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February 2016

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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*Authors' Note

The present report is a revision of a previous report of the same name published in October 2015. The previous report was revised to update numbers reported in certain results tables.

Acronyms and Abbreviations

BC3	Building Component Cost Community
BECP	Building Energy Codes Program
CPI	Consumer Price Index
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ERI	Energy Rating Index
ICC	International Code Council
IECC	International Energy Conservation Code
LCC	Life-Cycle Cost
NAHB	National Association of Home Builders
PNNL	Pacific Northwest National Laboratory

Highlights

> The 2015 IECC provides cost-effective savings for residential buildings in the District of Columbia. Moving to the 2015 IECC from the 2013 Washington DC Code base code is cost-effective for residential buildings in all climate zones in the District of Columbia.

The average statewide economic impact (per dwelling unit) of upgrading to the 2015 IECC is shown in the table below based on typical cost-effectiveness metrics. [1]

Metric	Compared to the 2013 Washington DC Code
Life-cycle cost savings of the 2015 IECC	$1367.32
Simple payback period of the 2015 IECC	3.0 years
Net annual consumer cash flow in year 1 of the 2015 IECC[2]	$79.85
Annual (first year) energy cost savings of the 2015 IECC ($)	$96.80
Annual (first year) energy cost savings of the 2015 IECC (%)	7.5%

[1] A weighted average is calculated across all climate zones in the state.
[2] The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc). First-year net cash flow is reported; subsequent years' cash flow will differ due to the effects of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.

Cost-Effectiveness Results for the 2015 IECC for the District of Columbia

This section summarizes the cost-effectiveness analysis in terms of three primary economic metrics:

- Life-Cycle Cost (LCC): Full accounting over a 30-year period of the cost savings, considering energy savings, the initial investment financed through increased mortgage costs, tax impacts, and residual values of energy efficiency measures
- Consumer Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)
- Simple Payback Period: Number of years required for energy cost savings to exceed the incremental first costs of a new code, ignoring inflation and fuel price escalation rates

LCC savings is the primary metric used by the U.S. Department of Energy (DOE) to assess the economic impact of residential building energy codes. Simple payback period and the Consumer Cash Flow analysis are reported to provide additional information to stakeholders. Both the LCC savings and the year-by-year cash flow values from which it is calculated assume that initial costs are mortgaged, that homeowners take advantage of mortgage interest tax deductions, that individual efficiency measures are replaced with like measures at the end of their useful lifetimes, and that efficiency measures may retain a residual value at the end of the 30-year analysis period.

1. Life-Cycle Cost

The Life-Cycle Cost (LCC) analysis computes overall cost savings per dwelling unit resulting from implementing the efficiency improvements of a new energy code. LCC savings are based on the net change in overall cash flows (energy savings minus additional costs) resulting from implementing a new energy code. LCC savings are summed over an analysis period of 30 years. Future cash flows are discounted to "present values" using a discount rate that accounts for the changing value of money over time. LCC savings is the economic metric used by DOE for decision making purposes.

Table 1 shows the LCC savings (discounted present value) over the 30-year analysis period for the 2015 IECC compared to the 2013 Washington DC Code.

Table 1. Life-Cycle Cost Savings of the 2015 IECC compared to the 2013 Washington DC Code

Climate Zone	Life-Cycle Cost Savings ($)
4A	$1,367.32

2. Consumer Cash Flow

The Consumer Cash Flow results are derived from the year-by-year calculations that underlie the Life-Cycle Cost savings values shown above. The specific cash flow values shown here allow an assessment of how annual cost outlays are compensated by annual energy savings and the time required for cumulative energy savings to exceed cumulative costs, including both increased mortgage payments and the down payment and other up-front costs.

Table 2 shows the per-dwelling-unit impact of the improvements in the 2015 IECC on Consumer Cash Flow compared to the 2013 Washington DC Code.

Table 2. Consumer Cash Flow from Compliance with the 2015 IECC Compared to the 2013 Washington DC Code

	Cost/Benefit	4A
A	Down payment and other up-front costs	$31.03
B	Annual energy savings (year one)	$96.80
C	Annual mortgage increase	$17.07
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	-$0.12
E = [B-(C+D)]	Net annual cash flow savings (year one)	$79.85
F = [A/E]	Years to positive savings, including up-front cost impacts	0.39
Note: Item D includes mortgage interest deductions, mortgage insurance, and property taxes for the first year. Deductions can partially or completely offset insurance and tax costs. As such, the "net" result appears relatively small or is sometimes even negative.		

3. Simple Payback Period

The simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc. The simple payback period is useful for its ease of calculation and understandability. Because it focuses on the two primary characterizations of a code change—cost and energy performance—it allows an assessment of cost effectiveness that is easy to compare with other investment options and requires a minimum of input data. DOE reports the simple payback period because it is a familiar metric used in many contexts. However, because it ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use the payback period as a primary indicator of cost effectiveness for its own decision-making purposes.

Table 3 shows the simple payback period for the 2015 IECC for the District of Columbia. The simple payback period is calculated by dividing the incremental construction cost by the first-year energy cost savings assuming time-zero fuel prices. It estimates the number of years required for the energy cost savings to pay back the incremental cost investment without consideration of financing of the initial costs through a mortgage, the favored tax treatment of mortgages, the useful lifetimes of individual efficiency measures, or future escalation of fuel prices.

Table 3. Simple Payback Period for the 2015 IECC Compared to the 2013 Washington DC Code

Climate Zone	Payback Period (Years)
4A	3.0

Overview of the Cost-Effectiveness Analysis Methodology

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the U.S. Department of Energy's (DOE) Building Energy Codes Program. DOE supports the development and implementation of energy efficient and cost-effective residential and commercial building energy codes. These codes help adopting states and localities establish minimum requirements for energy-efficient building design and construction, as well as ensure significant energy savings and avoided greenhouse gas emissions.

The present analysis evaluates the cost-effectiveness of the prescriptive path of the 2015 edition of the International Energy Conservation Code (IECC), relative to the 2013 Washington DC Code. The analysis covers one- and two-family dwelling units, town-homes, and low-rise multifamily residential buildings covered by the residential provisions of the 2015 IECC. The IECC's simulated performance path and the new Energy Rating Index (ERI) path included in the 2015 IECC are not in the scope of this analysis due to the large variety of building configurations those paths allow. While buildings complying via these paths are generally considered to provide equal or better savings compared to the prescriptive requirements, the intent of these paths is to provide additional design flexibility at a cost dictated by the builder or homeowner. DOE has established a methodology for determining energy savings and cost-effectiveness of various residential building energy codes (Taylor et al. 2012). The LCC analysis described in that methodology balances upfront costs with longer term consumer savings and is therefore DOE's primary economic metric for its decision making processes.

1. Estimation of Energy Usage and Savings

In order to estimate the energy impact of residential code changes, PNNL developed a single-family prototype building and a low-rise multifamily prototype building to represent typical new residential building construction (BECP 2012, Mendon et al. 2013 and Mendon et al. 2014). The key characteristics of these prototypes are described below:

- **Single-Family Prototype**: A two-story home with a 30-ft by 40-ft rectangular shape, 2,400 ft^2 of conditioned floor area excluding the basement (if any), and window area equal to 15% of the conditioned floor area equally distributed toward the four cardinal directions.
- **Multifamily Prototype**: A three-story building with 18 units (6 units per floor), each unit having conditioned floor area of 1,200 ft^2 and window area equal to approximately 23% of the exterior wall area (not including breezeway walls) equally distributed toward the four cardinal directions.

These two building prototypes are further expanded to cover four common heating systems (natural gas furnace, heat pump, electric resistance and oil-fired furnace), and four common foundation types (slab-on-grade, heated basement, unheated basement, crawlspace), leading to an expanded set of 32 residential prototype building models. This set is used to simulate the energy usage for typical homes built to comply with the requirements of the 2015 IECC and those built to comply with the requirements of the 2013 Washington DC Code for one location in each climate zone in the state using DOE's *EnergyPlus*™ software, version 8.0 (DOE 2013). A detailed discussion of the code provisions considered in this analysis is given by Mendon et. al. (2013 and 2015). Energy savings of the 2015 IECC relative to the 2013 Washington DC Code, including space heating, space cooling, water heating and lighting, are extracted from the simulation results.

2. Fuel Prices

The energy savings from the simulation analysis are converted to energy cost savings using the most recent state-specific residential fuel prices from DOE's Energy Information Administration (EIA 2014a, EIA 2014b, EIA 2014c). The fuel prices used in the analysis are shown in Table 4.

Table 4. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
$0.13	$1.45	$20.84

3. Financial and Economic Parameters

The financial and economic parameters used in calculating the LCC and annual consumer cash flow are based on the latest DOE cost-effectiveness methodology (Taylor et al. 2015) to represent the current economic scenario. The parameters are summarized in Table 5 for reference.

Table 5. Economic Parameters used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	5.00%
Loan fees	0.6% of the mortgage amount
Loan term	30 years
Down payment	10% of home value
Nominal discount rate (equal to mortgage rate)	5.00%
Inflation rate	1.60%
Marginal federal income tax	15%
Marginal state income tax	8.50%
Property tax	1.10%

4. Aggregation Scheme

Energy results, weighted by foundation and heating system type, are provided at the state level and separately for each climate zone within the state. The distribution of heating systems for the District of Columbia is derived from data collected by the National Association of Home Builders data (NAHB

2009) and is summarized in Table 6. The distribution of foundation types is derived from the Residential Energy Consumption Survey data (EIA 2009) and is summarized in Table 7. The single-family and multifamily results are combined for each climate zone in the state and the climate zone results are combined to calculate a weighted average for the state using housing starts from the 2010 U.S. Census data (Census 2010). The distribution of single- and multifamily building starts is summarized in Table 8.

Table 6. Heating Equipment Shares

Heating System	Share of New Homes (percent)	
	Single-Family	Multifamily
Natural Gas	19	24
Heat Pump	79	75
Electric Resistance	2	1
Oil	0	0

Table 7. Foundation Type Shares

Foundation Type	Slab-on-grade	Heated Basement	Unheated Basement	Crawlspace
Share of New Homes (percent)	28	31	18	23

Table 8. Construction by Building Type and Climate Zone

Climate Zone	Share of New Homes (percent)	
	Single-Family	Multifamily
4A	100	100

Incremental Construction Costs

In order to evaluate the cost-effectiveness of the changes introduced by the 2015 IECC over the 2013 Washington DC Code, PNNL estimated the incremental construction costs associated with these changes. For this analysis, cost data sources consulted by PNNL include:

- Building Component Cost Community (BC3) data repository (DOE 2012)
- Construction cost data collected by Faithful+Gould under contract with PNNL (Faithful + Gould 2012)
- RS Means Residential Cost Data (RSMeans 2012)
- National Residential Efficiency Measures Database (NREL 2014)
- Price data from nationally recognized home supply stores

The consumer price index (CPI) is used to adjust cost data from earlier years to the study year (BLS 2015). The estimated costs of implementing the prescriptive provisions of the 2012 IECC over the 2009 IECC are taken from an earlier PNNL study that evaluated the cost-effectiveness of the 2012 IECC (Lucas et al. 2012). The additional costs of implementing the prescriptive provisions of the 2015 IECC over the 2012 IECC are taken from the National 2015 IECC Cost-Effectiveness study (Mendon et.al. 2015). The national scope costs from those studies are adjusted to reflect local construction costs in the District of Columbia using location factors provided by Faithful+Gould (2011).

Table 9 and Table 10 show the incremental construction costs associated with the 2015 IECC compared to the 2013 Washington DC Code for an individual dwelling unit. Table 9 shows results for a house and Table 10 shows results for an apartment or condominium. These have been adjusted using a construction cost multiplier, 0.999, to reflect local construction costs in the District of Columbia based on location factors provided by Faithful + Gould (2011).

Table 9. Total Construction Cost Increase for the 2015 IECC Compared to the 2013 Washington DC Code ($)

	Single-family Prototype House			
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
4A	$336.78	$336.78	$383.75	$336.78

Table 10. Total Construction Cost Increase for the 2015 IECC Compared to the 2013 Washington DC Code ($)[1]

	Multifamily Prototype Apartment/Condo			
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
4A	$268.35	$268.35	$268.35	$268.35

[1] In the multifamily prototype model, the heated basement is added to the building, and not to the individual apartments. The incremental cost associated with heated basements is divided among all apartments equally.

Energy Cost Savings

Table 11 shows the estimated annual per-dwelling unit energy costs of end uses regulated by the IECC, which comprise heating, cooling, water heating, and lighting, that result from meeting the requirements of the 2015 and the 2013 Washington DC Code.

Table 11. Annual (First Year) Energy Costs for the 2015 IECC and the 2013 Washington DC Code

Climate Zone	2015 IECC					2012 IECC				
	Heating	Cooling	Water Heating	Lighting	Total	Heating	Cooling	Water Heating	Lighting	Total
4A	$341.30 (-19.2%)	$236.91 (-1.7%)	$325.17 (-3.4%)	$119.11 (0.0%)	$1022.49 (-8.6%)	$422.29	$241.12	$336.77	$119.11	$1,119.29

Table 12 shows the first year energy cost savings as both a net dollar savings and as a percentage of the total regulated end use energy costs. Results are weighted by single- and multifamily housing starts, foundation type, and heating system type.

Table 12. Total Energy Cost Savings (First Year) for the 2015 IECC Compared to the 2013 Washington DC Code

Climate Zone	First Year Energy Cost Savings	First Year Energy Cost Savings (percent)
4A	$96.80	7.5

Appendix – District of Columbia Amendments to the 2012 International Energy Conservation Code

The District of Columbia Energy Code is based on the 2012 IECC with the amendments described below.

Air Infiltration

> *2012 IECC reference*: Section R402.4.1.2 requires a maximum envelope air leakage rate of 3 air changes per hour when tested at 50 Pascals (ACH50).

The District of Columbia code amends the 3 ACH50 requirement to 5 ACH50. This analysis assumes the higher leakage rate when estimating the energy performance of homes complying with the District of Columbia code.

Duct Tightness

> *2012 IECC reference*: Section R403.2.2 requires a maximum total duct leakage rate of 4 cfm per 100 square feet of conditioned floor area when tested at 25 Pascals (CFM25). If tested at rough-in and the air handler is not yet installed, the maximum is 3 CFM25. No test is required if all ducts and air handlers are inside conditioned space.

The District of Columbia code amends both post-construction and rough-in duct leakage requirements to a maximum of 8 CFM25. The energy analysis in this report assumes a total leakage rate of 8 CFM25 for homes complying with the District of Columbia code.

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