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Energy Savings Analysis: 2018 IECC for Residential Buildings

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List of Acronyms

AFUE	annual fuel utilization efficiencies
CFL	compact fluorescent lamp
DOE	U.S. Department of Energy
ECPA	Energy Conservation and Production Act
EER	energy efficiency ratio
EF	energy factor
EIA	U.S. Energy Information Administration
ERI	Energy Rating Index
ERV	energy recovery ventilator
EUI	energy use intensity
HRV	heat recovery ventilator
HSPF	heating season performance factors
HVAC	heating, ventilating, and air conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IRC	International Residential Code
MEC	Model Energy Code
PNNL	Pacific Northwest National Laboratory
RECS	Residential Energy Consumption Survey
SEER	seasonal energy efficiency rating

Executive Summary

Section 304(a) of the Energy Conservation and Production Act (ECPA), as amended, directs the Secretary of Energy to review the International Energy Conservation Code (IECC)[1] and make a *determination* as to whether updated editions would improve energy efficiency in residential buildings. The IECC is developed by the International Code Council (ICC) through an established industry review and consensus process with updated editions typically published every three years. DOE reviews the energy savings impacts of updated code editions and publishes its findings in the *Federal Register*. The DOE determination and accompanying technical analysis serve as useful guidance to state and local governments as they review and update their building codes.

The most recent edition, the 2018 IECC, was published in August 2017, triggering the DOE review and determination process. In response, DOE and Pacific Northwest National Laboratory (PNNL) conducted a technical analysis to determine energy savings for the 2018 IECC residential provisions relative to the previous edition—the 2015 IECC. This report documents the methodology used to conduct the analysis and summarizes the results and findings.

Methodology

The determination analysis is based on an established DOE Methodology (Taylor et al. 2015) and is consistent with previously published determinations (Mendon et al. 2015). The analysis entails a combination of *qualitative* and *quantitative* components in order to identify changes that have a direct impact on residential energy efficiency, and which can be reasonably quantified in estimating overall national average savings impacts. This process can be summarized as follows:

- **Qualitative Assessment**: A compilation of all code changes approved by the ICC for inclusion in the IECC. Individual changes are characterized to identify those expected to have a direct impact on energy efficiency in a significant portion of typical residential buildings.
- **Quantitative Assessment**: Changes are filtered to retain those which could be reasonably quantified through energy modeling and analysis. The resulting collection is then further analyzed to estimate combined effects, with the results aggregated and weighted across the range of climates and building types in order to quantify the national average impacts of the updated IECC.

Results

A total of 47 approved code change proposals were identified and analyzed for the 2018 IECC. Analyses of those changes indicate the following:

- 14 changes with a direct impact on energy use in residential buildings—11 of these are expected to reduce energy use and 3 increase energy use; and
- 33 additional changes—changes in this category are often administrative or impact non-energy portions of the code.

Of the 14 changes characterized as having a direct impact on energy efficiency, only 2 are expected to impact a significant fraction of new homes to warrant further quantitative analysis to assess the overall magnitude of the new code's impact. Those two changes are analyzed as part of the quantitative analysis, the results of which

[1] ECPA originally recognized the 1992 CABO Model Energy Code and its successor editions. The IECC is the contemporary successor to the CABO Model Energy Code.

indicate that residential buildings meeting the 2018 IECC incur the following savings on a weighted national average basis:

- 1.68 percent of annual site energy use intensity (EUI),
- 1.91 percent of annual source EUI, and
- 1.97 percent of annual energy cost.

Table ES.1 shows energy savings results, tabulated by climate zone. Relative savings in terms of annual energy costs vary modestly across climate zones, ranging from 1.35 percent in climate zone 2 to 2.22 percent in climate zone 4. Table ES.2 and Table ES.3 summarize the estimated EUIs for the 2015 and 2018 IECC, respectively. Table ES.4, Table ES.5 and Table ES.6 show the results aggregated by building type.

Table ES.1. Relative Energy Savings of the 2018 IECC compared to the 2015 IECC by Climate Zone (percent)

Climate Zone	Weight (%)	Site EUI (%)	Source EUI (%)	Energy Costs (%)
1	1.20	1.51	1.68	1.69
2	20.50	1.03	1.30	1.35
3	26.09	2.04	2.15	2.18
4	23.23	2.03	2.16	2.22
5	20.83	1.57	1.91	2.01
6	6.88	1.62	1.98	2.10
7	1.26	1.58	1.84	1.93
8	0.01	1.44	1.59	1.63
National	100.00	1.68	1.91	1.97

Table ES.2. Energy Use of the 2015 IECC by Climate Zone

Climate Zone	Weight (%)	Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	Energy Costs ($/residence-yr)
1	1.20	14.3	38.2	906
2	20.50	16.9	41.3	1104
3	26.09	17.1	39.4	1007
4	23.23	20.5	44.7	1128
5	20.83	29.4	49.4	1192
6	6.88	31.1	51.3	1225
7	1.26	38.4	65.9	1582
8	0.01	54.2	94.4	2469
National	100.00	21.6	44.3	1115

Table ES.3. Energy Use of the 2018 IECC by Climate Zone

Climate Zone	Weight (%)	Site EUI (kBtu/ft^2-yr)	Source EUI (kBtu/ft^2-yr)	Energy Costs ($/residence-yr)
1	1.20	14.1	37.6	890
2	20.50	16.7	40.8	1089
3	26.09	16.7	38.6	985
4	23.23	20.1	43.7	1103
5	20.83	28.9	48.4	1168
6	6.88	30.6	50.3	1200
7	1.26	37.8	64.7	1551
8	0.01	53.5	92.9	2428
National	100.00	21.2	43.4	1093

Table ES.4. Relative Energy Savings of the 2018 IECC compared to the 2015 IECC by Building Type (percent)

Building Type	Weight (%)	Site EUI (%)	Source EUI (%)	Energy Costs (%)
Tropical Semi-Conditioned Single-family	0.14	2.25	2.27	2.27
Single-family	82.53	1.71	1.92	1.97
Multifamily Unit	17.32	1.54	1.85	1.92
National	100.00	1.68	1.91	1.97

Table ES.5. Energy Use of the 2015 IECC by Building Type

Building Type	Weight (%)	Site EUI (kBtu/ft2-yr)	Source EUI (kBtu/ft2-yr)	Energy Costs ($/residence-yr)
Tropical Semi-Conditioned Single-family	0.14	9.0	26.4	780
Single-family	82.53	21.7	44.4	1222
Multifamily Unit	17.32	21.2	43.6	606
National	100.00	21.6	44.3	1115

Table ES.6. Energy Use of the 2018 IECC by Building Type

Building Type	Weight (%)	Site EUI (kBtu/ft2-yr)	Source EUI (kBtu/ft2-yr)	Energy Costs ($/residence-yr)
Tropical Semi-Conditioned Single-family	0.14	8.8	25.8	762
Single-family	82.53	21.3	43.6	1198
Multifamily Unit	17.32	20.9	42.8	594
National	100.00	21.2	43.4	1093

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1 Introduction

The International Energy Conservation Code (IECC) is recognized by the U.S. Congress as the national model energy code for residential buildings under the Energy Conservation and Production Act, as amended (ECPA) (42 USC 6833). Section 304(a) of the ECPA provides that whenever the 1992 CABO Model Energy Code (MEC) or any successor to that code, is revised, the U.S. Secretary of Energy 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 IECC is the contemporary successor to the 1992 CABO MEC specified in the ECPA.

On June 11, 2015, the U.S. Department of Energy (DOE) issued an affirmative determination of energy savings for the 2015 IECC (ICC 2014), the relevant successor to the 1992 MEC at the time, that concluded that the 2015 IECC would achieve greater energy efficiency in residential buildings than the 2012 IECC (80 FR 33250). Through this determination, the 2015 IECC became the national model energy code for residential buildings. Consequently, and consistent with previous determinations, the 2015 IECC also became the baseline to which future changes are compared, including the current review of the 2018 IECC.

To support DOE in fulfilling its statutory directive, Pacific Northwest National Laboratory (PNNL) conducted an analysis to determine energy savings for the 2018 IECC residential provisions compared to those of the 2015 IECC. This report documents the methodology used to conduct the analysis and provides a summary of results and findings.

Section 2 of this report provides an overview of the analysis, which is based on a combination of both qualitative and quantitative components. Section 3 provides the qualitative and quantitative analysis results. A comprehensive list of all code change proposals approved for inclusion in the 2018 IECC is included in Appendix A. Additionally, Appendix B and Appendix C detail weighting factors and updates to the energy savings calculation methodology. Appendix D details the modeling strategies used in the quantitative analysis.

2 Methodology

2.1 Overview

The current analysis is based on an established DOE Methodology (Taylor et al. 2015) and is consistent with previously published determinations (Mendon et al. 2015). The analysis is based on a combination of *qualitative* and *quantitative* components in order to identify changes that have a direct impact on residential energy efficiency, and which can be reasonably quantified in estimating overall savings impacts. This process can be summarized as follows:

- **Qualitative Assessment**: A compilation of all code changes approved by the ICC for inclusion in the IECC. Individual changes are characterized to identify those expected to have a direct impact on energy efficiency in a significant portion of typical residential buildings.

- **Quantitative Assessment**: Changes are filtered to retain those which could be reasonably quantified through energy modeling and analysis. The resulting collection is then further analyzed to estimate combined effects, with the results aggregated and weighted across the range of climates and building types in order to quantify the national average impacts of the updated IECC.

The proceeding sections provide additional detail on the analysis methodology. Several individual changes warrant additional consideration and are discussed in Section 3.1.1. Findings resulting from the analysis are covered in Section 3.2.

2.2 Qualitative Assessment

The first step of the analysis is a qualitative assessment by which all approved code change proposals are categorized according to their effect on homes, with particular attention to their expected impact on energy use. Changes expected to have an impact on residential energy efficiency are characterized as:

1. *Decreases Energy Use*: The change is expected to have a beneficial efficiency impact on some or all homes complying with the code (increased energy efficiency and savings)

2. *Increases Energy Use*: The change is expected to have a detrimental efficiency impact on some or all homes complying with the code (decreased energy efficiency and savings)

Many changes do not have a direct impact on energy efficiency and are therefore not designated as falling into one of the above categories. Examples of such changes often include:

- Changes affecting only procedural aspects of complying with the code, such as those providing guidance on inspection protocols or modeling rulesets;

- Changes where impacts are captured under a complementary code requirement, such as the relationship between air tightness testing, associated thresholds (e.g., 5 ACH50), and component air sealing requirements—this serves to avoid double-counting in the quantitative analysis;

- Changes targeting non-energy aspects of the IECC, such as water efficiency requirements[2], and;

- Administrative changes, including editorial corrections, reordering or numbering of code sections, clarifications and reference updates.

Code changes characterized as increasing or decreasing energy use are further evaluated as to whether they can be reasonably quantified through quantitative energy analysis. Appendix A contains a full list of all code changes included in the 2018 IECC and their categorizations.

2.3 Quantitative Assessment

The current analysis is based on an established DOE Methodology (Taylor et al. 2015) and builds on previous work by PNNL (Mendon et al. 2015). DOE has historically focused its review of model codes on changes which affect the *mandatory* and *prescriptive* requirements of the code, as such changes are considered to have the most direct and quantifiable impact on energy efficiency in buildings and have also historically been viewed as the predominant compliance option employed by users of the IECC. While all changes are reviewed individually and assessed as to their anticipated impact during the qualitative analysis, only those changes with a direct and reasonably measurable energy impact are included in the quantitative assessment and therefore the final savings estimates.

Further, the code includes a number of performance-based compliance options which are intended to provide increased flexibility while ensuring that the resulting building is designed to use less (or equal) energy compared to an established baseline. Performance-based alternatives have received increased attention and emphasis in recent code updates. However, they are generally considered optional alternatives to the more traditional prescriptive requirements, and in all cases remain subject to the mandatory code requirements. Such changes can be difficult to reasonably quantify via commonly accepted methods, or are speculative in terms of their expected uptake in practice (i.e., have not been widely implemented in the field to date). For this

[2] Note that no such changes were identified in the current 2018 IECC development cycle

reason, performance-based changes are generally excluded from the quantitative assessment, in which case DOE often defers to the qualitative assessment of the individual change.

The proceeding sections describe the analysis procedures and simulation models relied upon in the quantitative assessment.

2.3.1 Building Types and Model Prototypes

DOE's established methodology uses a suite of representative residential prototype buildings, including a single-family and a low-rise multifamily residential building, each with four different foundation types (slab-on-grade, vented crawlspace, heated basement, unheated basement), and four different heating system types (gas furnace, electric resistance, heat pump, fuel oil furnace). The entire set of configurations is designed to represent the majority of the new residential building construction stock in the United States and was created based on construction data from the U.S. Census (Census 2010), the Residential Energy Consumption Survey (RECS 2013) and the National Association of Home Builders (NAHB 2009). Additionally, a tropical, semi-conditioned, single-family residential prototype building was added during the 2015 IECC determination analysis to capture the impact of alternative requirements for buildings meeting certain criteria added in the 2015 IECC development cycle (Mendon et al. 2015). Thus, a total of 48 prototype buildings and configurations are represented (i.e., 3 building types, 4 foundation types, and 4 fuel/equipment types) resulting in 992 individual energy simulation models. Detailed descriptions of the prototype building models and their representative operational assumptions are documented by Mendon et al. (2013, 2015) and Mendon and Taylor (2014).

2.3.2 Climate Zones

The eight standardized climate zones used by the International Code Council (ICC) for residential applications are used in this analysis, as shown in Figure 1 (Briggs et al. 2003).

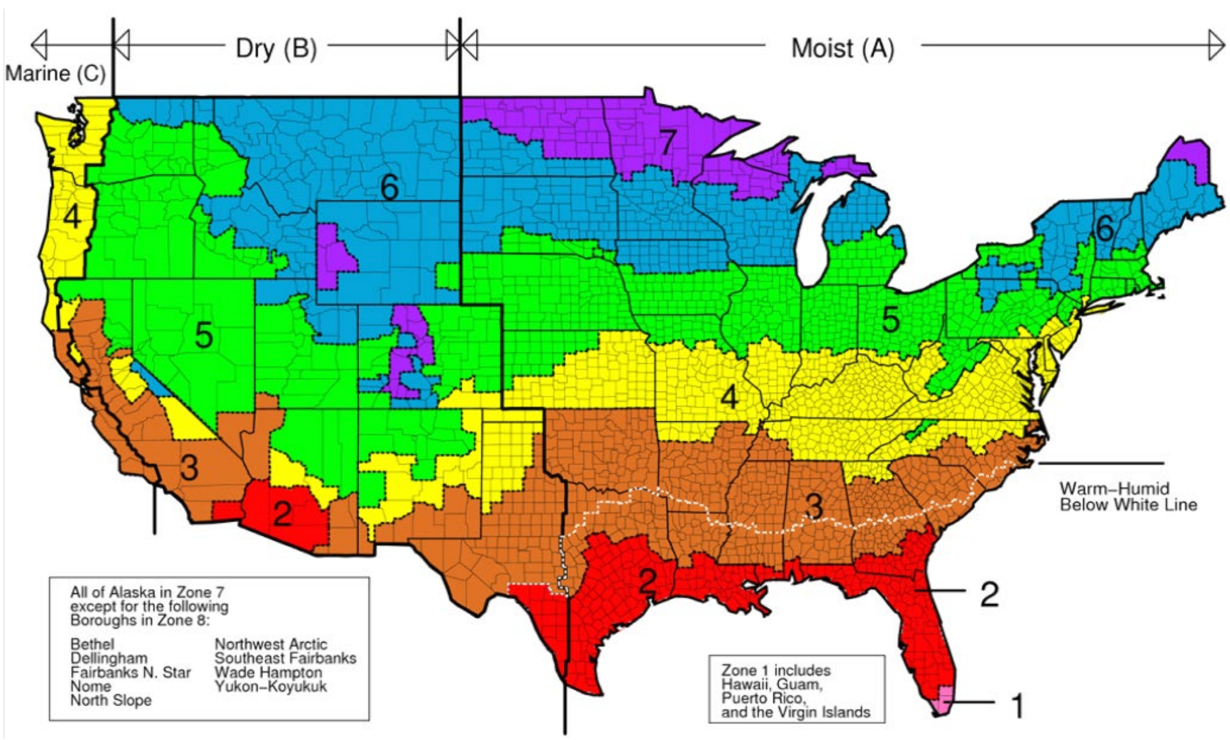

Figure 1. U.S. Climate Zone Map

Zones are divided into moist (A), dry (B), and marine (C) regions. However, not all of the moisture regimes apply to all climate zones in the United States and some zones have no moisture designations at all; thus, only 15 thermal-moisture zones exist in the IECC. In addition, the IECC includes a tropical climate designation with an alternative prescriptive compliance path for semi-conditioned buildings meeting certain criteria. This alternative compliance path is simulated using the tropical semi-conditioned single-family building prototype.

The IECC further defines a warm-humid region in the southeastern United States. 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 determination analysis, however, as it affects only whether basement insulation is required in climate zone 3, where basements are relatively rare.

For this analysis, a specific climate location (city) was selected to represent each of those 16 climate designations:

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

For the determination analysis, one set of prototype models was configured to represent construction practices as dictated by the 2015 IECC, another set was configured to represent the 2018 IECC, and then both sets were simulated in all the climate zones and moisture regimes defined in the IECC. An exception is the tropical semi-conditioned single-family prototype, which was simulated only in the tropical location of Honolulu because it is representative of a special subset of buildings common in tropical climates only. Annual energy simulations were carried out for each of the 992 models using *EnergyPlus* version 8.6. The resulting energy use data were converted to energy costs using national average fuel prices, and the energy and energy cost results were weighted to the national level using the weighting factors.

2.3.3 Weighting Factors

Weighting factors for each of the prototype buildings were developed for all U.S. climate zones using new residential construction starts and residential construction details from the U.S. Census (Census 2010), RECS (2013), and NAHB (2009). Table 1 through Table 4 summarize the weights aggregated to building type, foundation type, heating system, and climate zone levels. The detailed weighting factors for each prototype building are included in Appendix B.

Table 1. Weighting Factors by Building Type

Building Type	Weight (%)
Tropical Semi-Conditioned Single-family	0.14
Single-family	82.53
Multifamily	17.32
Total	100.00

Table 2. Weighting Factors by Foundation Type

Foundation Type	Weight (%)
Crawlspace	27.76
Slab-on-grade	47.70
Heated Basement	13.28
Unheated Basement	11.26
Total	100.00

Table 3. Weighting Factors by Heating System

Heating System Type	Weight (%)
Gas-fired Furnace	49.81
Electric Furnace	6.08
Oil-fired Furnace	1.56
Heat Pump	42.56
Total	100.00

Table 4. Weighting Factors by Climate Zone

Climate Zone	Weight (%)
1	1.20
2	20.50
3	26.09
4	23.23
5	20.83
6	6.88
7	1.26
8	0.01
Total	100.00

2.4 Conversion of Energy Units

The determination analysis is based on three metrics of energy consumption:

1. *Site Energy*: The energy consumed at the end of the generation cycle within the building site, sometimes references as ‘behind the meter’ or as shown on the building’s utility bill.

2. *Source Energy*: The energy required to power a building including generation and distribution.

3. *Energy Cost*: The total cost of energy required for building functions.

The annual site energy results for the end uses regulated by the IECC—heating, cooling, fans, domestic water heating, lighting, and ventilation—from the simulation analysis of the residential prototype models that minimally comply with the prescriptive and mandatory requirements of the 2015 and 2018 IECC were converted to annual site EUIs based on the conditioned floor area of the residential prototype models. The site energy use was converted to source energy (or primary energy), which accounts for the inefficiencies of generation and losses involved in delivering energy to the site.

The source-site conversion ratios for electricity and natural gas were calculated from the 2016 values reported in Table 2 of the 2017 Annual Energy Outlook produced by the U.S. Energy Information Administration (EIA 2017). Table 5 and Table 6 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. Calculation of the Source-Site Ratio for Electricity

Electricity (quadrillion Btu)	Electricity-Related Losses (quadrillion Btu)	Source-Site Ratio[(a)]
4.81	9.39	2.95

(a) Source-Site ratio= (4.81+9.39)/4.81=2.95

Table 6. 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)]
28.58	26.27	1.09

(a) Source-Site ratio= 26.27/28.58= 1.09

Finally, the annual energy results from the simulation analysis were converted to annual energy costs using the 2016 national average fuel prices from the EIA. To avoid seasonal fluctuations and regional variations in the price of electricity, the analysis used the average annual residential electricity price of 12.55 ¢/kWh (EIA 2016a). The EIA reports a national annual average cost of \$10.06/1,000 ft^3 for natural gas and an average heat content of 1,037 Btu/ft^3 for natural gas delivered to consumers in 2016 (EIA 2016b, 2016c). The resulting national average price of \$1.092/therm for natural gas was used in this analysis. In addition, the EIA reports a national annual average cost of \$1.716/gallon for No. 2 fuel oil (EIA 2016d). The heat content of No. 2 fuel oil is assumed to be 138,000 Btu/gallon (NCHH 2015), resulting in a national average price of \$12.43/million Btu for fuel oil.

3 Results

3.1 Qualitative Assessment

The approved code changes incorporated into the 2018 IECC that have a direct effect on energy use are listed in Table 7. The following information is shown for each change:

1. **Proposal Number**: Change proposal designation assigned by the ICC;
2. **Code Section(s)**: Section numbers in the 2015 IECC that are affected by the code change[3];
3. **Description of Change(s)**: Descriptive summary of the change;
4. **Impact on Energy Efficiency:** Qualitative characterization of those changes expected to increase or decrease energy use;
5. **Included in Energy Analysis:** Indication whether the change can be reasonably assessed through further quantitative analysis, and;
6. **Discussion:** A brief discussion expanding on the description and providing additional rationale.

[3] Because sections are often added or deleted, section numbers will often differ in the 2018 IECC.

Table 7. Qualitative Analysis of 2018 IECC Code Changes Affecting Energy Use

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Impact on Energy Efficiency	Included in Energy Analysis	Discussion
RE17-16	R402.1 (IRC N1102.1)	Exempts log homes designed in accordance with ICC-400 from the thermal envelope requirements of the IECC	Increases Energy Use	No	ICC-400 allows less efficient walls than the IECC, resulting in an expected increase in energy use. Log homes make up a relatively small portion of the housing stock, therefore this change affects about 0.4% of new homes[(c)]. Log construction is not a feature of typical homes as represented by the standard residential prototypes. See additional discussion in Section 3.1.2.
RE22-16	Table R402.1.2 (IRC Table N1102.1.2)	Requires R-5 under the entire slab-on-grade when the slab is heated	Decreases Energy Use	No	Reduces heat loss in homes with heated slabs, thereby decreasing energy use. Heated slabs are not a feature in typical homes as represented by the prototypes.
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	Yes	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.
RE53-16	Table R402.2.6 (IRC Table N1102.2.6)	Corrects an inconsistency in the steel framing R-value equivalency table	Decreases Energy Use	No	Effectively requires an additional R-1 continuous insulation if R-19 wall cavity insulation is used, thereby decreasing energy use. Typical home designs as represented by the prototype models do not include steel framing.

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Impact on Energy Efficiency	Included in Energy Analysis	Discussion
RE99-16	R403.3 (IRC N1103.3), R403.3.6 (New) [IRC N1103.3.6 (New)]	Adds provisions for ducts buried in attic insulation	Decreases Energy Use	No	Adds new provisions for buried ducts as an optional feature. Not included in the quantitative analysis because buried ducts are not a feature of typical homes as represented by the prototypes, and because buried ducts are provided as an optional alternative to standard practice. See additional discussion in Section 3.1.2.
RE100-16	R403.3 (IRC N1103.3), R403.3.6 (New) [IRC N1103.3.6 (New)], R403.3.7 (New) [(IRC N1103.3.7) (New)]	Allows buried attic ducts meeting specified insulation and air-sealing criteria to be considered equivalent to ducts located entirely within conditioned space in the simulated performance alternative compliance path	Increases Energy Use	No	Increases heat loss/gain and air leakage into attics compared to ducts entirely within conditioned space, a comparison relevant to a limited number of homes that both have buried ducts and comply via the performance path. Not included in the quantitative analysis as the provision for buried ducts is provided as an optional alternative, and because buried ducts are not a feature in typical homes as represented by the prototypes. See additional discussion in Section 3.1.2.
RE121-16	R403.6.1 (IRC N1103.6.1), Table R403.6.1 (IRC Table N1103.6.1)	Adds HRV/ERV-specific fan-efficacy requirements	Decreases Energy Use	No	Replaces prior efficacy values (for generic "in-line fans") that were considered inappropriate when installing an HRV/ERV systems. Not included in the energy analysis because HRV/ERV systems are an optional feature and not required by the IECC. See additional discussion in Section 3.1.2.

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Impact on Energy Efficiency	Included in Energy Analysis	Discussion
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	Yes	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.
RE149-16	Table R405.5.2 [IRC Table N1105.5.2(1)]	Reformulates equation for ventilation fan energy in the Standard Reference Design of the simulated performance alternative compliance path to reference prescriptive fan-efficacy requirements.	Decreases Energy Use	No	Because the equation in the prior code used a term based on outdated fan efficacies, the change reduces ventilation fan energy in homes complying via the performance path. Not included in the quantitative analysis as this provision is offered as an option under the performance path and is intended to create alignment with current prescriptive baseline requirements. See additional discussion in Section 3.1.2.
RE166-16	R406.3 (IRC N1106.3), R406.3.1 (IRC N1106.3.1), R406.6.1 (IRC N1106.6.1), R406.7 (IRC N1106.7), R406.7.1 (IRC N1106.7.1), R406.7.2 (IRC N1106.7.2), R406.7.3 (IRC N1106.7.3)	Replaces definition of Energy Rating Index (ERI) with a reference to ANSI/RESNET/ICC 301, except for Reference Home ventilation rates, which are modified to be consistent with IRC requirements (Section M1507.3 of the 2015 IRC)	Decreases Energy Use	No	Bases ERI target on the IRC's ventilation rates, which are lower than those in ANSI/RESNET/ICC 301. This reduces ventilation energy in homes meeting the target in the ERI path. However, RE166-16 did not modify the 301 standard's ventilation specifications for the Rated Home, which are generally equivalent to those of the Reference home, so the actual energy difference owing to this code change is expected to be minimal. See additional discussion in Section 3.1.2.

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Impact on Energy Efficiency	Included in Energy Analysis	Discussion
RE173-16	Table R406.4 (IRC Table N1106.4)	Raises (relaxes) ERI thresholds	Increases Energy Use	No	Raising ERI thresholds allows higher energy use in residences under the ERI compliance path.
		Improves mandatory envelope requirements in the ERI compliance path for homes with on-site generation	Decreases Energy Use	No	By strengthening mandatory minimum envelope efficiency requirements, the change prevents degrading envelope efficiency in trade for on-site generation. See additional discussion in Section 3.1.2.
RE183-16	R502.1.1.2 (IRC N1108.1.1.2), R503.1.2 (IRC N1109.1.2)	Requires new HVAC systems in additions and alterations to comply with the same requirements as systems in new homes	Decreases Energy Use	No	Improves HVAC efficiency in some additions and alterations. Not included in the quantitative analysis because the established residential methodology and prototypes focus on new housing.
CE177-16, Part II	R403.10.3 (IRC N1103.10.3)	Modifies and clarifies an exception to the pool cover requirements	Decreases Energy Use	No	Modestly increases the level of site-recovered energy required to qualify for the exception. Not included in the quantitative analysis because pools are not part of typical homes as represented by the prototypes.

(a) Proposal numbers are as assigned by the ICC (http://media.iccsafe.org/codes/2015-2017/GroupB/CAH/IECC-R.pdf).
(b) Code sections refer to the 2015 IECC. Sections may be renumbered by the ICC in the 2018 IECC.
(c) Personal communication with Rob Pickett, Technical Consultant, Rob Pickett and Associates, LLC, 30 January 2017

3.1.1 Summary of Individual Changes

Figure 2 summarizes the changes to the 2018 IECC by category. Among a total of 47[4] changes, 14 were characterized as impacting energy use in residential buildings, 11 of which are expected to reduce energy use and 3 of which increase energy use. Only two of the energy-impacting changes were included in further quantitative analysis to assess the national average energy savings impact that can be expected with the 2018 IECC. Among the other remaining changes approved for inclusion in the 2018 IECC, three are non-energy related changes and 30 were identified as administrative in nature.

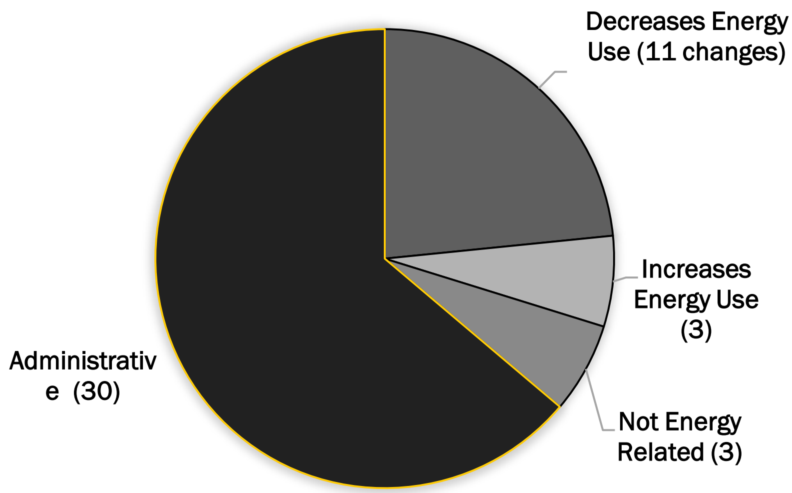

Figure 2. Categorization of Approved Code Changes (Number of changes)

3.1.2 Additional Discussion of Significant Changes

3.1.2.1 Log Home Envelopes (RE17-16)

This code change considers the thermal envelopes of log homes to comply with the IECC if they are "designed in accordance with ICC-400." ICC-400, *Standard on the Design and Construction of Log Structures*, covers many aspects of log construction, including energy efficiency requirements. In the most straightforward prescriptive approach, ICC-400 defers to the IECC for house components other than the walls, and results in less efficient homes for two primary reasons. First, ICC-400 was published in 2012 and references the 2012 IECC, which is not the current model energy code and is less efficient overall than the 2018 IECC. Second, ICC-400 replaces wall requirements with log-specific U-factors that are substantially less efficient than the IECC's "mass wall" requirements that would otherwise likely be employed in log homes complying with the IECC. Because log construction is not a typical feature of homes as represented by the prototypes in the established methodology, and log homes represent only about 0.4% of new home construction,[5] this change was not subject to further quantitative analysis.

3.1.2.2 Buried Ducts in Unconditioned Attics (RE99-16, RE100-16, and RE110-16)

These three changes provide specific requirements for "buried ducts"—attic ducts that include both their own insulation and are buried underneath the attic insulation. The three changes are related but distinct:

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[4] A total of 46 code change proposals were approved for inclusion in the 2018 IECC. However, RE173-16 has two distinct parts, thus leading to a total of 47 code changes evaluated in this analysis.

[5] Personal communication with Rob Pickett, Technical Consultant, Rob Pickett and Associates, LLC, 30 January 2017.

- RE99, although it does not require buried ducts, introduces prescriptive insulation requirements for ducts that are buried in attic insulation.
- RE110 makes changes to the performance compliance path to align it with the new prescriptive requirements added in RE99.
- RE100 makes an independent change to the performance path that allows buried ducts to be considered equivalent in efficiency to ducts located entirely within conditioned space, provided they meet insulation requirements that exceed those introduced by RE99 and achieve specified air leakage requirements.

Burying ducts is not required by any of the changes, but the practice does tend to increase the overall thermal resistance of ducts, and it is anticipated that RE99's (and RE110's) specific requirements will improve efficiency in homes that have buried ducts. RE100, on the other hand, will lower the overall efficiency of some homes complying by the performance path because it will allow certain buried ducts to be credited with zero energy loss even though there remain finite conductive losses and air leakage.

3.1.2.3 HRV/ERV-Specific Fan Efficacy Requirements (RE121-16)

Prior to the 2018 IECC, the code had no fan efficacy (CFM/Watt) requirements applicable to heat recovery (or energy recovery) ventilators. Arguably, the existing requirements for generic "in-line" fans would have applied, and those efficacies are substantially more stringent than the new HRV/ERV-specific requirements. However, the in-line fan requirements are generally deemed inappropriate for HRV/ERV applications because HRVs/ERVs require two fans, one for intake and one for exhaust. Based on data from the Home Ventilating Institute's Certified Home Ventilating Products Directory, less than 3% of the eligible market would meet the 2015 IECC's in-line fan efficacy requirements.[6] It is therefore unlikely that fan efficacy requirements for HRVs/ERVs have been enforced in the past. Consequently, while the new HRV/ERV provisions appear to imply a reduction in required fan efficacy, they are more appropriately considered new requirements where none existed before and have therefore been categorized as decreasing energy use in residential buildings.

3.1.2.4 Energy Rating Index Definition (RE166-16)

RE166 replaces the 2015 IECC's cursory definition of an Energy Rating Index (ERI) with a reference to ANSI/RESNET/ICC Standard 301. The new reference standard is largely equivalent to the prior definition but gives considerably more detail on how to calculate a rating. However, RE166 modifies ANSI/RESNET/ICC Standard 301's reference-design ventilation rates, making them equivalent to the lower flowrate requirements of the IRC (Section M1507.3 of the 2015 IRC). The lower flowrates imply lower energy in the reference design, which will push proposed home designs to lower overall energy consumption for the same ERI thresholds. This also introduces a potential complication for energy ratings, in that homes complying via the ERI path of the 2018 IECC would be required to follow a different ruleset than homes seeking a rating for other purposes, such as a HERS Index rating.

3.1.2.5 Energy Rating Index Thresholds and Mandatory Envelope Requirements in Homes Having On-Site Generation (RE173-16)

RE173 makes two independent changes: it raises (makes less stringent) the ERI thresholds required for compliance by the ERI path, and it strengthens the mandatory envelope provisions of homes that claim ERI credit for on-site generation. The former change is a direct reduction in the efficiency of homes complying by the ERI path, while the latter increases the efficiency of homes that might otherwise have their envelope efficiency traded down in exchange for solar PV panels, for example.

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[6] http://www.hvi.org/proddirectory/CPD_Reports/section_3/index.cfm, accessed February 2, 2017. Specific files analyzed were located at http://www.hvi.org/prodDirectory/CPD_Reports/section_3/section_3_airFlow.xls and http://www.hvi.org/prodDirectory/CPD_Reports/section_3/section_3_energyRatings.xls.

Although the 2018 IECC's relaxed ERI thresholds are a direct efficiency reduction compared to the 2015 IECC's ERI path, they are likely to result in homes that use less energy than if they had simply been constructed to meet the prescriptive requirements of either code. The ERI path is unique among the IECC's compliance paths in that it is not designed to be energy equivalent to the other paths. Consequently, RE173 is unusual in that its impact includes the possibility of influencing the choice of compliance path, which in turn can have a significant impact on energy.

It is generally understood that the 2015 IECC ERI path has not been used for a significant number of building permits, at least in part because its ERI thresholds imply significant efficiency improvement beyond the prescriptive path. Consequently, even with relaxed thresholds the 2018 IECC ERI path may be a net benefit if its more palatable thresholds induce builders to improve efficiency by using the ERI path instead of the prescriptive or performance path. There are additional marketing incentives to obtain home energy ratings, so the relaxed thresholds might induce some builders to use the ERI path. However, any such path switching is speculative and there is little data to inform impact estimates. Additional data is currently being sought by DOE and others to better quantify the impacts of the ERI path as it experiences additional market uptake amongst users of the IECC.

3.2 Quantitative Assessment

Table 8 and Table 9 show the results in terms of relative energy savings (percent) of the 2018 IECC compared to the 2015 IECC by climate zone and by building type. These results are based on changes identified as impacting energy efficiency through the qualitative component of the analysis, and that could also be reasonably measured via the established energy modeling and simulation methodology. The 2018 IECC includes only two code changes which fit this classification—RE31 (fenestration) and RE127 (lighting).

Results are shown in terms of three metrics—site EUI, source EUI, and energy cost. The energy cost metric is used by DOE in reporting its determinations of the energy savings of new code revisions; the other metrics are shown here for reference. The energy cost savings are higher at 1.97 percent relative to the site energy savings, reflecting the greater impact of reduced cooling and lighting loads when conversion costs of electricity are considered.

Relative savings in terms of annual energy costs vary from 1.35 percent in climate zone 2 to 2.22 percent in climate zone 4. The variations by climate zone reflect differences in the relative magnitudes of heating and cooling loads as well as nuances in the relative prevalence of building types, foundation types, and system types.

Table 10 through Table 13 show the raw energy savings values from which the percentages in Table 8 and Table 9 were calculated. The tables show the sum of all regulated energy end uses as calculated from the whole-building energy simulations.

Table 8. Relative Energy Savings of the 2018 IECC compared to the 2015 IECC by Climate Zone (percent)

Climate Zone	Weight (%)	Site EUI (%)	Source EUI (%)	Energy Costs (%)
1	1.20	1.51	1.68	1.69
2	20.50	1.03	1.30	1.35
3	26.09	2.04	2.15	2.18
4	23.23	2.03	2.16	2.22
5	20.83	1.57	1.91	2.01
6	6.88	1.62	1.98	2.10
7	1.26	1.58	1.84	1.93
8	0.01	1.44	1.59	1.63
National	100.00	1.68	1.91	1.97

Table 9. Relative Energy Savings of the 2018 IECC compared to the 2015 IECC by Building Type (percent)

Building Type	Weight (%)	Site EUI (%)	Source EUI (%)
Tropical Semi-Conditioned Single-family	0.14	2.25	2.27
Single-family	82.53	1.71	1.92
Multifamily Unit	17.32	1.54	1.85
National	100.00	1.68	1.91

Table 10. Energy Use of the 2015 IECC by Climate Zone

Climate Zone	Weight (%)	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)	Energy Costs ($/residence-yr)
1	1.20	14.3	38.2	906
2	20.50	16.9	41.3	1104
3	26.09	17.1	39.4	1007
4	23.23	20.5	44.7	1128
5	20.83	29.4	49.4	1192
6	6.88	31.1	51.3	1225
7	1.26	38.4	65.9	1582
8	0.01	54.2	94.4	2469
National	100.00	21.6	44.3	1115

Table 11. Energy Use of the 2015 IECC by Building Type

Climate Zone	Weight (%)	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)
Tropical Semi-Conditioned Single-family	0.14	9.0	26.4
Single-family	82.53	21.7	44.4
Multifamily Unit	17.32	21.2	43.6
National	100.00	21.6	44.3

Table 12. Energy Use of the 2018 IECC by Climate Zone

Climate Zone	Weight (%)	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)	Energy Costs ($/residence-yr)
1	1.20	14.1	37.6	890
2	20.50	16.7	40.8	1089
3	26.09	16.7	38.6	985
4	23.23	20.1	43.7	1103
5	20.83	28.9	48.4	1168
6	6.88	30.6	50.3	1200
7	1.26	37.8	64.7	1551
8	0.01	53.5	92.9	2428
National	100.00	21.2	43.4	1093

Table 13. Energy Use of the 2018 IECC by Building Type

Climate Zone	Weight (%)	Site EUI ($kBtu/ft^2$-yr)	Source EUI ($kBtu/ft^2$-yr)	Energy Costs ($/residence-yr)
Tropical Semi-Conditioned Single-family	0.14	8.8	25.8	762
Single-family	82.53	21.3	43.6	1198
Multifamily Unit	17.32	20.9	42.8	594
National	100.00	21.2	43.4	1093

3.3 Conclusion

A total of 47 approved code change proposals were analyzed for the 2018 IECC. The qualitative component of the analyses identified 14 changes with a direct impact on energy use in residential buildings—11 of which are expected to reduce energy use and 3 increase energy use. Further assessment of the two code changes included in the quantitative analysis, RE31 (fenestration) and RE127 (lighting), suggest national average savings of approximately:

- 1.68 percent of annual site energy use intensity (EUI);
- 1.91 percent of annual source EUI, and;
- 1.97 percent of annual energy cost.

Based on these results, the 2018 IECC is expected to improve energy efficiency in residential buildings.

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Appendix A - Comprehensive List of Code Change Proposals Approved for Inclusion in the 2018 IECC

There were 46 formal code change proposals resulting in 47 classifiable changes to the IECC, as shown in Table A.1. Of the 14 changes impacting energy use (11 decreasing, three increasing) two were further analyzed by energy simulation to quantify their impact.

Table A.1. Summary of Approved Code Changes in the 2018 IECC

Category of Change	Number
Decreases Energy Use	11
Increases Energy Use	3
Not Energy Related	3
Administrative	30
Total	47

Table A.2 lists all the successful code change proposals incorporated into the 2018 IECC. For each proposal, the following six columns of information are shown:

1. **Proposal Number**: the change proposal designation assigned by the ICC.
2. **Code Section(s)**: a list of the section numbers in the 2015 IECC that are affected by the code change. Because sections are often added or deleted, section numbers will often differ in the 2018 IECC.
3. **Description of Change(s)**: a brief summary of the changes made by the proposal.
4. **Category of Change**: the qualitative categorization of the nature of the change.
5. **Included in Energy Analysis**: an indication whether or not the change was subjected to an additional energy analysis in the subsequent quantitative analysis.
6. **Discussion**: a brief discussion expanding on the change categorization and providing additional rationale, for changes that impact energy use, explaining whether the change is to be included in the subsequent quantitative analysis.

Table A.2. Qualitative Analysis of All 2018 IECC Code Changes

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE3-16	R202	Copies definition of "air-impermeable insulation" from the IRC and adds new reference standard (ASTM E2178-13)	Administrative		
RE5-16	R202 (IRC N1101.6)	Enhances descriptive list of lighting types that meet the high-efficacy requirement	Administrative		
RE8-16	R202 (New) [IRC N1101.6 (New)]	Adds definition for "opaque door"	Administrative		
RE14-16	R401.3 (IRC N1101.14)	Modifies who may complete the home's energy features certificate	Not Energy Related		Changes procedural requirements only.
RE17-16	R402.1 (IRC N1102.1)	Exempts log homes designed in accordance with ICC-400 from the thermal envelope requirements of the IECC	Increases Energy Use	No	ICC-400 allows substantially less efficient walls than the IECC, resulting in an expected increase in energy use. Log homes make up a relatively small portion of the housing stock, therefore this change affects about 0.4% of new homes(c). Log construction is not a feature of typical homes as represented by the standard residential prototypes. See additional discussion in Section 3.1.2.

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE22-16	Table R402.1.2 (IRC Table N1102.1.2)	Requires R-5 under the entire slab-on-grade when the slab is heated	Decreases Energy Use	No	Reduces heat loss in homes with heated slabs, thereby decreasing energy use. Heated slabs are not a feature in typical homes as represented by the prototypes.
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	Yes	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.
RE40-16	R402.2.2 (IRC N1102.2.2)	Clarifies that the R-30 allowance for ceiling insulation at eaves with energy trusses applies to R-38 and R-49 ceilings	Administrative		
RE53-16	Table R402.2.6 (IRC Table N1102.2.6)	Corrects an inconsistency in the steel framing R-value equivalency table	Decreases Energy Use	No	Effectively requires an additional R-1 continuous insulation if R-19 wall cavity insulation is used, thereby decreasing energy use. Typical home designs as represented by the prototype models do not include steel framing.
RE64-16	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Clarifies requirements for sealing Heating, ventilation, and air conditioning (HVAC) register boots	Administrative		

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE65-16	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Clarifies requirements for sealing recessed lighting	Administrative		
RE71-16	Table R402.4.1.1 (IRC Table N1102.4.1.1)	Clarifies that sealing requirements for HVAC register boots apply to both supply and return ducts	Administrative		
RE83-16	R402.4.1.2 (IRC N1102.4.1.2)	Changes reference standard for testing envelope air tightness	Administrative		The new reference standard is better aligned with how the industry typically performs tests.
RE84-16	R402.4.1.2 (IRC N1102.4.1.2)	Clarifies requirements for testing envelope air tightness	Administrative		
RE90-16	R402.4.2 (IRC N1102.4.2)	Eliminates requirement that masonry fireplace doors be listed and labeled in accordance with UL 907	Administrative		Corrects an error in the code—UL 907 is not applicable to fireplace doors, so no such doors can be so listed/labeled.
RE99-16	R403.3 (IRC N1103.3), R403.3.6 (New) [IRC N1103.3.6 (New)]	Adds provisions for ducts buried in attic insulation	Decreases Energy Use	No	Adds new provisions for buried ducts as an optional feature. Not included in the quantitative analysis because buried ducts are not a feature of typical homes as represented by the prototypes, and because buried ducts are provided as an optional alternative to standard practice. See additional discussion in Section 3.1.2.

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE100-16	R403.3 (IRC N1103.3), R403.3.6 (New) [IRC N1103.3.6 (New)], R403.3.7 (New) [(IRC N1103.3.7) (New)]	Allows buried attic ducts meeting stringent insulation and air-sealing criteria to be considered equivalent to ducts entirely within conditioned space in the simulated performance alternative compliance path	Increases Energy Use	No	Increases heat loss/gain and air leakage into attics compared to ducts entirely within conditioned space, a comparison relevant to a limited number of homes that both have buried ducts and comply via the performance path. Not included in the quantitative analysis as the provision for buried ducts is provided as an optional alternative, and because buried ducts are not a feature in typical homes as represented by the prototypes. See additional discussion in Section 3.1.2.
RE102-16	R403.3.2 (IRC N1103.3.2)	Clarifies duct sealing requirements	Administrative		
RE105-16	R403.3.3 (IRC N1103.3.3)	Clarifies that heat recovery ventilator/ energy recovery ventilator (HRV/ERV) ducts not integrated with HVAC ductwork are not to be included in HVAC duct pressure tests	Administrative		

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE110-16	R403.3 (IRC N1103.3), R403.3.6 (New) [IRC N1103.3.6) (New)], R403.3.6.1 (New) [IRC N1103.3.6.1 (New)]	Adds provisions for accounting for the efficiency of ducts buried in attic insulation when using the simulated performance alternative compliance path	Administrative		Aligns performance path with provisions introduced by RE99-16.
RE121-16	R403.6.1 (IRC N1103.6.1), Table R403.6.1 (IRC Table N1103.6.1)	Adds HRV/ERV-specific fan-efficacy requirements	Decreases Energy Use	No	Replaces prior efficacy values (for generic “in-line fans”) that were considered inappropriate when installing an HRV/ERV systems. Not included in the energy analysis because HRV/ERV systems are an optional feature and not required by the IECC. See additional discussion in Section 3.1.2.
RE126-16	R404.1 (IRC N1104.1)	Eliminates exception for low-voltage lighting when determining high-efficacy lighting requirements	Administrative.		Adjusts code language to match market realities—many light-emitting diode (LED) fixtures, which are inherently high efficacy, could be considered low voltage.

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
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	Yes	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.
RE132-16	R405.1 (IRC N1101.5)	Modifies scope of simulated performance alternative compliance path to explicitly include energy used for mechanical ventilation	Administrative		Corrects an ambiguity in the code, aligning scope definition with detailed provisions already in the performance path.
RE140-16	R405.3 (IRC N1105.3)	Modifies an example data source for energy prices mentioned in the code	Administrative		The example data source is informative, not normative.
RE142-16	R405.4.2 (IRC N1105.4.2)	Allows sampling in the simulated performance alternative compliance path for stacked multifamily units	Not Energy Related		Changes enforcement procedures without changing efficiency requirements.
RE143-16	Table R405.5.2(1) [IRC Table N1105.5.2(1)]	Eliminates unused language related to buildings not tested for air leakage from simulated performance alternative compliance path	Administrative		Removes legacy text; the code now requires all buildings to be tested for air leakage, so the separate requirement for untested buildings is not needed.

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE149-16	Table R405.5.2 [IRC Table N1105.5.2(1)]	Reformulates equation for ventilation fan energy in the Standard Reference Design of the simulated performance alternative compliance path to reference prescriptive fan-efficacy requirements.	Decreases Energy Use	No	Because the equation in the prior code used a term based on outdated fan efficacies, the change reduces ventilation fan energy in homes complying via the performance path. Not included in the quantitative analysis as this provision is offered as an option under the performance path and is intended to create alignment with current prescriptive baseline requirements. See additional discussion in Section 3.1.2.
RE152-16	Table R405.5.2(1) [IRC Table N1105.5.2(1)]	Modifies distribution system efficiency of non-ducted, fan-less HVAC systems to be 1.0 in the simulated performance alternative compliance path	Administrative		Clarifies that there are no distribution system losses when there is no distribution system; aligns standard reference design specifications with default values for “ductless” systems.

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE166-16	R406.3 (IRC N1106.3), R406.3.1 (IRC N1106.3.1), R406.6.1 (IRC N1106.6.1), R406.7 (IRC N1106.7), R406.7.1 (IRC N1106.7.1), R406.7.2 (IRC N1106.7.2), R406.7.3 (IRC N1106.7.3)	Replaces definition of Energy Rating Index (ERI) with a reference to ANSI/RESNET/ICC 301, except for Reference Home ventilation rates, which are modified to be consistent with IRC requirements (Section M1507.3 of the 2015 IRC)	Decreases Energy Use	No	Bases ERI target on the IRC's ventilation rates, which are lower than those in ANSI/RESNET/ICC 301. This reduces ventilation energy in homes meeting the target in the ERI path. However, RE166-16 did not modify the 301 standard's ventilation specifications for the Rated Home, which are generally equivalent to those of the Reference home, so the actual energy difference owing to this code change is expected to be minimal. See additional discussion in Section 3.1.2.

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
RE173-16	Table R406.4 (IRC Table N1106.4)	Raises (relaxes) ERI thresholds	Increases Energy Use	No	Raising ERI thresholds allows higher energy use in residences under the ERI compliance path.
		Improves mandatory envelope requirements in the ERI compliance path for homes with on-site generation	Decreases Energy Use	No	By strengthening mandatory minimum envelope efficiency requirements, the change prevents degrading envelope efficiency in trade for on-site generation.
RE183-16	R502.1.1.2 (IRC N1108.1.1.2), R503.1.2 (IRC N1109.1.2)	Requires new HVAC systems in additions and alterations to comply with the same requirements as systems in new homes	Decreases Energy Use	No	Improves HVAC efficiency in some additions and alterations. Not included in the quantitative analysis because the established residential methodology and prototypes focus on new housing.
RE184-16	R503.1.1.1 (IRC N1109.1.1.1)	Allows area-weighted averaging for compliance with fenestration requirements in fenestration replacements	Administrative		
RE187-16	Appendix RA (IRC Appendix T)	Deletes informative appendix on worst-case testing of atmospheric venting systems	Administrative		
CE3-16, Part II	R202 (IRC N1101.6)	Modifies definition of “air barrier,” eliminating a redundant definition of “continuous air barrier”	Administrative		
CE4-16, Part II	R202 (IRC N1101.6)	Clarifies definition of “thermal envelope”	Administrative		

Proposal Number[a]	Code Section(s)[b]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
CE11-16, Part II	R202 (IRC N1101.6), R202	Slightly modifies definitions of fenestration, skylights, and doors	Administrative		
CE26-16, Part II	IECC: R303.1.1	Requires R-value mark for insulation installed above the roof deck consistent with International Building Code requirements	Not Energy Related		Simplifies required means of identifying R-values for enforcement purposes without changing the required R-values.
CE30-16, Part II	Table R303.1.3(2) [IRC Table N1101.10.3(2)]	Makes editorial changes to default U-factor table for fenestration	Administrative		
CE84-16, Part II	R402.2.5 (IRC N1102.2.5), Table R402.1.2 (IRC Table N1102.1.2), Table R402.1.4 (IRC Table N1102.1.4)	Makes editorial changes to clarify requirements for mass walls and mass floors	Administrative		
CE157-16, Part II	IECC: R101.4.1, R101.5	Clarifies terminology regarding mixed occupancy	Administrative		
CE174-16, Part II	R403.5.2 (IRC N1103.5.2)	Makes editorial changes to clarify definitions and requirements related to circulating hot water systems	Administrative		

Proposal Number[(a)]	Code Section(s)[(b)]	Description of Change(s)	Category of Change	Included in Energy Analysis	Discussion
CE176-16, Part II	R403.10.3 (IRC N1103.10.3)	Clarifies pool cover requirements	Administrative		
CE177-16, Part II	R403.10.3 (IRC N1103.10.3)	Modifies and clarifies an exception to the pool cover requirements	Decreases Energy Use	No	Modestly increases the level of site-recovered energy required to qualify for the exception. Not included in the quantitative analysis because pools are not part of typical homes as represented by the prototypes.
CE248-16, Part II	R406.3 (IRC N1106.3)	Explicitly excludes energy used to charge electric vehicles from the ERI calculations	Administrative		
CE274-16, Part II	R501.4 (IRC N1107.4)	Explicitly adds the International Existing Building Code to the list of codes that must be satisfied	Administrative		

(a) Proposal numbers are as assigned by the ICC (http://media.iccsafe.org/codes/2015-2017/GroupB/CAH/IECC-R.pdf).
(b) Code sections refer to the 2015 IECC. Sections may be renumbered by the ICC in the 2018 IECC.
(c) Personal communication with Rob Pickett, Technical Consultant, Rob Pickett and Associates, LLC, 30 January 2017

Appendix B - Detailed Weighting Factors for Each Residential Prototype

Bldg. Type	Foundation	Heating System	CZ1 (%)	CZ2 (%)	CZ3 (%)	CZ4 (%)	CZ5 (%)	CZ6 (%)	CZ7 (%)	CZ8 (%)	Weights by Prototype (%)
Tropical Semi-Conditioned Single-family	Crawlspace	Electric Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Crawlspace	Gas-fired Furnace	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Tropical Semi-Conditioned Single-family	Crawlspace	Heat pump	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Tropical Semi-Conditioned Single-family	Crawlspace	Oil-fired Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Heated Basement	Electric Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Heated Basement	Gas-fired Furnace	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Tropical Semi-Conditioned Single-family	Heated Basement	Heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Heated Basement	Oil-fired Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Slab-on-grade	Electric Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Slab-on-grade	Gas-fired Furnace	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Tropical Semi-Conditioned Single-family	Slab-on-grade	Heat pump	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02

Bldg. Type	Foundation	Heating System	CZ1 (%)	CZ2 (%)	CZ3 (%)	CZ4 (%)	CZ5 (%)	CZ6 (%)	CZ7 (%)	CZ8 (%)	Weights by Prototype (%)
Tropical Semi-Conditioned Single-family	Slab-on-grade	Oil-fired Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Unheated Basement	Electric Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Unheated Basement	Gas-fired Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Unheated Basement	Heat pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Semi-Conditioned Single-family	Unheated Basement	Oil-fired Furnace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Single-family	Crawlspace	Electric Furnace	0.01	0.31	0.46	0.17	0.07	0.02	0.01	0.00	1.04
Single-family	Crawlspace	Gas-fired Furnace	0.13	1.22	3.05	2.84	2.72	0.64	0.14	0.00	10.73
Single-family	Crawlspace	Heat pump	0.11	1.74	4.07	3.72	0.92	0.23	0.07	0.00	10.86
Single-family	Crawlspace	Oil-fired Furnace	0.00	0.00	0.01	0.04	0.15	0.04	0.00	0.00	0.24
Single-family	Heated Basement	Electric Furnace	0.00	0.01	0.02	0.07	0.08	0.04	0.01	0.00	0.23
Single-family	Heated Basement	Gas-fired Furnace	0.02	0.03	0.15	1.17	3.27	1.39	0.25	0.00	6.29
Single-family	Heated Basement	Heat pump	0.02	0.04	0.20	1.81	1.14	0.54	0.13	0.00	3.88
Single-family	Heated Basement	Oil-fired Furnace	0.00	0.00	0.00	0.02	0.23	0.11	0.00	0.00	0.37
Single-family	Slab-on-grade	Electric Furnace	0.01	1.27	0.73	0.17	0.08	0.02	0.01	0.00	2.29
Single-family	Slab-on-grade	Gas-fired Furnace	0.16	6.07	5.35	2.74	3.22	0.77	0.15	0.00	18.46
Single-family	Slab-on-grade	Heat pump	0.19	7.15	6.30	3.56	1.10	0.29	0.08	0.00	18.66
Single-family	Slab-on-grade	Oil-fired Furnace	0.00	0.01	0.01	0.04	0.19	0.06	0.00	0.00	0.31
Single-family	Unheated Basement	Electric Furnace	0.00	0.01	0.05	0.06	0.06	0.03	0.00	0.00	0.22
Single-family	Unheated Basement	Gas-fired Furnace	0.01	0.04	0.36	0.88	2.83	0.95	0.11	0.00	5.18
Single-family	Unheated Basement	Heat pump	0.00	0.06	0.47	1.46	1.01	0.38	0.06	0.00	3.44
Single-family	Unheated Basement	Oil-fired Furnace	0.00	0.00	0.00	0.02	0.23	0.08	0.00	0.00	0.34
Multifamily	Crawlspace	Electric Furnace	0.00	0.19	0.37	0.05	0.01	0.00	0.00	0.00	0.63

Bldg. Type	Foundation	Heating System	CZ1 (%)	CZ2 (%)	CZ3 (%)	CZ4 (%)	CZ5 (%)	CZ6 (%)	CZ7 (%)	CZ8 (%)	Weights by Prototype (%)
Multifamily	Crawlspace	Gas-fired Furnace	0.06	0.10	0.75	0.69	0.67	0.18	0.03	0.00	2.48
Multifamily	Crawlspace	Heat pump	0.05	0.18	0.56	0.73	0.09	0.02	0.01	0.00	1.63
Multifamily	Crawlspace	Oil-fired Boiler	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.00	0.07
Multifamily	Heated Basement	Electric Furnace	0.00	0.00	0.02	0.03	0.01	0.01	0.00	0.00	0.07
Multifamily	Heated Basement	Gas-fired Furnace	0.01	0.00	0.02	0.31	0.80	0.43	0.07	0.00	1.65
Multifamily	Heated Basement	Heat pump	0.00	0.00	0.02	0.44	0.13	0.07	0.02	0.00	0.69
Multifamily	Heated Basement	Oil-fired Boiler	0.00	0.00	0.00	0.02	0.05	0.02	0.00	0.00	0.09
Multifamily	Slab-on-grade	Electric Furnace	0.00	0.78	0.63	0.07	0.01	0.00	0.00	0.00	1.50
Multifamily	Slab-on-grade	Gas-fired Furnace	0.11	0.54	1.37	0.64	0.75	0.22	0.04	0.00	3.67
Multifamily	Slab-on-grade	Heat pump	0.16	0.73	0.93	0.72	0.11	0.03	0.01	0.00	2.68
Multifamily	Slab-on-grade	Oil-fired Boiler	0.00	0.00	0.00	0.02	0.04	0.01	0.00	0.00	0.08
Multifamily	Unheated Basement	Electric Furnace	0.00	0.01	0.04	0.03	0.01	0.01	0.00	0.00	0.09
Multifamily	Unheated Basement	Gas-fired Furnace	0.00	0.00	0.09	0.28	0.64	0.23	0.02	0.00	1.27
Multifamily	Unheated Basement	Heat pump	0.00	0.01	0.06	0.43	0.11	0.04	0.01	0.00	0.66
Multifamily	Unheated Basement	Oil-fired Boiler	0.00	0.00	0.00	0.01	0.05	0.01	0.00	0.00	0.07
Weights by Climate Zone			1.20	20.50	26.09	23.23	20.83	6.88	1.26	0.01	100.00

Appendix C - Updates to the Energy Savings Calculation Methodology

Although the present analysis of the 2018 IECC builds on the previous 2015 IECC energy savings analysis, it differs in a few ways:

1. A newer version of DOE's *EnergyPlus* building energy simulation software was used—this was done to accommodate the software update process and to incorporate software improvements and new data.

2. DOE's methodology has been revised since the 2015 IECC analysis to better represent typical construction. DOE typically updates its methodology through a public process at the beginning of each code cycle to ensure its analysis and underlying assumptions remain valid.

3. The efficiencies of furnaces, air conditioners, and heat pumps have been increased to reflect changes in federal minimum standards.

These changes are important because they impact the 2015 IECC models which are the baseline for this analysis. To ensure that the current analysis was both up-to-date and the comparison between the 2015 and 2018 IECC versions was valid, all 2015 models were re-run incorporating these changes.

C.1. EnergyPlus Version Upgrade

The determination of energy savings for the 2015 IECC was conducted using *EnergyPlus* version 8.0. In the intervening years, DOE has periodically updated its *EnergyPlus* software program. The current analysis used *EnergyPlus* version 8.6, which has resulted in changes to the energy use intensity (EUI) of the baseline relative to the previous analysis.

C.1.1 Updated Residential Prototypes

DOE's residential analysis methodology was updated in August 2015. Based on public comments, DOE made several changes to the single-family prototype, including increasing the aspect ratio—and hence, the relative areas of exterior walls and ceilings—to better reflect typical new home construction, and a simplification of roof/ceiling configurations when non-roof components are being evaluated. Table C.1 summarizes these differences.

In addition to the changes shown in Table C.1, a previously incorrect approach for modeling the interior shading fraction based on the fenestration solar heat gain coefficient was corrected. The regulated site energy calculation performed during post-processing was also revised to include the energy required to run the ventilation fans—assumed in the prototype models to be bathroom exhaust fans. This value ranges from 165 to 288 kWh annually, depending on the single-family or multifamily prototype building unit.

C.1.2 Federal Minimum Equipment Efficiencies

The efficiencies of many types of HVAC equipment are regulated by federal appliance and equipment standards (i.e., not the IECC); therefore, the IECC does not directly specify minimum annual fuel utilization efficiencies (AFUE) for furnaces, seasonal energy efficiency ratios (SEER) for air conditioners and heat pumps in cooling mode, heating season performance factors (HSPF) for heat pumps in heating mode, or energy factors (EF) for water heaters. Efficiencies for both the baseline models and the 2018 models were set at the prevailing federal minimum manufacturing standard levels as specified in DOE's energy savings analysis methodology. The federal minimum efficiencies for some equipment classes have changed since the 2015 IECC was published in June 2014. Table C.2 shows the efficiencies used for the previous 2015 IECC analysis and the present 2018 IECC.

Table C.1. Summary of Changes to Single-Family Prototype between 2015 IECC and 2018 IECC Energy Savings Analyses from DOE's Revised Methodology

Building Element	2015 IECC Energy Savings Analysis	2018 IECC Energy Savings Analysis
Conditioned Floor Area	2,400 ft^2	2,376 ft^2
Aspect Ratio	1.33:1 (40' x 30')	2.45:1 (54' x 22')
Ceiling Area	1,200 ft^2, 70% under attic, 30% cathedral	1,188 ft^2, 100% under attic unless specific roof/ceiling measures warrant other (or multiple) roof/ceiling types[(a)]
Gross Exterior Wall Area	2,380 ft^2	2,584 ft^2
Foundation Perimeter Length	140 ft	152 ft
(a) The change to 100% ceiling under attic was also applied to the multifamily prototype.		

Table C.2. Summary of Equipment Efficiencies Used in Previous and Present Analyses

IECC Edition	Gas Furnace AFUE (%)	Oil Furnace AFUE (%)	Air Conditioner/ Heat Pump SEER (Btu/Wh)	Air Conditioner/ Heat Pump EER (Btu/Wh)	Heat Pump HSPF (Btu/Wh)	Oil Boiler AFUE (%)	Gas-fired Storage Water Heater (EF)	Electric Storage Water Heater (EF)
2015 IECC	78%	83%	13	N/A	7.7	80%	0.627	0.948
2018 IECC	80%	83%	13/14[(a)]	12.2[(b)]	8.2	84%	0.615	0.948

(a) The higher SEER of 14 applies in Alabama, Arkansas, Delaware, Florida, Georgia, Hawaii, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and in the District of Columbia.
(b) The energy efficiency ratio (EER) requirement, shown for a cooling capacity less than 45,000 Btu/hr, applies only in Arizona, California, Nevada, and New Mexico.

C.2. Overall Energy Impact

Table C.3 shows a comparison between the published 2015 IECC EUIs from the 2015 IECC determination (Mendon et al. 2015) and the 2015 IECC EUIs calculated after performing the updates discussed above. The revised EUIs are 4.8% higher than the previously published EUIs. The main reasons for this are the higher heating loads used in *EnergyPlus* version 8.6 compared to version 8.0, the inclusion of ventilation fan energy in the total site energy calculation, and the revised dimensions of the single-family prototype building with a smaller footprint and higher above-grade wall area.

Table C.3. Impact of Changes on 2015 IECC Estimated Regulated Annual EUI, by Climate Zone

Climate Zone	Weight (%)	Estimated Regulated Annual Site EUI, by Climate Zone (2015 IECC)		Difference (%)
		Published in the 2015 IECC Determination	Current Results with Changes	
1	1.20	13.8	14.3	3.07
2	20.50	16.8	16.9	0.29
3	26.09	16.7	17.1	2.25
4	23.23	19.3	20.5	6.44
5	20.83	27.4	29.4	7.23
6	6.88	29.0	31.1	7.06
7	1.26	35.9	38.4	7.18
8	0.01	49.8	54.2	8.92
National	100.00	20.6	21.6	4.80

Appendix D - Modeling of Individual Code Changes

This section describes the modeling strategies used for modeling the two code changes in the quantitative analysis.

D.1. RE31-16: Fenestration U-Factors

This code change reduces the heat transfer coefficient (U-factor), and thus the building heating consumption, for fenestration in climate zones 3 through 8, and Table D.1 compares the new requirements in the 2018 IECC to those in the 2015 IECC.

Table D.1. Fenestration U-Factors Requirements of the 2015 IECC and 2018 IECC

Climate Zone	Fenestration U-Factor (Btu/hr-ft2-F)	
	2015 IECC	**2018 IECC**
1	NR	NR
2	0.40	0.40
3 and 4 (except 4C)	0.35	0.32
4C, and 5 through 8	0.32	0.30

D.2. RE127-16: High-Efficacy Lighting Requirements

RE127-16 reduces the lighting energy consumption in homes by increasing the requirement of high-efficacy lighting from 75 percent of permanently installed lighting fixtures to 90 percent. It also eliminates the option of calculating percentages based on lamp counts instead of fixture counts.

Lighting energy in the DOE prototypes is calculated based on the Building America House Simulation Protocols as detailed by Mendon et al. (2013) and divided into hardwired, plug-in, exterior, and garage lighting. The Building America protocols establish a set of equations that can be used to calculate annual lighting energy consumption depending on the fraction of incandescent lamps, compact fluorescents (CFLs), light emitting diodes (LEDs), and linear fluorescents (LFs) present in the home (Wilson et al. 2014). Because RE127-16 applies only to permanently installed (hardwired) fixtures, the impact of this code change is calculated using Building America's smart lamp replacement approach using Equations 3.1 and 3.2 and the fractions specified in Table D.2. While LEDs are gaining popularity in the residential market, this analysis assumes that low-efficacy lighting is replaced by CFLs only—this yields a conservative estimate of energy savings from this measure.

$$\textit{Baseline Interior Hardwired Lighting Energy (kWh/yr)} = 0.8 \times (\textit{Conditioned Floor Area} \times 0.542 + 334) \quad (3.1)$$

$$\textit{Interior Hardwired lighting energy (kWh/yr)} = L_{HW} \times \{[(F_{inc,\,HW} + 0.34) + (F_{CFL,\,HW} - 0.21) \times 0.27 + F_{LED,\,HW} \times 0.30 + (F_{LF,\,HW} - 0.13) \times 0.17] \times SAF \times 0.9 + 0.1 \quad (3.2)$$

where
- L_{HW} = Baseline annual interior hardwired lighting energy from equation 3.1
- $F_{inc,\,HW}$ = Fraction of hardwired lamps that are incandescent
- $F_{CFL,\,HW}$ = Fraction of hardwired lamps that are CFLs
- $F_{LF,\,HW}$ = Fraction of hardwired lamps that are LFs
- SAF = Smart replacement algorithm factor: $1.1 \times F_{inc}^{4} - 1.9 \times F_{inc}^{3} + 1.5 \times F_{inc}^{2} - 0.7 \times F_{inc} + 1$

Table D.2. Lighting Type Fractions for the 2015 and 2018 IECC

	2015 IECC	2018 IECC
Fraction Incandescent (F_{inc})	0.25	0.10
Fraction CFL (F_{CFL})	0.62	0.77

Fraction Linear Fluorescent (F_{LF})	0.13	0.13

Table D.3 summarizes the resulting annual hardwired interior lighting energy consumption for the 2015 and 2018 IECC for the single-family building prototype and the multifamily prototype building unit. This value is converted to a lighting power density input for the models using the annual hours of use based on the lighting schedule. In addition to the direct reduction in lighting energy use, the energy simulation also accounts for the interactive effects between the reduced internal gains from the high-efficacy lighting and the corresponding increase in heating energy and reduction in cooling energy.

Table D.3. Calculated Annual Interior Hardwired Lighting Energy for the 2015 and 2018 IECC by Building Type

Building Type	2015 IECC	2018 IECC
Tropical Semi-Conditioned Single-family	858 kWh	744 kWh
Single-family	858 kWh	744 kWh
Multifamily Unit	521 kWh	452 kWh

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