16.90	40.43	988
4	19.52	44.00	1069
5	27.62	47.49	1162
6	29.28	49.21	1195
7	36.18	63.25	1501
8	50.28	89.49	2320
National Weighted Average	**20.82**	**44.17**	**1086**

Table 5.4. Estimated Regulated Annual Site and Source Energy Use Intensities (EUI), and Energy Costs by Climate-Zone (2015 IECC)

Climate-Zone	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)	Energy Costs ($/residence-yr)
1	13.85	38.33	841
2	16.84	42.90	1096
3	16.71	40.03	980
4	19.31	43.56	1060
5	27.38	47.14	1155
6	29.03	48.84	1187
7	35.86	62.72	1490
8	49.80	88.65	2299
National Weighted Average	**20.61**	**43.78**	**1078**

Table 5.5. Regulated Annual Energy Savings Estimated between the 2012 and 2015 Edition of the IECC

Climate-Zone	Site EUI[(a)]	Source EUI[(a)]	Energy Costs[(a)]
1	0.78%	0.61%	0.43%
2	0.88%	0.79%	0.68%
3	1.13%	0.99%	0.83%
4	1.08%	0.99%	0.82%
5	0.87%	0.74%	0.63%
6	0.85%	0.75%	0.61%
7	0.88%	0.84%	0.71%
8	0.95%	0.94%	0.94%
National Weighted Average	**0.98%**	**0.87%**	**0.73%**

(a) Percentages are calculated before rounding and may not exactly match percentages calculated directly from Table 5.3 and Table 5.4.

6.0 References

42 U.S.C. 6831. Chapter 42, U.S. Code, Section 6831. Available at http://www.gpo.gov/fdsys/granule/USCODE-2010-title42/USCODE-2010-title42-chap81-subchapII-sec6831

42 U.S.C. 6833. Chapter 42, U.S. Code, Section 6833. Available at http://www.gpo.gov/fdsys/pkg/USCODE-2011-title42/pdf/USCODE-2011-title42-chap81-subchapII.pdf.

77 FR 29322. *Updating State Residential Building Energy Efficiency Codes*. Available at http://www.gpo.gov/fdsys/pkg/FR-2012-05-17/pdf/2012-12000.pdf

ASHRAE. 2013. *ASHRAE Handbook of Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

BECP. 2012a. Residential Prototype Building Models developed by DOE's Building Energy Codes Program. Available at http://www.energycodes.gov/development/residential/iecc_models/

BECP. 2012b. *Hawaii Energy and Cost Savings for New Single- and Multifamily Homes: 2012 IECC as Compared to the 2009 IECC*. Available at http://www.energycodes.gov/sites/default/files/documents/HawaiiResidentialCostEffectiveness.pdf

Briggs RL, RG Lucas, and ZT Taylor. 2003. "Climate Classification for Building Energy Codes and Standards: Part 1 – Development Process," *ASHRAE Transactions* (1):4610-4611.

CASE. 2011. *Draft Measure Information Template – Single Family Water Heating Distribution System Improvements*. Codes and Standards Enhancement Initiative (CASE), California Utilities Statewide Codes and Standards Team. Available at http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-05-24_workshop/review/2013_MEASURE_TEMPLATE-SF_DHW_DEG_052311.pdf

Census. 2010. *Characteristics of New Housing*. U.S. Census Bureau, Washington, D.C. Available at http://www.census.gov/construction/chars/completed.html

Dentz J, H Henderson, and K Varshney. 2013. *Hydronic Heating Retrofits for Low-rise Multifamily Buildings: Boiler Control Replacement and Monitoring*. National Renewable Energy Laboratory, Golden, Colorado. Available at http://www.nrel.gov/docs/fy14osti/60051.pdf

DOE. 2013. *EnergyPlus Energy Simulation Software, Version 8.0*. U.S. Department of Energy, Washington, D.C. Available at http://apps1.eere.energy.gov/buildings/EnergyPlus/

EIA. 2009. *2009 Residential Energy Consumption Survey Data, Table HC8.1*. U.S. Energy Information Administration, Washington DC. Available at http://www.eia.gov/consumption/residential/data/2009/

EIA. 2014a. *Annual Energy Outlook*. U.S. Energy Information Administration. Washington D.C. Available at http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=0-AEO2014&table=2-AEO2014&region=1-0&cases=ref2014-d102413a

EIA. 2014b. *Natural Gas Monthly*. U.S. Energy Information Administration, Washington D.C. Available at http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm

EIA. 2014c. *Electric Power Monthly*. U.S. Energy Information Administration, Washington D.C. Available at http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

EIA. 2014d. *Petroleum Marketing Monthly*. U.S. Energy Information Administration. Washington D.C. Available at http://www.eia.gov/petroleum/marketing/monthly/

ENERGY STAR. 2013. *Energy Star Portfolio Manager Technical Reference: Source Energy*. U.S. Environmental Protection Agency. Washington D.C. Available at https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf?2da5-f44d

ICC. 2011. *2012 International Energy Conservation Code*. International Code Council, Washington, D.C.

ICC. 2013. *Results of the Final Action Hearings of the 2013 ICC code development cycle*. Available at http://www.iccsafe.org/cs/codes/Documents/2012-2014Cycle/2013FAA/results/Summary-FinalActionGroupB.pdf

ICC. 2014. *2015 International Energy Conservation Code*. International Code Council, Washington, D.C.

Lutz JD. (Lawrence Berkeley National Laboratory). 2008. *Water Heaters and Hot Water Distribution Systems*. California Energy Commission, PIER Buildings End-Use Energy Efficiency. Available at http://eetd.lbl.gov/sites/all/files/water_heaters_and_hot_water_distribution_systems.pdf

Mendon VV, RG Lucas and SG Goel. 2013. *Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document*. Pacific Northwest National Laboratory, Richland, Washington. Available at http://www.energycodes.gov/sites/default/files/documents/State_CostEffectiveness_TSD_Final.pdf

Mendon VV and ZT Taylor. 2014. *Development of Residential Prototype Building Models and Analysis System for Large-Scale Energy Efficiency Studies Using EnergyPlus*. 2014 ASHRAE/IBPSA-USA Building Simulation Conference, Atlanta, Georgia.

NACHI. 2014. Hot Water Recirculation Systems. International Association of Certified Home Inspectors, Boulder, Colorado. Available at http://www.nachi.org/hot-water-recirculation-systems.htm

NAHB. 2009. *Builder Practices Reports*. National Association of Home Builders, Upper Marlboro, Maryland. Available at http://www.homeinnovation.com/trends_and_reports/data/new_construction

NYSERDA. 1999. DHW Recirculation System Control Strategies. New York State Energy Research and Development Authority. Available at http://www.emra.com/NYSERDA%20DHW%20Report%2099-1%20(Recirc%20Control)%20(a5-0).pdf

Taylor ZT, N Fernandez, and RG Lucas. 2012. *Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes*. Pacific Northwest National Laboratory, Richland, Washington. Available at http://www.energycodes.gov/sites/default/files/documents/residential_methodology.pdf

Taylor ZT and VV Mendon. 2014. *Identification of RESNET HERS Index Values Corresponding to Minimal Compliance with the IECC.* Pacific Northwest National Laboratory, Richland, Washington. Available at http://www.energycodes.gov/hers-and-iecc-performance-path

Wilson E, C Engebrecht Metzger, S Horowitz, and R Hendron. 2014. *2014 Building America House Simulation Protocols*. National Renewable Energy Laboratory, Golden, Colorado. Available at http://energy.gov/sites/prod/files/2014/03/f13/house_simulation_protocols_2014.pdf

Zobrist D. 2012. *Resolving the Circulation Dilemma in Multifamily Buildings*. Home Energy September/October 2012, 22-24.

Zhang Y. (Heschong Mahone Group). 2013. *Multifamily Central Domestic Hot Water Distribution Systems*. California Energy Commission. Available at http://www.energy.ca.gov/2013publications/CEC-500-2013-011/CEC-500-2013-011.pdf

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

U.S. DEPARTMENT OF
ENERGY

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