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National Cost-Effectiveness of the Residential Provisions of the 2018 IECC

April 2021

ZT Taylor

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

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The U.S. Department of Energy (DOE) Building Energy Codes Program (BECP) supports the development and implementation of model building energy codes and standards for new residential and commercial construction. These codes set the minimum requirements for energy-efficient building design and construction and impact energy use over the life of the buildings. Building energy codes are developed through consensus-based public processes. DOE participates in the code development process by recommending technologically feasible and economically justified energy efficiency measures for inclusion in the latest model codes. Ensuring the cost-effectiveness of model code changes also encourages their adoption and implementation at the state and local levels. Pacific Northwest National Laboratory (PNNL) conducted this analysis to support DOE in evaluating the energy and economic impacts associated with updated codes in residential buildings.

This analysis focuses on one- and two-family dwellings, townhomes, and low-rise multifamily residential buildings based on the International Energy Conservation Code (IECC). The IECC is developed by the International Code Council (ICC) on a three-year cycle through a public development and public hearing process. While proponents of code changes often include the energy and cost-effectiveness criteria for their respective code change, the IECC process does not include an energy or cost-effectiveness analysis of the entire edition of the code.

PNNL evaluated the cost-effectiveness of the changes in the prescriptive and mandatory residential provisions of the 2018 edition of the IECC, hereafter referred as the 2018 IECC, compared to those in the prior edition, the 2015 IECC. The simulated performance path and the Energy Rating Index (ERI) path (introduced in the 2015 IECC) are not considered in this analysis due to the wide variation in building construction characteristics they allow.

The process of examining the cost-effectiveness of the code changes has four main parts:

- Identification of the building components affected by the updates to the prescriptive and mandatory residential provisions of the IECC
- Assessment of construction costs associated with these updates
- Analysis of energy and cost impacts associated with these updates
- Cost-effectiveness analysis of the updates that combines the incremental costs of these updates with the associated energy impact

The current analysis builds on the builds on the DOE technical report titled *Energy Savings Analysis: 2018 IECC for Residential Buildings* (DOE 2019a) which identified the prescriptive and mandatory changes introduced by the 2018 IECC compared to the 2015 IECC and determined their energy savings impact.

DOE has an established methodology for determining the energy savings and cost-effectiveness of residential building energy codes (Taylor et al. 2012) [1]. This methodology forms the basis of this analysis

[1] See DOE Residential Energy and Cost Analysis Methodology at: http://www.energycodes.gov/development/residential/methodology

and defines three cost-effectiveness metrics to be calculated in assessing cost-effectiveness of code changes:

- Life-Cycle Cost (LCC) – This is reported as the savings (reduction) in LCC
- Simple Payback – A simple metric that estimates the number of years required for energy cost savings to make up for increased construction costs, assuming no escalation in prices or discounting of future cash flows
- Cash Flow – A small suite of metrics summarizing the net cash flows (outlays versus savings) in the early years of the analysis period

Table ES.1 summarizes the weighted LCC savings per dwelling unit for the 2018 IECC compared to the 2015 IECC for each climate zone, aggregated over all residential prototype buildings. Tables ES.2 and ES.3 summarize the associated simple payback periods and impacts on consumer cash-flows. The results show that construction based on the 2018 IECC is cost-effective when compared to construction based on the 2015 IECC across all climate zones. Simple payback ranges from immediate to 2.8 years for construction based on the 2018 IECC when compared to construction based on the 2015 IECC. In all cases, homeowners see net positive cash flows in the first year.

Table ES.1. Life-Cycle Cost Savings for the 2018 IECC

Climate Zone	Compared to the 2015 IECC ($/dwelling-unit)
1	405
2	408
3	532
4	622
5	633
6	685
7	832
8	1,174
National Average	562

Table ES.2. Simple Payback Period for the 2018 IECC

Climate Zone	Compared to the 2015 IECC (Years)
1	0.0
2	0.0
3	2.8
4	2.6
5	1.9
6	1.8
7	1.5
8	1.0
National Average	2.0

Table ES.3. Impacts on Consumers' Cash Flow from Compliance with the 2018 IECC

	Compared to the 2015 IECC	
Climate Zone	Net Annual Cash Flow Savings ($ for Year 1)	Years to Cumulative Positive Cash Flow
1	11	1
2	11	1
3	20	1
4	25	1
5	23	1
6	25	1
7	31	1
8	44	1
National Average	20	1

Acknowledgements

This report was prepared by Pacific Northwest National Laboratory (PNNL) for the U.S. Department of Energy (DOE) Building Energy Codes Program. The author would like to thank Jeremy Williams at DOE for providing oversight and guidance throughout the project.

Acronyms and Abbreviations

ACH50	air changes at 50-pascal pressure differential
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BC3	Building Component Cost Community
BECP	Building Energy Codes Program
Btu	British thermal unit(s)
CF	cubic foot (feet)
CFM	cubic feet per minute
CPI	Consumer Price Index
DOE	U.S. Department of Energy
ECPA	Energy Conservation and Production Act
EIA	Energy Information Administration
ERI	Energy Rating Index
EUI	Energy Use Intensity
°F	degree(s) Fahrenheit
ft^2	square foot(feet)
hr	hour(s)
ICC	International Code Council
IECC	International Energy Conservation Code
IPC	International Plumbing Code
IRC	International Residential Code
kWh	kilowatt-hour(s)
LCC	life-cycle cost
million Btu	million British thermal units
PID	proportional, integral, derivative
PNNL	Pacific Northwest National Laboratory
SHGC	solar heat gain coefficient
yr	year(s)

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1.0 Introduction

The U.S. Department of Energy (DOE) supports the development and adoption of energy-efficient building energy codes. Title III of the Energy Conservation and Production Act (ECPA), as amended, requires DOE to participate in the development of model building energy codes and assist states in the adoption and implementation of these codes (42 U.S.C. 6831 et seq.). ECPA also mandates DOE to conduct a determination analysis to evaluate whether the new edition of the code saves energy compared to its immediate predecessor, within 1 year of a new code being published (42 U.S.C. 6833(a)(5)(A)).

Building energy codes set the minimum requirements for energy-efficient building design and construction for new buildings and impact energy consumed by the building over its life. These are developed through consensus-based public processes which DOE participates in by proposing changes which are technologically feasible and economically justified. Pacific Northwest National Laboratory (PNNL) provides technical analysis and support to DOE during the code development processes.

This analysis focuses on one- and two-family dwellings, townhomes, and low-rise multifamily residential buildings. The basis of the energy codes for these buildings is the International Energy Conservation Code (IECC). The IECC is updated on a 3-year cycle, i.e., a new edition of the code is published every 3 years, by the International Code Council (ICC). The 2018 edition of the IECC, hereafter referred as the 2018 IECC, was published in August 2017 (ICC 2017). Subsequently, DOE published a notice of preliminary determination of the 2018 IECC in May 2019 (DOE 2019b) followed by a notice of final determination in December 2019. DOE's 2018 IECC determination analyses (DOE 2019a) indicate a small increase in energy efficiency in one- and two-family dwellings, townhomes, and low-rise multifamily residential buildings subject to 2018 IECC compared to the 2015 IECC.

1.1 Purpose

The IECC is developed through a public process administered by the ICC.[1] While proponents of code changes often include the energy and cost-effectiveness criteria associated with their respective code change proposals, the IECC process does not include an energy or cost-effectiveness analysis of the entire edition of the code. Ensuring the cost-effectiveness of model code changes encourages their adoption and implementation at the state and local levels. In support of this goal, DOE conducts cost-effectiveness analyses of the latest edition of the code compared to its predecessor, following the publication of an updated edition of the IECC. These analyses are conducted at the national and state level by accounting for regional construction and fuel costs.

DOE provides technical assistance, such as the present cost-effectiveness analysis, to states to ensure informed decision-making during their consideration of adopting, implementing, and enforcing the latest model building energy codes. DOE has commissioned prior cost-effectiveness analyses of the 2009 and 2012 IECC (Mendon et al 2013), and the 2015 IECC (Mendon et al 2015). Figure 1.1 shows the status of the adoption of residential building energy codes as of December 2018 (BECP 2018).

[1] https://www.iccsafe.org/codes-tech-support/codes/code-development/

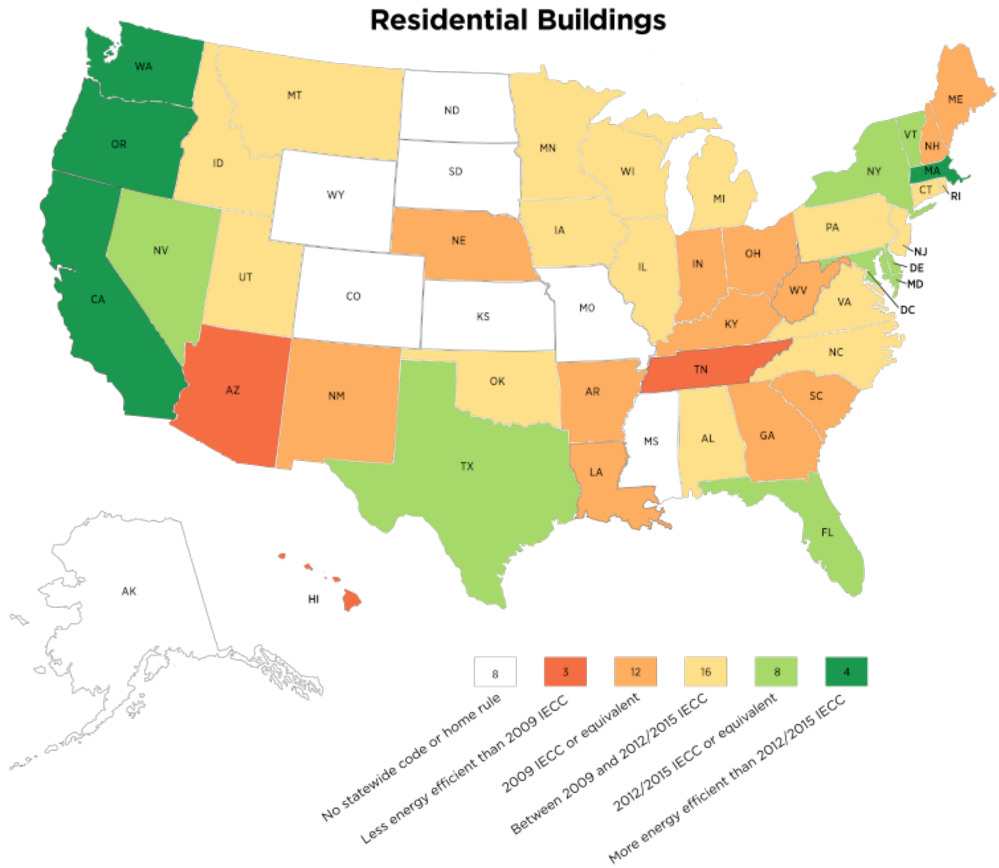

Figure 1.1. Current Residential Building Energy Code Adoption Status in the U.S. (BECP 2018)

1.2 Overview

This analysis examines the cost-effectiveness of the prescriptive and mandatory residential provisions of the 2018 IECC. The simulated performance path and the Energy Rating Index (ERI) path (introduced in the 2015 IECC) are not considered in this analysis due to the wide variation in building construction characteristics they allow. While some states choose to adopt amended versions of the IECC, this analysis focuses on the un-amended provisions of the 2018 and 2015 IECC. The methodology established by DOE for determining the energy savings and cost-effectiveness of residential building energy codes (Taylor et al. 2012) forms the basis of this cost-effectiveness analysis.

1.2.1 Building Prototypes

The DOE methodology proposes a suite of 32 residential prototype building models to represent the U.S. new residential building construction stock. This suite, summarized in Table 1.1, 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 and operational assumptions are documented in previous reports by Mendon et al. (2013 and 2014).

Table 1.1. Residential Prototype Buildings

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
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

Energy models created for the determination analysis of the 2018 IECC (DOE 2019) as well as earlier state and national cost-effectiveness analyses of the 2012 IECC (Mendon et al. 2015 and 2013) are leveraged in the present analysis. Annual energy simulations are carried out using *EnergyPlus*™ *Version 8.0* (DOE 2013).

1.2.2 Climate Locations

The analysis uses the eight standard IECC temperature-oriented climate zones covering the entire U.S., as shown in Figure 1.2 (Briggs et al. 2003). The thermal climate zones are further divided into moist (A), dry (B), and marine (C) regions where appropriate resulting in 15 combined temperature/moisture zones (out of 24 that are theoretically possible). For this analysis, a specific city was selected to represent each climate zone, plus one additional city for homes meeting the IECC's definition of a "tropical" location. The 16 cities are:

- 1A: Miami, Florida (very hot, moist)
- 1AT: Honolulu, Hawaii (tropical)
- 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)

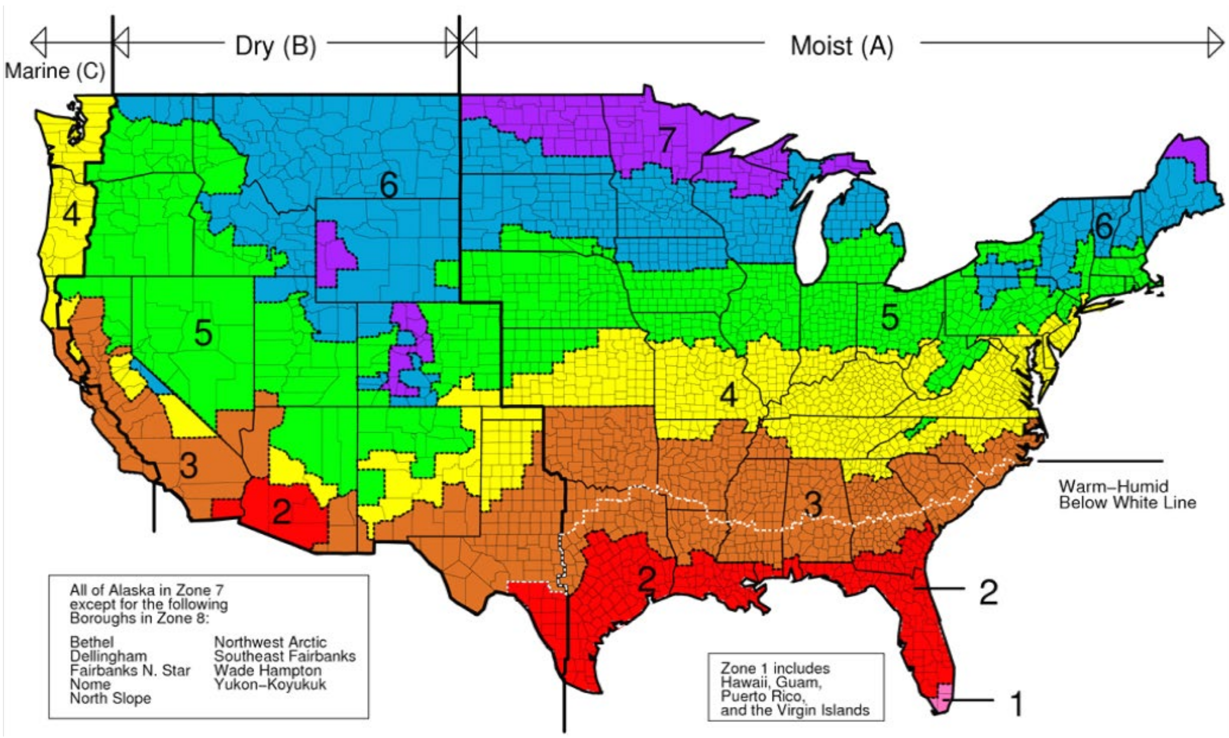

Figure 1.2. Climate Zone Map

1.2.3 Weighting Factors

Weighting factors for each of the 32 residential prototype buildings are 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 (2009). These weighting factors are used to aggregate energy and costs across all building types for each climate zone. Tables 1.2 through 1.5 summarize the weights aggregated to building type, foundation type, heating system, and climate zone levels. Table 1.6 shows the detailed weighting factors for all 32 residential prototype buildings.

Table 1.2. Weighting Factors by Building Type

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

Table 1.3. Weighting Factors by Foundation Type

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

Table 1.4. Weighting Factors by Heating System

Heating System	Weight (%)
Gas-fired Furnace	49.7
Electric Furnace	6.1
Oil-fired Furnace	1.6
Heat Pump	42.7

Table 1.5. Weighting Factors by Climate Zone

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

[1] The tropical climate zone accounts for 50% of all single-family construction starts in climate zone 1

Table 1.6. 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%

Table 1.6. (continued)

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%

1.3 Report Contents and Organization

This report documents the methodology and results of the cost-effectiveness analysis of the prescriptive and mandatory provisions of the 2018 IECC, compared to those of the 2015 IECC. The present analysis builds on earlier work conducted by PNNL during the determination analysis of the 2018 IECC (DOE 2019a).

Building energy models were developed to evaluate the energy performance of the 2018 and 2015 IECC editions as applied to DOE's established residential prototypes. Incremental cost estimates for the provisions of the 2018 IECC compared to the 2015 IECC are combined with the energy performance results to calculate the cost effectiveness of the 2018 IECC.

This report is divided into three parts. Section 2 provides a summary of residential code changes in the 2018 IECC compared to the 2015 IECC and the details of the code changes considered in the present cost-effectiveness analysis. Section 3 details the methodology and cost items for the code changes considered in this analysis. Finally, Section 4 provides an overview of the economic analyses and summarizes the aggregated results of the cost-effectiveness analysis at the climate zone level.

Additional details about the building energy models created for simulating the energy use of buildings built to meet the provisions of the various editions of the IECC are provided in Appendix A. Appendix B provides disaggregated energy costs and cost-effectiveness results for each building type.

2.0 Changes Introduced in the 2018 IECC

Following the publication of the 2018 IECC, DOE conducted both a qualitative and a quantitative energy savings analysis of that code compared to its immediate predecessor, the 2015 IECC. All the changes introduced to the 2015 IECC were identified, and their impact on energy efficiency was qualified. Forty-six formal code change proposals were accepted into the 2018 IECC, resulting in 47 classifiable changes as shown in Table A.2 of the Energy Savings Analysis: 2018 IECC for Residential Buildings (DOE 2019a). Of the 47 changes, 14 were identified as impacting energy use (11 decreasing, three increasing), and two were identified as requiring further analysis by energy simulation to quantify their impact using whole-building energy simulations of the 32 PNNL residential prototype buildings across the 15 IECC climate zones.

Table 2.1 summarizes the characterization of the two approved code changes with quantifiable energy impacts considered in the present cost-effectiveness analysis.

Table 2.1. Summary of Analyzed Changes to the 2018 IECC

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Impact on Energy Efficiency	Discussion
RE31-16	Table R402.1.2 (IRC Table N1102.1.2), Table R402.1.4 (IRC Table N1101.1.4)	Lowers (improves) fenestration U-factors in climate zones 3-8	Decreases Energy Use	Reduces heat loss/gain through windows and doors, thereby decreasing energy use. This change affects all residences in 6 of the IECC's 8 climate zones.
RE127-16	R404.1 (IRC N1104.1)	Increases high-efficacy lighting requirements from 75% to 90% of permanently installed lighting fixtures in all homes. Eliminates option of calculating percentages based on lamp counts instead of fixture counts.	Decreases Energy Use	The increased percentage of high-efficacy lighting results in a clear reduction in energy use. This change is applicable across all homes complying with the IECC.

3.0 Construction Cost Estimates

This section describes the methodology used for calculating the incremental costs of construction of the 2018 IECC compared to the 2015 IECC. Detailed incremental cost estimates for the new provisions of the 2018 IECC considered in this analysis are provided along with a summary of total incremental costs by building type and climate zone.

3.1 Methodology

The present analysis includes only the prescriptive and mandatory provisions of the IECC pertaining to residential buildings. The first step in evaluating the cost-effectiveness of these changes introduced by the 2018 IECC is estimating their incremental construction costs. Data sources consulted for these estimates include but are not limited to:

- Building Component Cost Community (BC3) data repository (DOE 2012)
- Residential construction cost data collected by Faithful + Gould under contract with PNNL (Faithful + Gould 2012)
- RS Means Residential Cost Data (RS Means 2015)
- National Renewable Energy Laboratory (NREL's) National Residential Efficiency Measures Database (NREL 2012)
- Cost data from prominent and commonly recognized home supply stores

The incremental costs are calculated separately for each code change and then added together to obtain a total incremental cost by climate zone and building type. The following sections discuss the specific cost estimates identified for the efficiency measures that changed in the 2018 IECC.

3.2 Incremental Cost Estimates for New Provisions of the 2018 IECC

The incremental construction costs associated with the two changes in Table 2.1 are detailed below.

3.2.1 Increase in the Fraction of Interior Lighting that Must Be High-Efficacy

The 2018 IECC increases the fraction of permanently-installed lighting fixtures that must be high-efficacy from 75% to 90%. High-efficacy lighting is defined such that most fluorescent lighting and LED lighting qualifies, while incandescent does not. Because the efficacy of lighting fixtures and lamps is regulated by federal standards that now effectively prohibit incandescent options in most residential applications, the incremental cost estimate for the 75% to 90% change is defined as zero. Because the 2018 IECC allows up to 10% of residential lighting to be exempt from the high-efficacy requirements, there is provision for the occasional application that might require incandescent fixtures or lamps, and the cost impact on buildings built in 2018 and beyond is zero.

3.2.2 Lowered Fenestration U-Factors in Climate Zones 3-8

The 2018 IECC lowers (makes more efficient) the U-factor required for residential fenestration (windows and doors) in climate zones 3 through 8. In zones 3 and 4, the U-factor was lowered from 0.35 to 0.32 and in zones 5 through 8, the U-factor was lowered from 0.32 to 0.30. A review of offerings at major home improvement stores shows that window units with a U-factor of 0.35 (the least efficient U-factor under consideration here) are difficult to find, and the incremental cost is consequently low. Window units with a U-factor of 0.32 or 0.30 are more common, but a survey of the data sources indicates that this too is a minimal-cost change. The BC3 cost database (DOE 2012) includes a residential summary report giving average/typical costs for various window unit upgrades.[1] Table 5.2.1 of that summary shows the cost difference between window units with U-factors of 0.35 and 0.32 is $0.18 per square foot of window area. Extrapolating that cost change per U-factor to the 0.30-U window unit gives a cost change of $0.12 per square foot of window area. These costs were adjusted from 2012 to 2019 dollars using a consumer price index increase of 10% as looked up on the Inflation Calculator provided by the Bureau of Labor Statistics website,[2] resulting in costs of $0.197/ft^2 to move from U=0.35 to 0.32, and $0.131/ft^2 to move from U=0.32 to 0.30.

3.3 Summary of Incremental Costs

Table 3.1 summarizes the incremental costs for each new code provision of the 2018 IECC evaluated in the present analysis compared to the 2015 IECC.

Table 3.1. Construction Cost Increase of the New Provisions of the 2018 IECC

Provision	Specifications	Scope	Associated Cost	Incremental Cost Used in Analysis ($/dwelling-unit)
High-efficacy lighting fraction	Required fraction of high-efficacy lighting in permanent fixtures up from 75% to 90%	All new dwelling units, both single-family and multifamily	$0.00/ft^2	$0.00
Fenestration U-factor	Improve from 0.35 to 0.32 in climate zones 3 and 4; improve from 0.32 to 0.30 in climate zones 5-8	All new dwelling units, both single-family and multifamily	$0.197/ft^2 in zones 3-4; $0.131/ft^2 in zones 5-8	$36.23 to $105.27 depending on the building type and foundation type

The total incremental costs for the prescriptive and mandatory provisions of the 2018 IECC compared to those of the 2015 IECC are summarized in Table 3.2.

[1] https://bc3.pnnl.gov/sites/default/files/Residential_Report.pdf
[2] http://www.bls.gov/data/inflation_calculator.htm

Table 3.2. Total Construction Cost Increase for the 2018 IECC Compared to the 2015 IECC

Climate Zone	2,376 ft^2 House		1,200 ft^2 Apartment/Condo	
	Slab, Unheated Basement, or Crawlspace	Heated Basement	Slab, Unheated Basement, or Crawlspace	Heated Basement
1	$0	$0	$0	$0
1-tropical	$0	$0	$0	$0
2	$0	$0	$0	$0
3	$70	$105	$54	$72
4	$70	$105	$54	$72
5	$47	$70	$36	$48
6	$47	$70	$36	$48
7	$47	$70	$36	$48
8	$47	$70	$36	$48
National Average	$48	$72	$37	$49

4.0 Economic Analysis

This section provides an overview of the methodology used in evaluating the cost-effectiveness of the prescriptive and mandatory provisions of the 2018 IECC compared to those of the 2015. Cost-effectiveness results for Life-Cycle Cost (LCC) savings, simple payback, and cash flow are calculated for each building type in each climate zone, and the results are weighted using factors detailed in Section 1.2.3 to aggregate results to the climate zone level.

4.1 DOE Residential Cost-effectiveness Methodology

DOE developed a standardized methodology for determining the cost-effectiveness of residential energy code changes through a public Request for Information (76 FR 56413). The established methodology[1] describes the process of assessing energy savings and cost-effectiveness and is used by DOE in the evaluation of published codes as well as code changes proposed by DOE for inclusion in the IECC (Taylor et al. 2012). The methodology forms the basis of this cost-effectiveness analysis by:

- defining an energy analysis procedure, including definitions of two building prototypes (single-family and multifamily), identification of preferred calculation tools, and selection of climate locations to be analyzed;
- establishing preferred construction cost data sources;
- defining cost-effectiveness metrics and associated economic parameters; and
- defining a procedure for aggregating location-specific results to state, climate-zone, and national levels.

Per the methodology, DOE calculates three metrics from the perspective of the homeowner—LCC, Simple Payback, and Cash Flow. LCC is the primary metric used by DOE for determining the cost-effectiveness of an overall code or individual code change. The economic parameters used in the current cost-effectiveness analysis are summarized in Table 4.1.

[1] See DOE Residential Energy and Cost Analysis Methodology at: http://www.energycodes.gov/development/residential/methodology

Table 4.1. Summary of Economic Parameters Used in Cost-Effectiveness Analysis

Parameter	Value
Mortgage Interest Rate	5%
Loan Term	30 years
Down-Payment Rate	10% of home price
Points and Loan Fees	0.7% (non-deductible)
Analysis Period	30 years
Property Tax Rate	1.5% of home price/value
Income Tax Rate	12% federal
Inflation Rate	2.52% annual
Home Price Escalation Rate	Equal to Inflation Rate

4.2 Fuel Prices and Escalation Rates

Data published by the EIA are used to determine the latest national average fuel prices for the three fuel types considered in this analysis—electricity, natural gas, and fuel oil. The EIA reports an average annual residential electricity price of $0.13/kWh for 2018 (EIA 2018a). This average price for electricity is used in the analysis to avoid seasonal fluctuations and regional variations. EIA reports a national annual average cost of $10.68/1000 cubic foot (CF) for natural gas for 2018 (EIA 2018b). Assuming a heat content of 1,012 Btu/CF, a resulting national average cost of $1.081/therm for natural gas is used in this analysis. EIA reports a national annual average cost of $3.202/gallon for No. 2 fuel oil for 2018 (EIA 2018c). The heat content of No. 2 fuel oil is assumed to be 138,874 Btu/gallon, resulting in a national average cost of $23.05/million Btu for fuel oil used in this analysis.

Fuel escalation rates are calculated separately for electricity, natural gas and fuel oil using annual projected fuel prices published in the 2018 Annual Energy Outlook (EIA 2018d). The AEO year-by-year projections are used in the 30-year analysis.

4.3 Energy Cost Savings

The calculation of cost-effectiveness metrics primarily requires annual energy cost savings and the associated incremental costs. Energy estimates from the simulations are converted to energy costs using latest fuel prices described in Section 4.2. Table 4.2 summarizes the annual energy cost savings per dwelling unit for the 2018 IECC compared to the 2015 IECC, aggregated over all 32 residential prototype building models using weighting factors described in Section 1.2.3.

Table 4.2. Average Annual Energy Cost Savings for the 2018 IECC

Climate Zone	Compared to the 2015 IECC ($/dwelling-unit-yr)
1	15
2	15
3	24
4	28
5	27
6	29
7	35
8	47
National Average	24

4.4 Life-Cycle Cost

LCC is the primary metric used by DOE to determine the cost-effectiveness of the code or specific code changes. LCC is the total consumer cost of owning a home for a single homeowner calculated over a 30-year period. The economic analysis assumes that initial costs are mortgaged, that homeowners take advantage of the mortgage interest deductions, that short-lived efficiency measures are replaced at end-of-life, and that all efficiency measures with useful life remaining at the end of the 30-year period of analysis retain a residual value at that point.

Table 4.3 shows the LCC savings (discounted present value) per home over the 30-year analysis period for the prescriptive and mandatory provisions of the 2018 IECC compared to those of the 2015 IECC. These savings are aggregated over all 32 residential prototype buildings using weights described in Section 1.2.3.

Table 4.3. Life-Cycle Cost Savings for the 2018 IECC

Climate Zone	Compared to the 2015 IECC ($/dwelling-unit)
1	405
2	408
3	532
4	622
5	633
6	685
7	832
8	1,174
National Average	562

4.5 Simple Payback

Simple payback is a commonly used measure of cost-effectiveness, defined as the number of years required for the sum of the annual returns on an investment to equal the original investment. Simple payback does not take into consideration any financing of the initial costs through a mortgage or favored tax treatment of mortgages. In other words, simple payback is the ratio of the incremental cost of construction and the first-year energy cost savings. The simple payback is reported for information purposes only and is not used as a basis for determining the cost-effectiveness of the 2018 IECC.

Table 4.4 shows the simple payback period of the 2018 IECC when compared to the 2015 IECC aggregated over all 32 residential prototype buildings using weights described in Section 1.2.3. As seen from the table, the simple payback period for the 2018 IECC compared to that of the 2015 IECC ranges from immediate to 2.8 years, depending on climate zone.

Table 4.4. Simple Payback Period for the 2018 IECC

Climate Zone	Compared to the 2015 IECC (Years)
1	0.0
2	0.0
3	2.8
4	2.6
5	1.9
6	1.8
7	1.5
8	1.0
National Average	2.0

4.6 Cash Flow

Most houses are financed and the financial implications of buying a home constructed to meet the provisions of the 2018 IECC compared to the provisions of the 2015 IECC are important to homeowners. Mortgages spread the payment for the cost of a house or an apartment over a long period of time and the cash flow analysis clearly depicts the impact of mortgages. This analysis assumes a 30-year fixed-rate mortgage and that the homebuyers will deduct the interest portion of the payments from their income taxes.

Table 4.5 shows the impact of the provisions of the 2018 IECC on a typical consumer's cash flow compared to that of the 2015 IECC aggregated over all 32 residential prototype buildings using weights described in Section 1.2.3. In every climate zone, beginning in year one, there is a net positive cash flow per year to the customer for the 2018 IECC-compliant home when compared to the 2015 IECC-compliant home. Positive cumulative savings, including payment of up-front costs, are achieved in the first year in all cases.

Table 4.5. Impacts on Consumer Cash Flow from the 2018 IECC

	Compared to the 2015 IECC	
Climate Zone	Net Annual Cash Flow Savings ($ in Year 1)	Years to Cumulative Positive Cash Flow
1	11	1
2	11	1
3	20	1
4	25	1
5	23	1
6	25	1
7	31	1
8	44	1
National Average	20	1

5.0 Conclusions

As seen from the cost-effectiveness results presented in Chapter 4, residential buildings constructed to the prescriptive and mandatory requirements of the 2018 IECC save homeowners money over the life of their homes compared to those built to the prescriptive and mandatory requirements of the 2015 IECC. Although the prescriptive and mandatory provisions of the 2018 IECC only vary slightly from the 2015 IECC, the incremental costs are likewise very small.

6.0 References

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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.

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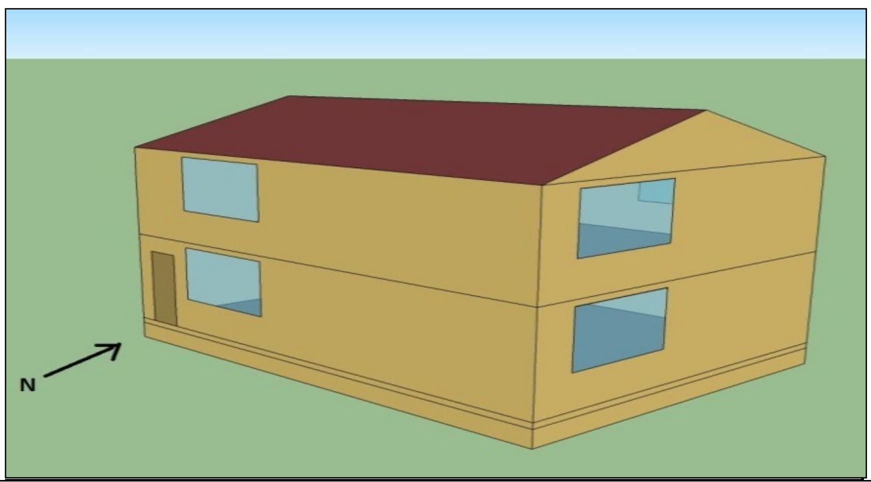
Appendix A

Prototype Building Model Description

A.1. Single-Family Prototype Model

	Item	Description	Data Source
General			
	Vintage	New Construction	
	Locations	See under Section 1.42.2	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Available fuel types	Natural Gas/Electricity/Fuel Oil	
	Building Type (Principal Building Function)	Residential	
	Building Prototype	Single-family Detached	
Form			
	Total Floor Area (sq. feet)	2,376 (29.8' x 39.8' x 2 stories)	
	Building shape		Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes

	Item	Description	Data Source
General			
	Aspect Ratio	1.33	
	Number of Floors	2	
	Window Fraction (Window-to-Floor Ratio)	Average Total: 15.0% divided equally among all facades	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Window Locations	All facades	
	Shading Geometry	none	
	Orientation	Back of the house faces North (see image)	
	Thermal Zoning	The house is divided into three thermal zones: 'living space', 'attic' and 'crawlspace', 'heated basement', 'unheated basement' when applicable.	
	Floor to ceiling height	8.5’	
Architecture			
	Exterior walls		
	Construction	Wood-Frame Walls (2x4 16" O.C. or 2x6 24" O.C.) 1" Stucco + Building Paper Felt + Insulating Sheathing (if applicable) + 5/8" Oriented Strand Board + Wall Insulation + 1/2" Drywall	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Walls, above grade, Wood Frame	IECC
	Dimensions	based on floor area and aspect ratio	
	Tilts and orientations	Vertical	
	Roof		
	Construction	Asphalt Shingles	

	Item	Description	Data Source
General			
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Roofs, Insulation entirely above deck	IECC
	Tilts and orientations	Gabled Roof with a Slope of 4/12	
	Window		
	Dimensions	based on window fraction, location, floor area and aspect ratio	
	Glass-Type and frame	Hypothetical window with the exact U-factor and SHGC shown below	
	U-factor (Btu / h * ft^2 * °F)	IECC Requirements Residential; Glazing	IECC
	SHGC (all)		
	Operable area	100%	
	Skylight		
	Dimensions	Not Modeled	
	Glass-Type and frame	NA	
	U-factor (Btu / h * ft^2 * °F)		
	SHGC (all)		
	Visible transmittance		
	Foundation		
	Foundation Type	Four Foundation Types are Modeled- i. Slab-on Grade ii. Vented Crawlspace Depth 2' iii. Heated Basement - Depth 7' iv. Unheated Basement- Depth 7'	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Insulation level	IECC Requirements for floors and basement walls	IECC
	Dimensions	based on floor area and aspect ratio	

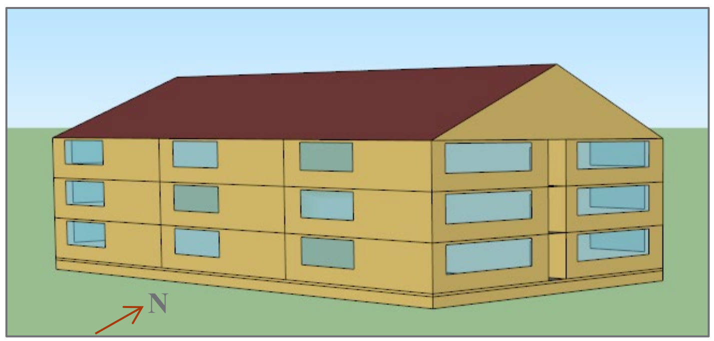
	Item	Description	Data Source
General			
	Internal Mass	8 lb/ft^2 of floor area	IECC 2015 Section 404
	Infiltration (ACH)	2006 IECC: 8 Air Changes/Hour at 50 Pa (8 ACH50) 2009 IECC: 7 Air Changes/Hour at 50 Pa (7 ACH50) 2012 IECC: 5 or 3 Air Changes/Hour at 50 Pa (5 or 3 ACH50) depending on climate zone	
HVAC			
	System Type		
	Heating type	Four Heating System Types are Modeled- i. Gas Furnace ii. Oil Furnace iii. Electric Furnace iv. Heat Pump	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Cooling type	Central DX Air-Conditioner/Heat Pump	
	HVAC Sizing		
	Cooling	autosized to design day	
	Heating	autosized to design day	
	HVAC Efficiency		
	Air Conditioning	SEER 13	Federal minimum efficiency
	Heating	AFUE 78% / HSPF 7.7	Federal minimum efficiency
	HVAC Control		

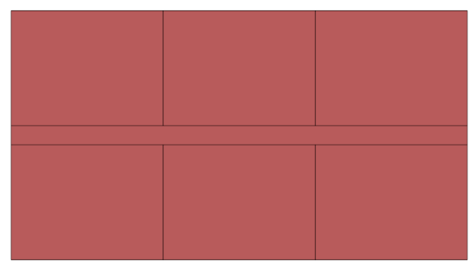
	Item	Description	Data Source
General			
	Thermostat Setpoint	75°F Cooling/72°F Heating	
	Thermostat Setback	No setback	
	Supply air temperature	Maximum 110 F, Minimum 52 F	
	Ventilation	60 CFM Outdoor Air; Continuous Supply	2015 IRC
	Supply Fan		
	Fan schedules	See Appendix A.3	
	Supply Fan Total Efficiency (%)	Depending on the fan motor size	Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document.[1]
	Supply Fan Pressure Drop	Depending on the fan supply air cfm	
	Domestic Hot Water		
	DHW type	Individual Residential Water Heater with Storage Tank	
	Fuel type	Natural Gas/Electricity	
	Thermal efficiency (%)	EF = 0.59 for Gas-fired Water Heaters EF = 0.917 for Electric Water Heaters	Federal minimum efficiency
	Tank Volume (gal)	40 for Gas-fired Water Heaters 52 for Electric Water Heaters	Reference: Building America Research Benchmark
	Water temperature setpoint	120 F	
	Schedules	See Appendix A.2	
Internal Loads & Schedules			
	Lighting		

[1] Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document – Chapter 7 'Energy Use Characterization' http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_07_energy-use_2011-04-25.pdf

	Item	Description	Data Source
General			
	Average interior power density (W/ft^2)	Living space: Lighting Power Density is 0.68 W/sq.ft. (For interior lighting) Lighting loads for Garage and Exterior Lighting have also been included	Reference: 2014 Building America House Simulation Protocols
	Interior Lighting Schedule	See Appendix A.3	
	Internal Gains		
	Load (Btu/day)	17,900 + 23.8 x CFA + 4104 x Nbr See Appendix A.4 for the detailed calculations	Reference: IECC 2015 and Building America Research Benchmark
	Internal gains Schedule(s)	See Appendix A.3	
	Occupancy		
	Average people	800 ft2/per person for conditional total and 1601 ft2/per person for total	
	Occupancy Schedule	See Appendix A.3	

A.2. Multifamily Prototype Model

	Item	Description	Data Source
General			
	Vintage	New Construction	
	Location	See Section 1.2.2	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Available Fuel Types	Natural Gas/Electricity/Fuel Oil	
	Building Type	Residential	
	Building Prototype	Low-rise Multifamily	
Form			
	Total Floor Area	Whole Building- 23,400 sq.ft. Each Dwelling Unit - 1200 sq.ft.	
	Building Shape		Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Aspect Ratio	Whole Building- 1.85 Each Dwelling Unit - 1.33	
	Number of Floors	3	
	Number of Units per Floor	6	
	Orientation	Back of the house faces North (see image)	

	Item	Description	Data Source
	Dimensions	Whole Building - 120' x 65' x 25'6" Each Dwelling Unit - 40' x 30' x 8'6"	
	Conditioned Floor Area	Each Dwelling Unit- 1200 sq.ft.	
	Window Area (Window-to- Exterior Wall Ratio)	23% WWR (Does not include breezeway walls)	
	Exterior Door Area	Each Dwelling Unit - 21 sq.ft. Whole Building - 378 sq.ft.	
	Shading Geometry	None	
	Thermal Zoning	Each floor has 6 dwelling units with a breezeway in the center. Each dwelling unit is modeled as a separate zone. The other thermal zones are: attic, breezeway and foundation (basements and crawlspace only) 	
	Floor to ceiling height	8.5’	
Architecture			
	Exterior walls		
	Construction	Wood-Frame Walls (2x4 16" O.C. or 2x6 24" O.C.) 1" Stucco + Building Paper Felt + Insulating Sheathing (if applicable) + 5/8" Oriented Strand Board + Wall Insulation + 1/2" Drywall	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Wood-Frame Wall R-value	IECC

	Item	Description	Data Source
	Dimensions	Each Dwelling Unit: 40' x 8'6" and 30' x 8'6"	
	Tilts and orientations	Vertical	
	Roof		
	Construction	Built-up Roof: Asphalt Shingles+ 1/2 in. OSB	
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	IECC Requirements Residential; Ceiling R-value	IECC
	Tilts and orientations	Gabled Roof with a Slope of 4/12	
	Window		
	Dimensions	based on window fraction, location, glazing sill height, floor area and aspect ratio	
	Glass-Type and frame	Hypothetical window with the exact U-factor and SHGC shown below.	
	U-factor (Btu / h * ft^2 * °F)	IECC Requirements Fenestration U-Factor & SHGC	
	SHGC (all)		
	Operable area	100%	
	Skylight		
	Dimensions	Not Modeled	
	Glass-Type and frame	NA	
	U-factor (Btu / h * ft^2 * °F)		
	SHGC (all)		
	Visible transmittance		
	Foundation		
	Foundation Type	Four Foundation Types are Modeled- i. Slab-on Grade ii. Vented Crawlspace Depth 2' iii. Heated Basement - Depth 7' iv. Unheated Basement- Depth 7'	Reference: Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes
	Insulation level	IECC Requirements for floors, slabs and basement walls	

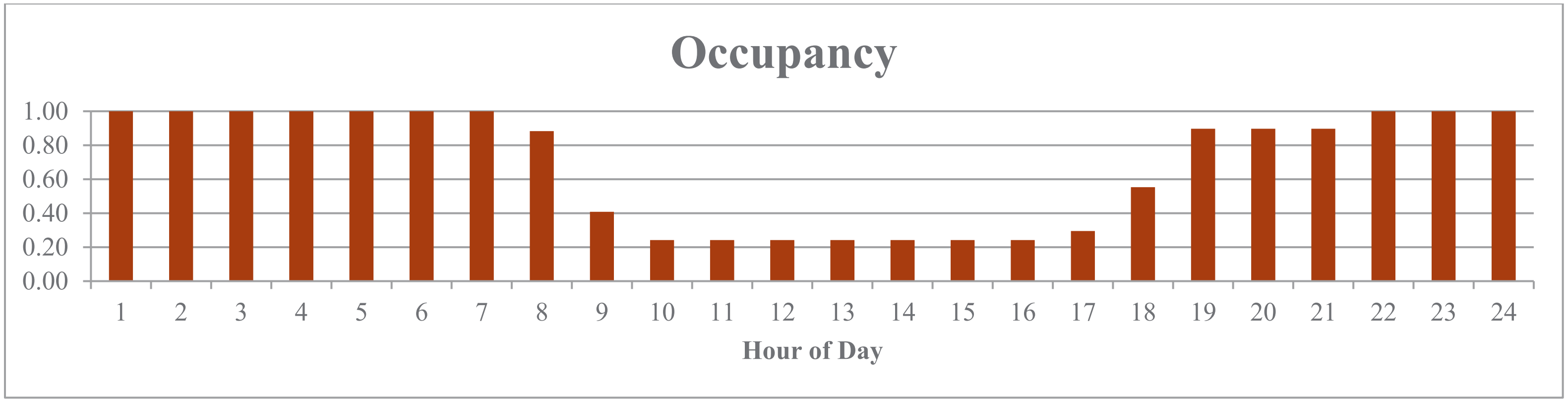
	Item	Description	Data Source
	Dimensions	based on floor area and aspect ratio	
	Internal Mass	8 lb/ft^2 of floor area	IECC 2006 Section 404
	Infiltration (ACH)	2006 IECC: 8 Air Changes/Hour at 50 Pa 2009 IECC: 7 Air Changes/Hour at 50 Pa 2012 IECC: 5 or 3 Air Changes/Hour at 50 Pa depending on climate zone	
HVAC			
	System Type		
	Heating type	Four Heating System Types are Modeled- i. Gas Furnace ii. Oil Furnace iii. Electric Furnace iv. Heat Pump	
	Cooling type	Central DX Air-Conditioner/Heat Pump (1 per unit)	
	HVAC Sizing		
	Cooling	autosized to design day	
	Heating	autosized to design day	
	HVAC Efficiency		
	Air Conditioning	SEER 13	Federal Minimum Equipment Efficiency for Air Conditioners and Condensing Units
	Heating	AFUE 78% / HSPF 7.7	Federal Minimum Equipment Efficiency
	HVAC Control		
	Thermostat Setpoint	75°F Cooling/72°F Heating	
	Thermostat Setback	No setback	
	Supply air temperature	Maximum 110 F, Minimum 52 F	
	Ventilation	45 CFM Outdoor Air per dwelling unit; Continuous Supply	2015 International Residential Code (IRC)
	Supply Fan		
	Fan schedules	See Appendix A.3	

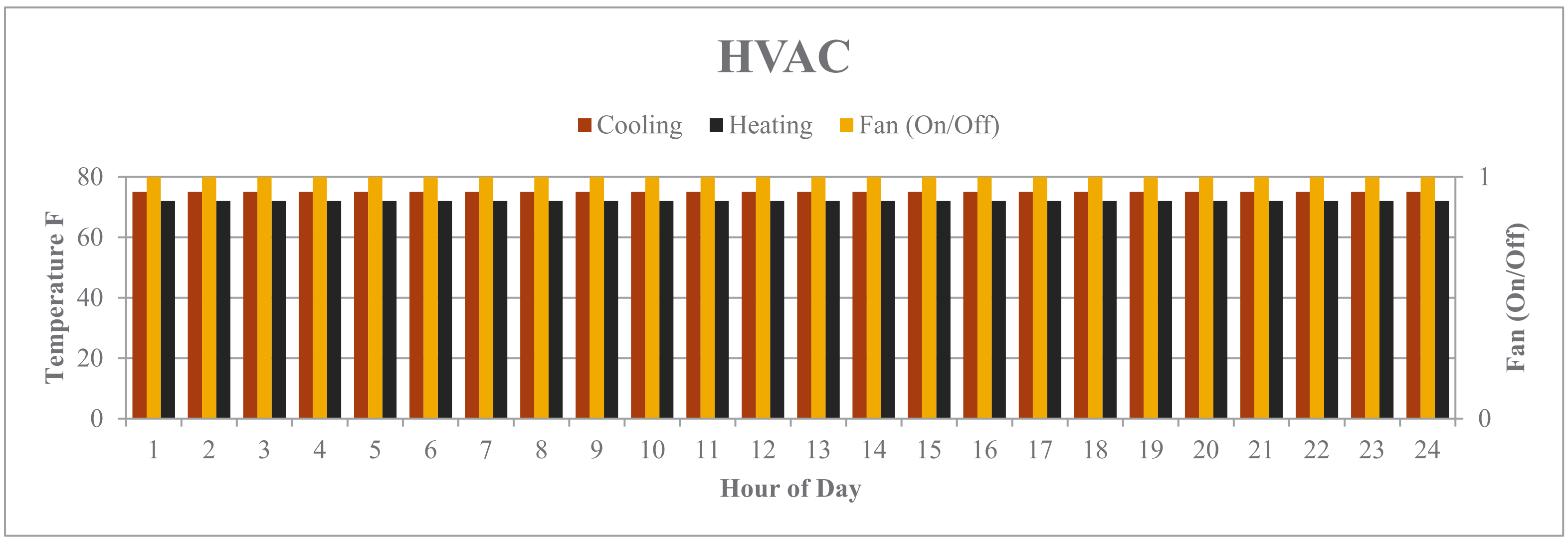
	Item	Description	Data Source
	Supply Fan Total Efficiency (%)	Fan efficiency 58%; Motor efficiency 65% (PSC motor)	Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document[1]
	Supply Fan Pressure Drop	0.6" w.g.	
	Service Water Heating		
	SWH type	Individual Residential Water Heater with Storage Tank	
	Fuel type	Natural Gas / Electricity	
	Thermal efficiency (%)	EF = 0.59	Federal Minimum Equipment Efficiency
	Tank Volume (gal)	40	
	Water temperature setpoint	120 F	
	Schedules	See Appendix A.3	
Internal Loads & Schedules			
	Lighting		
	Average power density (W/ft^2)	Apartment units: Lighting Power Density is 0.82 W/sq.ft. (For interior lighting) Lighting loads for Garage and Exterior Lighting have also been included	2014 Building America House Simulation Protocols
	Interior Lighting Schedule	See Appendix A.3	
	Internal Gains		
	Internal Gains (Btu/day per Dwelling Unit)	17,900 + 23.8 x CFA + 4104 x N_{br} See Appendix A.4 for the detailed calculations	

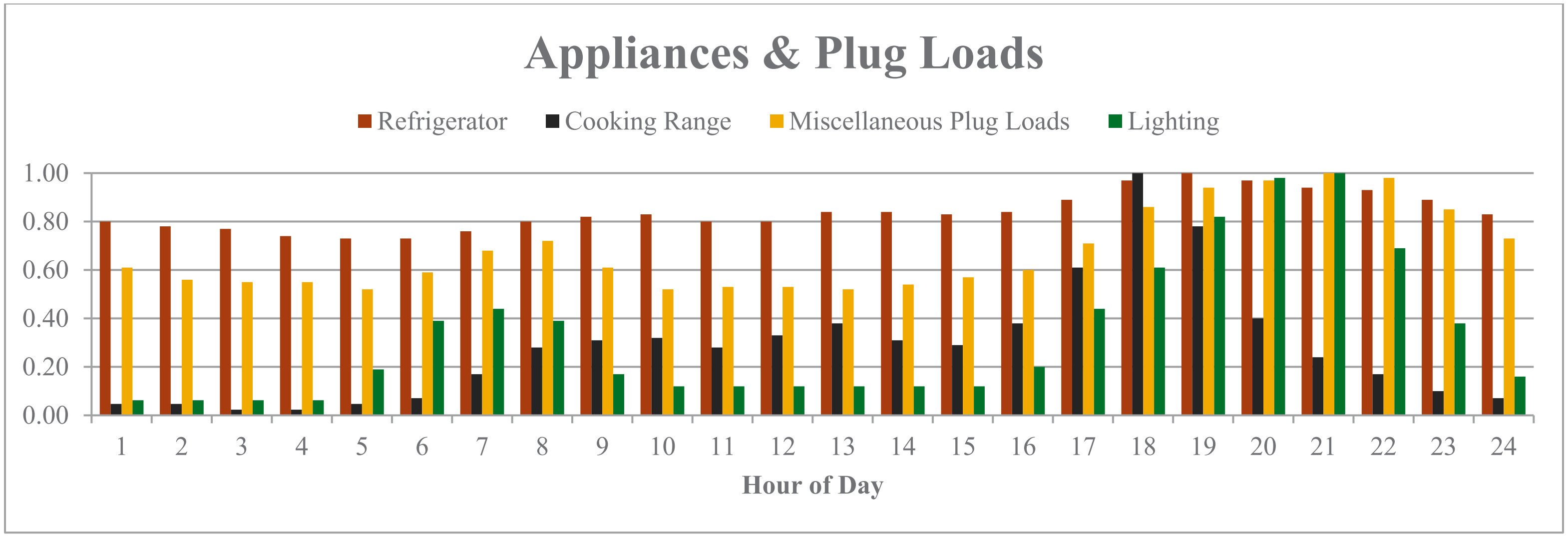
[1] Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document: Chapter 7 'Energy Use Characterization' Residential Furnaces and Centralized Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document

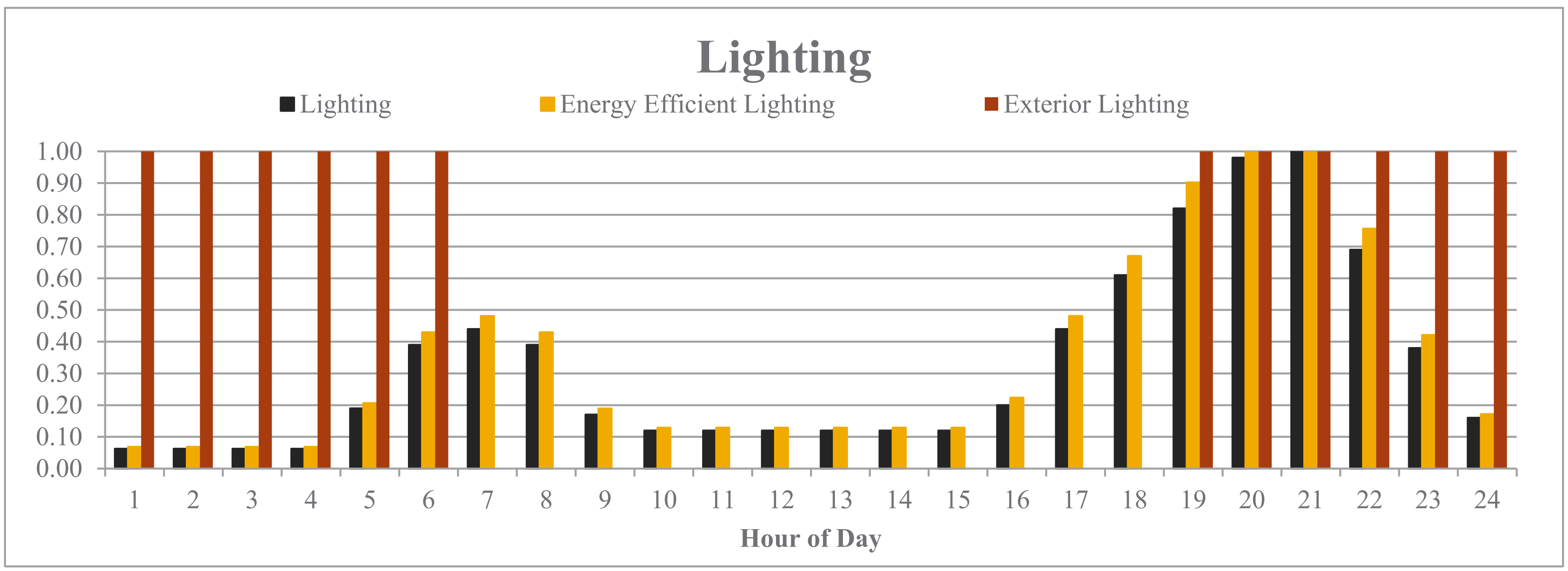
	Item	Description	Data Source
	Internal Gains Schedule(s)	See under Appendix A.3	
	Occupancy		
	Average people	2 people/apartment unit	
	Occupancy Schedule	See Appendix A.3	

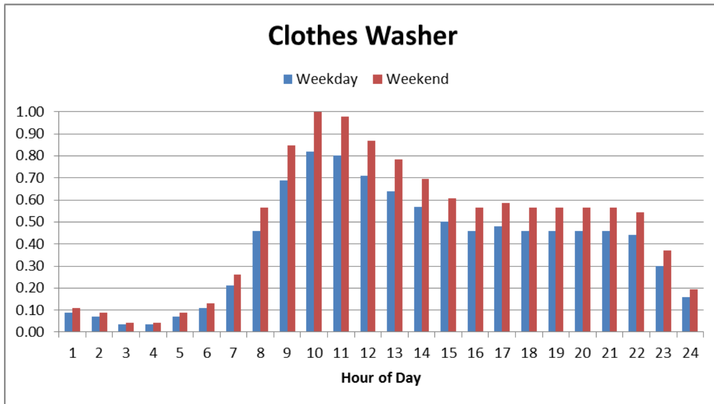
A.3. Schedules

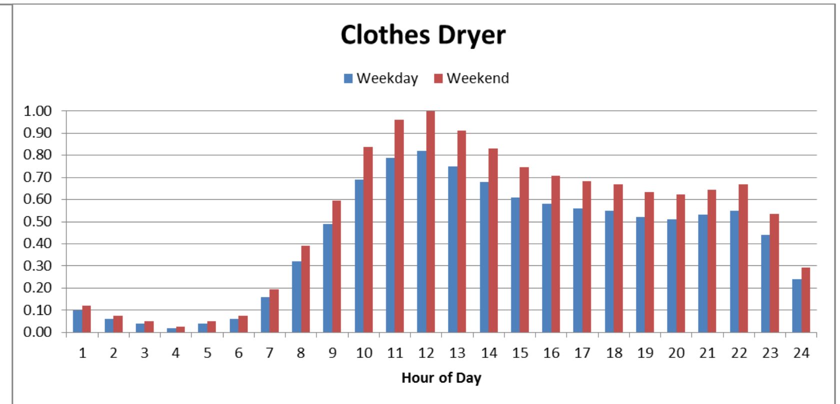


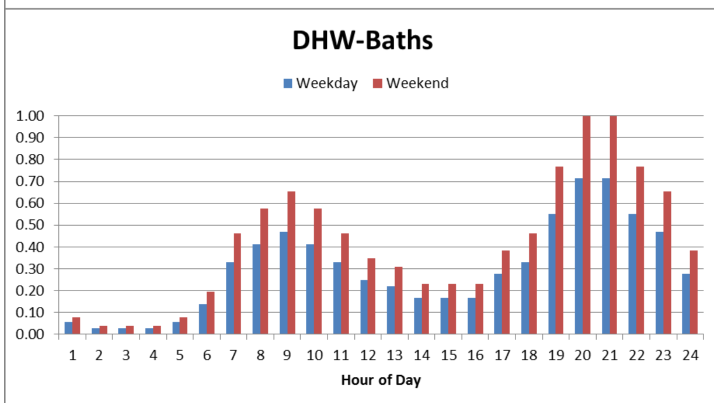


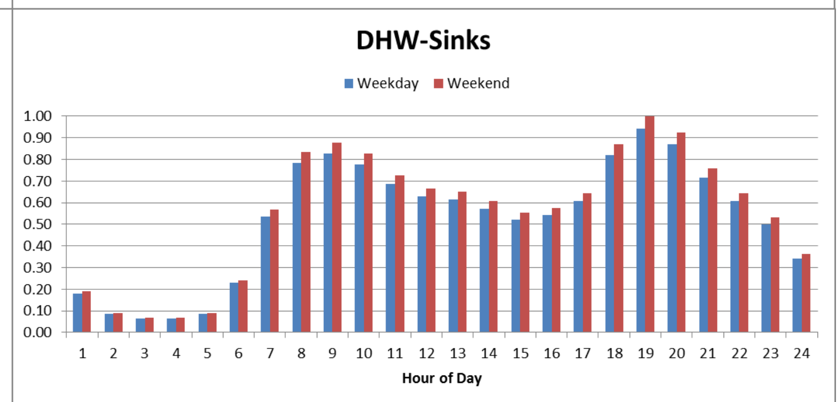

Appliances & Plug Loads
Refrigerator
Cooking Range
Miscellaneous Plug Loads
Lighting
1.00
0.80
0.60
0.40
0.20
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day

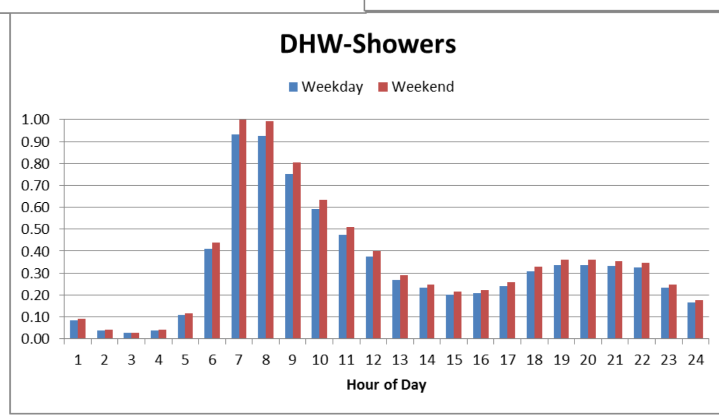

Lighting
Lighting
Energy Efficient Lighting
Exterior Lighting
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day


Clothes Washer
Weekday
Weekend
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day


Clothes Dryer
Weekday
Weekend
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day


DHW-Baths
Weekday
Weekend
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day


DHW-Sinks
Weekday
Weekend
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day


DHW-Showers
Weekday
Weekend
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day

A.4. Internal Gains Assumptions

A.4.1 Total Internal Gains for the single-family prototype for the 2009, 2012 and 2015 IECC

Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction of electricity use not turned into heat	Internal Heat Gains (kWh/yr)		
						2009 IECC	**2012 IECC**	**2015 IECC**
Refrigerator	91.09 W	668.90	1.00	0.00	0.00	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.20	87	87	87
Clothes Dryer	222.11 W	868.15	0.15	0.05	0.80	174	174	174
Dishwasher	68.33 W	214.16	0.60	0.15	0.25	161	161	161
Range	248.97 W	604.90	0.40	0.30	0.30	423	423	423
Misc. Plug Load	0.228 W/sq.ft.	3238.13	0.69	0.06	0.25	2429	2429	2429
Miscellaneous Electric Loads	182.5 W	1598.00	0.69	0.06	0.25	1199	1199	1199
IECC adjustment factor	0.0275 W/sq.ft.	390.56	0.69	0.06	0.25	293	293	293
Lighting			1.00	0.00	0.00	1345	1164	1164
Occupants	3 Occupants					2123	2123	2123
Total					**kWh/yr**	**8902**	**8721**	**8721**
					kBtu/yr	**30373**	**29755**	**29755**
					Btu/day	**83213**	**81522**	**81522**

A.4.2 Total Internal Gains for the multifamily prototype for the 2009, 2012 and 2015 IECC (per dwelling unit)

Appliance	Power	Total Electricity (kWh/yr)	Fraction Sensible	Fraction Latent	Fraction of electricity use not turned into heat	Internal Heat Gains (kWh/yr)		
						2009 IECC	**2012 IECC**	**2015 IECC**
Refrigerator	91.09 W	668.90	1.00	0.00	0	669	669	669
Clothes Washer	29.6 W	109.16	0.80	0.00	0.2	87	87	87
Clothes Dryer	222.11 W	868.15	0.15	0.05	0.8	174	174	174
Dishwasher	68.33 W	214.16	0.60	0.15	0.25	161	161	161
Range	248.97 W	604.00	0.40	0.30	0.3	423	423	423
Misc. Plug Load	0.228 W/sq.ft.	1619.00	0.69	0.06	0.25	1214	1214	1214
Miscellaneous Electric Loads	121.88 W	1067.00	0.69	0.06	0.25	800	800	800
IECC adjustment factor	0.0275 W/sq.ft.	195.28	0.69	0.06	0.25	146	146	146
Lighting			1.00	0.00	0	405	351	351
Occupants	2 Occupants					1416	1416	1416
Total					**kWh/yr**	**5495**	**5440**	**5440**
					kBtu/yr	**18748**	**18562**	**18562**
					Btu/Day	**51364**	**50855**	**50855**

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