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Energy Savings Analysis of the Proposed Revision of the Washington, D.C. Non-Residential Energy Code

December 2017

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U.S. DEPARTMENT OF ENERGY

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

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Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CO_2	carbon dioxide
CZ	climate zone
D.C.	District of Columbia
DCV	demand controlled ventilation
DDC	direct digital control
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ft	feet
LCC	life cycle cost
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
sf	square feet
SHGC	solar heat gain coefficient
SRI	solar reflectance index
TMY	typical meteorological year
U.S.	United States
VAV	variable air volume
VRF	variable refrigerant flow
VRV	variable refrigerant volume (VRV is a trademark of Daikin Industries, Ltd.)
W	Watt(s)
WSHP	water source heat pump

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1.0 Introduction

The U.S. Department of Energy (DOE) provides technical assistance to help states and local code enforcement jurisdictions adopt, upgrade, implement, and enforce their residential and commercial building energy codes. At the request of Washington, D.C's Department of Consumer and Regulatory Affairs, DOE asked Pacific Northwest National Laboratory (PNNL) to analyze the impacts of a proposed new energy code for non-residential buildings[1] as compared with ANSI/ASHRAE/IESNA Standard 90.1-2010 (ASHRAE 2010). The results of the analysis include annual and life cycle savings for site energy, source energy, energy cost, and carbon dioxide emissions that would result from adoption and enforcement of the proposed code for newly constructed buildings in Washington, D.C. over a five-year period.

The report contains three main parts:

- Proposed Code – Section 2 in the report discusses the changes in the proposed new code for adoption in Washington, D.C.
- Analysis Methodology – Section 3 discusses the simulation methodology including the prototype buildings, simulation software, representative weightings for new construction, and the metrics used to present results.
- Results – Section 4 summarizes the energy, energy cost, and carbon reduction benefits that could accrue annually and over the life of new buildings constructed in Washington, D.C. using the proposed code as compared to Standard 90.1-2010.

[1] For the purpose of building energy codes, non-residential codes typically apply to all commercial buildings and multi-family residential buildings greater than three stories.

2.0 Proposed Code

A proposed new energy code was provided to PNNL by the Washington, D.C. Department of Consumer and Regulatory Affairs. The proposed code uses ASHRAE Standard 90.1-2013 (Standard 90.1-2013) as the base code to which further changes are made. It is important to note that the base code to which Washington, D.C. wants a final quantitative comparison (Standard 90.1-2010) is not the same as the base code that has been modified (Standard 90.1-2013).

In reviewing the proposed code, PNNL identified 46 individual changes to Standard 90.1-2013 that could potentially impact energy use in new buildings constructed to comply with the code. Most of the proposed changes are taken from ASHRAE Standard 189.1-2014, Standard for the Design of High-Performance Green Buildings (ASHRAE 2014).

Table 2.1 provides a summary of the 46 changes proposed to Standard 90.1-2013 that were considered in this analysis. Changes to Standard 90.1-2010 incorporated into Standard 90.1-2013 also impact the results of this analysis and those are documented separately in DOE's determination of the energy savings of Standard 90.1-2013 (Halverson et al. 2014).

Table 2.1. Summary of Prescriptive Changes to Standard 90.1-2013 Included in the Proposed Washington, D.C. Energy Code

Section Modified Beyond 90.1-2013	Change Title	Change Summary
3.2	Modifies daylighted area definition	a. Deletes secondary sidelighted area. b. Redefines sidelighted area as equal to window width (plus 3 ft on either side) times 15 ft depth.
3.2	Adds high efficacy lighting definition	Requires 60 lumens/W for lamps >40 W, 50 lumens/W for lamps from 15W to 40W, and 40 lumens/W for lamps <15W.
5.4.1.1	Adds continuous thermal barrier requirements	Requires elimination or mitigation of thermal barriers.
5.4.3.1	Removes air barrier exceptions	Exceptions in 5.4.3.1 to not apply. No exceptions for semiheated spaces, metal coiling doors in semiheated spaces, and single wythe constructions.
5.4.3.4	Clarifies vestibules doors	Clarifies that doors in building entrances are required to have vestibules.
5.4.4	Requires PV-ready roof areas	Requires buildings to allocate space and pathways for future renewable systems.
5.5.3	Improves envelope U-factors throughout	More stringent requirements for all construction classes and assemblies in CZ-4.
5.5.3.1.1	Requires higher solar reflectance	a. Requires cool roofs in CZ-4. b. Changes minimum initial SRI to 82 from 64 for roofs less than 2:12 in slope, and to 39 for roofs higher than 2:12 in slope. c. Removes tradeoff for higher roof insulation levels. d. Changes multiple exceptions.

Section Modified Beyond 90.1-2013	Change Title	Change Summary
5.5.3.5.1	Adds exposed slab-edge insulation	Requires continuous insulation on exposed slabs.
5.5.3.7	Lowers high speed door U-factor	Lowers U-factor to 1.20 for high speed doors that operate on average 75 cycles per day.
5.5.4.4.1	Reduced SHGC multiplier	Only provides credit for projection factors greater than 0.60, and gives less credit for projections for all orientations.
5.5.4.5	Increases SHGC orientation limits	Provides area trade-off for east and west fenestration up to one quarter of the sum of the north and south fenestration area. Similarly, provides SHGC-weighted area trade-off up to one sixth of the sum of the north and south SHGC-weighted area.
5.5.4.7	Permanent projections required	Requires vertical fenestration on the west, south, and east to be shaded by permanent projections with a projection factor of 0.50.
5.8.1.5.1	Limit on floors over unconditioned spaces	Specifies insulation location for floors above unconditioned spaces.
6.3.2; 6.4.1.1.1	Renewable or higher efficiency	Buildings complying with the alternate renewables approach in Section 13.1.1.2 shall comply with equipment efficiency requirements from Section 13.1.1.2 instead of the requirements in Chapter 6.
6.4.1.1.2	Heat pump for heating	Requires heating to be supplied by heat pumps for unitary cooled systems.
6.4.3.8	Expands DCV to all sys with economizers	a. Removes 500 sf area threshold. b. Lowers outdoor airflow threshold to 1000 cfm from 3000 cfm. c. Removes exception for systems without DDC. d. Requires DCV system to be designed using Standard 62.1.
6.4.4.1.2	Duct and plenum insulation	Prescribes separate requirements for alternate renewables path.
6.5.1	Lowers economizer exception threshold	a. Lowers economizer exception threshold to 33,000 Btu/h. b. Units smaller than 54,000 Btu/h to require first stage of cooling to be economizer. c. VAV systems must be capable of performing SAT reset when economizing. d. Improved efficiency requirements to eliminate economizer to be applied to appropriate efficiency requirements depending upon renewable path that is chosen. e. WSHP systems can eliminate controls if condenser water temperature of 55°F can supply the full load. f. VRV and VRF systems are exempted from economizer requirements.
6.5.2.1	Removes exception for non-DDC control	Removes exception for simultaneous heating and cooling of zone supply air for zones without DDC.

Section Modified Beyond 90.1-2013	Change Title	Change Summary
6.5.3.1	Reduces fan power limits	Reduces the amount of fan power available for constant and variable volume systems.
6.5.6.1	Improves energy recovery effectiveness	Requires energy recovery systems to have at least 60% effectiveness.
6.5.6.3	Adds supermarket heat recovery	Requires supermarkets with a floor area of 25,000 sf or higher to include heat recovery from the condensers of refrigeration equipment.
6.5.7.1	Adjustment to kitchen exhaust	A decrease in threshold and an increase in efficiency requirements for commercial kitchen exhaust hoods.
6.5.12	Adds hotel guestroom HVAC controls	In hotels and motels with over 50 guestrooms, automatic controls for thermostat setback and ventilation turn off are required.
7.4.2	Alternate SWH requirements for renewable approach	Allows water heating equipment to meet alternate requirements based on approach chosen for renewables in Section 13.1.
7.4.5.2.1	Requires spa pool insulation	Requires pools heated to more than 90F to have side and bottom surfaces insulated to R-12.
8.1.5	Adds automated demand response requirements	Requires buildings with HVAC systems to have certain capabilities and infrastructure that enable automated demand response.
8.4.2	Reduces receptacle control requirements	Requires one, instead of half, receptacle(s) in private offices and individual workstations to be controlled.
8.4.3	Increases specifics for metering	Expands metering, monitoring, and reporting requirements, including adding requirements for sources other than electricity.
8.5.1	Requires guest room TV and lighting control	Requires hotels and motels with more than 50 guestrooms to have switched outlets, lighting, and televisions automatically turn off after 30 minutes of occupants leaving the guestroom.
9.1.1	Requires high efficacy dwelling unit lighting	Requires 85% of permanently installed lamps in dwelling units to be high efficacy.
9.4.1.1.e/f	Daylighting controls	a. Primary sidelighted area as defined in the definitions to be controlled. b. Control daylighting using one sensor only. c. Exempted if building total lighting power is less than 80% of that allowed. d. Toplighting threshold reduced to 105 W from 150 W.

Section Modified Beyond 90.1-2013	Change Title	Change Summary
9.4.1.1.h	Increases restroom occupancy sensor time limit	Allows 30 minutes, instead of 20 minutes, of time lag after occupants leave restrooms before lights are turned off.
9.4.1.4.1	Improves uncovered parking lot control	Requires luminaires with an input power of more than 50 W and where the luminaire is at least 24 feet above ground to be automatically controlled such that their power is reduced by at least 40% when no activity is detected in the controlled zone for 15 minutes.
9.4.2	Lowers exterior lighting power allowances	Allows less exterior lighting power allowance
9.5.2.1	Adds Hotel/Motel lighting control	Same as 8.5.1.
9.5.2.2	Adds storage stack light control	Requires commercial and industrial storage stack areas to be controlled with occupancy sensors.
9.5.2.3	Adds egress lighting control	Requires egress lighting to be less than 0.1 W/sf. Additional egress lighting must be controlled by an occupancy sensor.
9.5.2.4	Adds exterior sign lighting control	Sign lighting operating for more than one hour during daylight hours shall automatically reduce input power to 35% of full power for a period from one hour after sunset to one hour before sunrise.
9.5.1/9.6.1	Lowers interior lighting power densities	Reduces interior lighting power allowance when using both the building area method and the space-by-space method.
9.6.2.a	Additional allowance	Changes decorative lighting allowance from 1.0 W/sf to 5% of the total interior lighting power allowance.
9.6.2.b	Changes additional retail allowance	Changes retail area allowance to use a percentage basis instead of a W/sf basis.
10.5	Adds Energy Star Requirements	Requires all buildings to comply with ENERGY STAR requirements for new equipment not covered by federal appliance efficiency regulations. For projects using the alternate renewables approach, ENERGY STAR requirements for equipment covered by federal appliance efficiency regulations shall also be met.
11	Adds commissioning requirements	Whole building air leakage shall not exceed 0.25 cfm/sf of above- and below-grade building envelope area.

Section Modified Beyond 90.1-2013	Change Title	Change Summary
13	Prescriptive Renewables	One of two approaches shall be chosen for compliance: a. Standard approach: Renewable systems shall provide annual energy production of at least 6.0 kBtu/sf of roof area for single-story buildings and 10.0 kBtu/sf of roof area for all other buildings b. Alternate approach: Renewable systems shall provide annual energy production of at least 4.0 kBtu/sf of roof area for single-story buildings, and 7.0 kBtu/sf of roof area for all other buildings. In addition, buildings are required to comply with various other high-efficiency equipment requirements (HVAC, SWH, ENERGY STAR)

3.0 Analysis Methodology

To support the development and implementation of non-residential building energy codes, PNNL researchers have developed a suite of prototype building models that comply with various editions of energy codes including Standard 90.1 (DOE 2017). These building prototypes represent the majority of new commercial building stock and were developed using DOE's EnergyPlus Version 8.0 building energy simulation software (DOE 2013). The development of those models and details of systems and components present in each are described in several reports (Thornton et al. 2011, Goel et al. 2014). Analyzing the savings potential of a proposed new energy code requires creating two sets of building energy models of prototype buildings, with one set complying with the base code (Standard 90.1-2010), and the other set complying with the advanced code (proposed Washington, D.C. code). These two sets of models are then simulated using representative weather data files, and the results are then compared. For this analysis Typical Meteorological Year Version 3 (TMY3) weather files for Dulles International Airport were used.

3.1 Prototype Buildings used in this Analysis

To quantify the improvement of state energy codes, PNNL typically selects a subset of the 17 prototype buildings with a goal of capturing about 50% of the new construction volume in a particular state. This often requires the use of six of the 17 prototypes. However, based on new building construction permit data over the last six years provided by the Department of Consumer and Regulatory Affairs, commercial building construction in Washington, D.C. is dominated by two building types; large office buildings (greater than 50,000 ft^2) and mid-rise multi-family residential (between four and 14 stories). Together, these two building types represent approximately 69% of new non-residential floor space constructed in Washington, D.C. between September 2011 and August 2017. Therefore estimates of future savings from the proposed Washington, D.C. code are made considering only those two building types. Savings from each of those building types is weighted according to their construction volume to come up with estimates for all new future construction. Potential drawbacks of this approach include that there is limited representation of different HVAC systems and that the future construction may favor other building types.

Table 3.1 shows the floor area of new construction in Washington, D.C. over the last six years.

Table 3.1. Washington, D.C. New Building Construction Weightings 2011 to 2017

Prototype	Floor Area (ft^2)	Percentage of New Construction
Mid-Rise Apartment	39,003,126	54.2%
Large Office	10,519,962	14.6%
Other	9,905,687	13.8%
Large Hotel	3,404,309	4.7%
Secondary School	2,520,876	3.5%
Primary School	1,911,168	2.7%
Retail Strip-Mall	1,663,750	2.3%
Warehouse	1,563,984	2.2%
Retail Stand-Alone	469,131	0.7%
Hospital	355,740	0.5%
High-Rise Apartment	303,114	0.4%
Medium Office	200,122	0.3%
Outpatient Healthcare	148,931	0.2%
Sit-Down Restaurant	29,610	0.0%
Small Office	6,416	0.0%
Quick Service Restaurant	-	0.0%
Small Hotel	-	0.0%
Total	72,005,924	100.0%

3.1.1 Baseline Prototype Changes

For the current analysis, two significant changes were made to the prototype buildings to provide a more accurate representation of energy use in a variety of building types. The first change involved the Large Office prototype. Several years ago, in order to capture the growing impact of data centers and other large computing facilities in the non-residential building population, a large data center, operating at full capacity 24 hours a day was added to the Large Office prototype. This change more than doubled the energy use of that building. For national level analyses, the Large Office prototype is one of three office prototypes and represents only 3.3% of total construction volume, but for the Washington, D.C. analysis it is the only office prototype and represents 14.6% of total construction. Therefore, the exaggerated impact of the data center would not be realistic. To lessen the impact of the data center for this analysis, its usage schedule was changed from running at full capacity all the time to instead follow the usage schedule prescribed for computing facilities by the Standard 90.1 Appendix G Performance Rating Method. Using that schedule reduced the data center computer usage to about 60% of what it was before the change.

The second baseline change was triggered by a proposed provision to the Washington, D.C. energy code requiring a *continuous thermal barrier* intended to reduce the heat loss through the building envelope due to thermal bridging that short circuits the reduction in heat transfer caused by insulation materials. Energy codes historically have not accounted for the impact of most thermal bridging. U-factor requirements in the code generally ignore those impacts as they occur with common construction practices, the exception being the impact on batt insulation between large framing members. The prototype building models also ignored most these thermal bridges. In order to capture the impact of the continuous thermal barrier requirement, thermal bridges associated with standard construction practices were added to the baseline prototype building's envelope properties.

3.1.2 Modeling Code Change Measures

Two tiers of improvements to the baseline Standard 90.1-2010 compliant prototype models are incorporated into this analysis. The first represents the 110 changes made to Standard 90.1-2010 that resulted in the published version of Standard 90.1-2013. Those changes that impacted energy use in the Large Office and Mid-Rise Apartment prototypes are described in DOE's determination of the energy savings of Standard 90.1-2013 (Halverson et al. 2014).

The second tier includes changes to Standard 90.1-2013 made as part of the development process of the proposed Washington, D.C. code which are listed in Table 2.1. Appendix A includes a similar table that also indicates for each change whether there is a direct energy impact and if that impact is captured in the prototype simulation.

3.1.3 Fuel Prices, Site-Source Conversions, Carbon Emission, and Life Cycle Economic Parameters

Impacts on energy cost, source energy, and carbon dioxide (CO_2) emissions both annually and over the life of a population of new buildings can be determined based on information provided by the United States Energy Information Administration (U.S. EIA).

3.1.3.1 Fuel Prices

The energy savings from the simulation exercise are converted to energy cost savings using state average annual commercial fuel prices for 2015 from the U.S. EIA (EIA 2015). The fuel prices used in the analysis for Washington, D.C. are $0.1201/kWh for electricity and $1.060/therm of natural gas.

3.1.3.2 Site Energy to Source Energy Conversions

Site energy refers to the energy consumed at the building site and source energy (or primary energy) refers to the energy required to generate and deliver energy to the site. To calculate source energy, conversion factors were applied to the electricity and natural gas consumption. The electric energy source conversion factor of 10,072 was calculated from EIA's Annual Energy Outlook (AEO) 2017 Table A2 as follows (EIA 2017A):

- Delivered commercial electricity, 2016: 4.64 quads
- Commercial electricity related losses, 2016: 9.06 quads
- Total commercial electric energy use, 2016: 13.70 quads
- Commercial electric source ratio, U.S. 2016: 2.95

- Source electric energy factor (3413 Btu/kwh site) 10,072 Btu/kWh[1]

Natural gas energy use was converted to source energy using a factor of 1.088 Btu of source energy per Btu of site natural gas use, based on the 2016 national energy use estimate shown in Table A2 of the AEO 2017 as follows:

- Delivered total natural gas, 2016: 26.27 quads
- Natural gas used in well, field and pipeline: 2.31 quads
- Total gross natural gas use, 2016: 28.58 quads
- Total natural gas source ratio, U.S. 2016: 1.088
- Source natural gas energy factor (100,000 Btu/therm site): 108,800 Btu/therm

3.1.3.3 Economic Parameters Used in Life Cycle Savings

Life Cycle Cost (LCC) savings includes the calculation of the present value of savings over a 30-year period including energy savings expected from the upgrade in energy code. Future cost savings are discounted to their present value based on a discount rate. The 30-year study period captures most building components useful lives and is commonly used in building project economic analyses. This period is consistent with both previous and related national 90.1 cost-effectiveness analyses (Hart et al. 2015).

Overall, the life cycle energy cost savings is determined based on the current commercial DOE methodology for building codes analysis (Hart & Liu 2015). The LCC savings are calculated as the Base Code (ASHRAE Standard 90.1-2010) LCC minus the proposed Washington, D.C. energy code LCC. Two cost scenarios are analyzed:

- **Scenario 1** (also referred to as the Publicly-Owned Method): LCC analysis method representing government or public ownership (without borrowing or taxes). This scenario uses a real dollar methodology and economic inputs that have been established for federal projects under the Federal Energy Management Program as amended by the Energy Independence and Security Act of 2007.

- **Scenario 2** (also referred to as the Privately-Owned Method): LCC analysis method representing private or business ownership (includes loan and tax impacts). This scenario uses typical commercial economic inputs, with initial costs being financed, and considers tax impacts for savings, interest, and depreciation. The general methodology is identical to that used under Scenario 1, except that it is a nominal dollar analysis with the addition of consideration for income and property taxes, financing, and a private sector discount rate.

The financial and economic parameters used in both scenarios are shown in Table 3.2.

[1] The final conversion value of 10,072 is calculated using the full seven digit values available in Table A2 of AEO2017. Other values shown in the text are rounded.

Table 3.2. Life Cycle Cost Parameters

Economic Parameter		Scenario 1, Public	Scenario 2, Private
Study Period – Years		30	30
Nominal Discount Rate[1]		2.40%	5.63%
Real Discount Rate[1]		3.00%	3.73%
Effective Inflation Rate[2]		-0.60%	1.83%
Electricity Price[4]	per kWh	$0.1201	$0.1201
Natural Gas Price[4]	per therm	$1.0600	$1.0600
Energy Price Escalation Factors[5]		*EIA AEO 2017*	*EIA AEO 2017*
Commercial Loan rates[6]		N/A	5.63%
Scenario sector representation		Public	Private

1. The scenario 1 real and nominal discount rates are from the National Institute of Standards and Technology (NIST) and Technology 2017 annual LCC update for the federal LCC method (Lavappa et al. 2017). The scenario 2 nominal discount rate is assumed to be the marginal cost of capital, which is set equal to the loan interest rate (see footnote 4). The real discount rate for Scenario 2 is calculated from the nominal discount rate and inflation.
2. The scenario 1 effective inflation rate is from the NIST 2017 annual LCC update for the federal LCC method (Lavappa et al. 2017). It is imputed from a prescribed discount rate of 3% related to the actual nominal discount rate. The scenario 2 inflation rate is the interest equivalent for the Producer Price Index for non-residential construction (series 801), June 2009 to Sept 2017 (https://fred.stlouisfed.org/series/WPU801)
3. Scenario 1 energy price escalation rates are based on table 3 reference case projections in the EIA Annual Energy Outlook 2017 Table A3 (EIA 2017 D).
4. The commercial loan interest rate is estimated from multiple online sources (Commercial Loan Direct 2017; Watts 2017; Valuepenguin 2017).

3.1.3.4 Carbon Dioxide Reduction Calculations

Savings in electricity and natural gas can be converted to avoided CO_2 emissions using the following conversion factors developed by the U.S. EIA (EIA 2017A, EIA 2017B)

6.60884×10^{-7} million metric tons CO_2/megawatt hour electricity

5.307×10^{-6} million metric tons CO_2 /thousand therms natural gas

4.0 Results

This section summarizes the annual and life cycle savings for site energy, source energy, energy cost, and carbon dioxide emissions that would result from adoption and enforcement of the proposed code for newly constructed buildings in Washington, D.C. over a five-year period. In considering these results, it should be noted that the analysis is based on only two building types: Large Office buildings (greater than 50,000 ft^2) and Mid-Rise multi-family residential (between four and 14 stories). However, these two building types represent approximately 69% of new non-residential floor space constructed in Washington, D.C. over the past six years and therefore provide a reasonable projection of future savings.

4.1 Annual Savings

Table 4.1 and Table 4.2 show the annual energy and energy cost savings projections for the Large Office and Mid-Rise Apartment prototypes. Adoption and compliance with the proposed Washington, D.C. energy code is expected to save 11.1% of site energy, 9.9% of source energy, and 9.7% of energy cost for the Large Office building prototype and 26.5% of site energy, 18.6% of source energy, and 17.6% of energy cost for the Mid-Rise building prototype. The significant difference between site energy savings and the other metrics for the Mid-Rise Apartment is due to a single new requirement in the proposed code which disallows gas heating and requires heat pumps for unitary systems providing both heating and cooling functions. Savings by energy end use are provided in Appendix B.

Table 4.1. Annual Savings Projections Office Building Prototype

Building	ECI & EUI		Savings vs. 90.1-2010	
Large Office Building	90.1-2010	D.C. EC-2017	Amount	%
Total kWh/ft^2-year	15.65	14.24	1.41	*9.0%*
Total therms/ft^2-year	0.096	0.075	0.022	*22.5%*
Total site energy kBtu/ft^2-yr	63.1	56.1	7.0	*11.1%*
Total source energy kBtu/ft^2-yr	168.1	151.5	16.6	*9.9%*
Total Energy Cost $/$ft^2$-year	$1.98	$1.79	$0.19	*9.7%*

Table 4.2. Annual Savings Projections Apartment Building Prototype

Building	ECI & EUI		Savings vs. 90.1-2010	
Mid-Rise Apartment Building	90.1-2010	D.C. EC-2017	Amount	%
Total kWh/ft^2-year	12.35	10.73	1.62	*13.1%*
Total therms/ft^2-year	0.077	0.000	0.077	*100.0%*
Total site energy kBtu/ft^2-yr	49.9	36.6	13.2	*26.5%*
Total source energy kBtu/ft^2-yr	132.8	108.1	24.7	*18.6%*
Total Energy Cost $/$ft^2$-year	$1.57	$1.29	$0.28	*17.6%*

Table 4.3 shows the annual energy, energy cost, and carbon emission savings projections combined for Washington, D.C. from implementation of the proposed new energy code. Savings from the Large

Office and Mid-Rise Apartment buildings are weighted according to the recent six-year construction volume to come up with overall estimates for all new future construction.

Adoption and compliance with the proposed Washington, D.C. energy code are expected to save 23.2% of site energy, 16.7% of source energy, 16.0% of energy cost, and 15.3% of CO_2 emissions.

Table 4.3. Annual Savings Projections Combined Washington, D.C.

Combined D.C. Energy Code	Permit	ECI & EUI		Savings vs. 90.1-2010	
Annual Savings Projection	Weight	90.1-2010	D.C. EC-2017	Amount	%
Large Office kWh/ft²-year	21.2%	15.65	14.24	1.41	*9.0%*
Large Office therms/ft²-year	21.2%	0.096	0.075	0.022	*22.5%*
Mid-Rise Apt. kWh/ft²-year	78.8%	12.35	10.73	1.62	*13.1%*
Mid-Rise Apt. therms/ft²-year	78.8%	0.077	0.000	0.077	*100.0%*
Population kWh/ft²-year		13.05	11.48	1.57	*12.2%*
Population therms/ft²-year		0.081	0.016	0.065	*83.5%*
Population site energy kBtu/ft2-yr		52.7	40.8	11.9	*23.3%*
Population source energy kBtu/ft2-yr		140.3	117.3	23.0	*16.7%*
Population Energy Cost $/ft²-year		$1.65	$1.40	$0.26	*16.0%*
Population CO_2 Impact kg/ft²-year		9.057	7.670	1.387	*15.3%*

4.2 Life Cycle Savings

This section provides results for the expected savings for five years of new building construction over the life of those buildings. As discussed in Section 3.1.3.3, a 30-year life is considered. Energy and carbon emission savings are simply the sum of 30 years of annual savings, while future energy cost savings are discounted to a present value as described in Section 3.1.3.3. Savings from the Large Office and Mid-Rise Apartment buildings are weighted according to their construction volume as previously described. Table 4.4 shows the projected life cycle savings for five years of new building construction based on approximately 12 million ft^2 of construction per year consistent with historical building permit data between September 2011 and August 2017. Expected savings are 21,500,000 million Btus of site energy, 41,400,000 million Btus of source energy, and 2.5 million metric tons of CO_2 emissions. Energy cost savings over the life of those buildings are expected to be $358 million or $226 million based on the perspective of publically owned buildings or privately owned buildings respectively, as described in Section 3.1.3.3.

Table 4.4. Summary of LCC Savings for 5 Years of New Buildings Constructed to the Proposed Washington, D.C. Energy Code.

Life cycle savings results for construction from 2018-2022			
Construction from 2018 to 2022		5	years
Total floor area per year		12	million ft^2
Total floor area constructed		60	million ft^2
Measure Savings Life (average)		30	years
Cumulative electric savings		2,840,000	MWh
Cumulative natural gas Savings		118,000	k therms
Cumulative site energy savings		21,500,000	million Btu
Cumulative source energy savings		41,400,000	million Btu
Public *nominal discount rate, Scenario 1*	*2.40%*		
Present value of energy $ savings, Scenario 1		$358	million
Private *nominal discount rate, Scenario 2*	*5.63%*		
Present value of energy $ savings, Scenario 2		$226	million
Carbon dioxide reduction, million metric tons		2.50	MMT CO_2

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Appendix A
Summary of Prescriptive and Mandatory Changes to Standard 90.1-2013 Included in the Proposed Washington, D.C. Energy Code

Appendix A

Summary of Prescriptive and Mandatory Changes to Standard 90.1-2013 Included in the Proposed Washington, D.C. Energy Code

Table A.1. Summary of Prescriptive and Mandatory Changes to Standard 90.1-2013 Included in the Proposed Washington, D.C. Energy Code

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	Applicable to Prototypes? MA	Comments: Large Office	Comments: Mid-Rise Apartment
3.2	Modifies daylighted area definition	a. Deletes secondary sidelighted area. b. Redefines sidelighted area as equal to window width (plus 3 ft on either side) times 15 ft depth.	y	n	Daylight areas will be recalculated and the amount of area controlled by the two daylighting sensors will be changed accordingly	Dwelling areas exempted
3.2	Adds high efficacy lighting definition	Requires 60 lumens/W for lamps >40 W, 50 lumens/W for lamps from 15 to 40W, and 40 lumens/W for lamps <15W.	n	y	Only applicable to dwelling units	Modeled per Section 9.1.1
5.4.1.1	Adds continuous thermal barrier requirements	Requires elimination or mitigation of thermal barriers.	y	y	Standard thermal barriers are identified and applied to the baseline U-factor. Advanced U-factor assumed to have no thermal bridges.	
5.4.3.1	Removes air barrier exceptions	Exceptions in 5.4.3.1 to not apply. No exceptions for semiheated spaces, metal coiling doors in semiheated spaces, and single wythe constructions.	n	n	Spaces affected by changes not in prototypes	
5.4.3.4	Clarifies vestibules doors	Clarifies that doors in building entrances are required to have vestibules.	n	n	Clarification only, no direct impact on energy	

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
5.4.4	Requires PV-ready roof areas	Requires buildings to allocate space and pathways for future renewable systems.	n	n	No direct impact on energy	
5.5.3	Improves envelope U-factors throughout	More stringent requirements for all construction classes and assemblies in CZ-4.	y	y	U-factors will be changed for assemblies in prototypes	
5.5.3.1.1	Requires higher solar reflectance	a. Requires cool roofs in CZ-4. b. Changes minimum initial SRI to 82 from 64 for roofs less than 2:12 in slope, and to 39 for roofs higher than 2:12 in slope. c. Removes tradeoff for higher roof insulation levels. d. Changes multiple exceptions.	n	n	Option (a) was not changed and this option is used to model cool roofs in the prototypes; thus, no impact to the models	
5.5.3.5.1	Adds exposed slab-edge insulation	Requires continuous insulation on exposed slabs.	n	n	Accounted for by changes to Section 5.4.1.1 eliminating thermal bridging	
5.5.3.7	Lowers high speed door U-factor	Lowers U-factor to 1.20 for high speed doors that operate on average 75 cycles per day.	n	n	No high-speed doors in the two prototypes	
5.5.4.4.1	Reduced SHGC multiplier	Only provides credit for projection factors greater than 0.60, and gives less credit for projections for all orientations.	n	n	Provides credit, which is not taken in the prototypes	
5.5.4.5	Increases SHGC orientation limits	Provides area trade-off for east and west fenestration up to one fourth of the sum of the north and south fenestration area. Similarly, provides SHGC-weighted area trade-off up to	y	n	SHGC of fenestration will be reduced to meet requirements	Requirements are met in existing prototype

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
		one sixth of the sum of the north and south SHGC-weighted area.				
5.5.4.7	Permanent projections required	Requires vertical fenestration on the west, south, and east to be shaded by permanent projections with a projection factor of 0.50.	y	y	Add overhangs with a PF of 0.50 to east, south, and west glazing	
5.8.1.5.1	Limit on floors over unconditioned spaces	Specifies insulation location for floors above unconditioned spaces.	n	n	Installation requirement only. No floors above unconditioned spaces in prototypes	
6.3.2; 6.4.1.1.1	Renewable or higher efficiency	Buildings complying with the alternate renewables approach in Section 13.1.1.2 shall comply with equipment efficiency requirements from Section 13.1.1.2 instead of the requirements in Chapter 6.	n	n	Used standard renewables approach for analysis	
6.4.1.1.2	Heat pump for heating	Requires heating to be supplied by heat pumps for unitary cooled systems.	n	y	No unitary cooled systems	Heating system changed to heat pump from gas furnace
6.4.3.8	Expands DCV to all sys with economizers	a. Removes 500 sf area threshold. b. Lowers outdoor airflow threshold to 1000 cfm from 3000 cfm. c. Removes exception for systems without DDC. d. Requires DCV system to be designed using Standard 62.1.	y	n	Savings applied to conference rooms (1.5% total building area)	No densely occupied spaces in prototype
6.4.4.1.2	Duct and plenum insulation	Prescribes separate requirements for alternate renewables path.	n	n	No impact because standard renewables approach is used	

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
6.5.1	Lowers economizer threshold	a. Lowers economizer threshold to 33,000 Btu/h. b. Units smaller than 54,000 Btu/h to require first stage of cooling to be economizer. c. VAV systems must be capable of performing SAT reset when economizing. d. Improved efficiency requirements to eliminate economizer to be applied to appropriate efficiency requirements depending upon renewable path that is chosen. e. WSHP systems can eliminate controls if condenser water temperature of 55F can supply the full load. f. VRV and VRF systems are exempted from economizer requirements.	y	n	Implement 33,000 Btu/h threshold; no other change	No systems exceed the residential capacity exception of five times the non-residential requirement
6.5.2.1	Removes exception for non-DDC control	Removes exception for simultaneous heating and cooling of zone supply air for zones without DDC.	n	n	Prototypes already assumed to have zone DDC controls	
6.5.3.1	Reduces fan power limits	Reduces the amount of fan power available for constant and variable volume systems.	y	n	Fan power will be reduced according to the allowable limit	Existing fan power meets allowable limit
6.5.6.1	Improves energy recovery effectiveness	Requires energy recovery systems to have at least 60% effectiveness.	n	n	Standard practice uses ERVs that are more efficient than requirement	

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
6.5.6.3	Adds supermarket heat recovery	Requires supermarkets with a floor area of 25,000 sf or higher to include heat recovery from the condensers of refrigeration equipment.	n	n	Supermarket spaces not in prototypes	
6.5.7.1	Adjustment to kitchen exhaust	A decrease in threshold and an increase in efficiency requirements for commercial kitchen exhaust hoods.	n	n	No commercial kitchens in prototypes	
6.5.12	Adds hotel guestroom HVAC controls	In hotels and motels with over 50 guestrooms, automatic controls for thermostat setback and ventilation turn off are required.	n	n	No guestrooms in prototypes	
7.4.2	Alternate SWH requirements for renewable approach	Allows water heating equipment to meet alternate requirements based on approach chosen for renewables in Section 13.1.	n	n	Using standard renewables approach	
7.4.5.2.1	Requires spa pool insulation	Requires pools heated to more than 90F to have side and bottom surfaces insulated to R-12.	n	n	No spa pools in prototypes	
8.1.5	Adds automated demand response requirements	Requires buildings with HVAC systems to have certain capabilities and infrastructure that enable automated demand response.	n	n	No impact on energy because auto-DR is not required	
8.4.2	Reduces receptacle control requirements	Requires one, instead of half, receptacle(s) in private offices and individual workstations to be controlled.	n	n	Most private offices likely to have a maximum of two receptacles; so, requiring control of one instead of half does not make an impact	Not applicable

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes?		Comments	
			LO	MA	Large Office	Mid-Rise Apartment
8.4.3	Increases specifics for metering	Expands metering, monitoring, and reporting requirements, including adding requirements for sources other than electricity.	n	n	Metering requirements do not directly impact energy savings	
8.5.1	Requires guest room TV and lighting control	Requires hotels and motels with more than 50 guestrooms to have switched outlets, lighting, and televisions automatically turn off after 30 minutes of occupants leaving the guestroom.	n	n	No guestrooms in prototypes	
9.1.1	Requires high efficacy dwelling unit lighting	Requires 85% of permanently installed lamps in dwelling units to be high efficacy.	n	y	Not applicable	Will reduce lighting power in response to high-efficacy requirements
9.4.1.1.e/f	Daylighting controls	a. Primary sidelighted area as defined in the definitions to be controlled. b. Control daylighting using one sensor only. c. Exempted if building total lighting power is less than 80% of that allowed. d. Toplighting threshold reduced to 105 W from 150 W.	y	n	Daylighting control assigned to single sensor	NA
9.4.1.1.h	Increases restroom occupancy sensor time limit	Allows 30 minutes, instead of 20 minutes, of time lag after occupants leave restrooms before lights are turned off.	y	n	Savings from occupancy sensors in restrooms will be reduced	No restroom spaces in multi-family

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
9.4.1.4.1	Improves uncovered parking lot control	Requires luminaires with an input power of more than 50 W and where the luminaire is at least 24 feet above ground to be automatically controlled such that their power is reduced by at least 40% when no activity is detected in the controlled zone for 15 minutes.	y	n	New control requirement that will reduce parking lot lighting consumption	No impact because building operates continuously
9.4.2	Lowers exterior lighting power allowances	Allows less exterior lighting power allowance.	y	y	Exterior lighting power will be recalculated based on new allowances	
9.5.2.1	Adds Hotel/Motel lighting control	Same as 8.5.1.	n	n	No guestrooms in prototypes	
9.5.2.2	Adds storage stack light control	Requires commercial and industrial storage stack areas to be controlled with occupancy sensors.	n	n	No commercial or industrial storage stack spaces in prototypes	
9.5.2.3	Adds egress lighting control	Requires egress lighting to be less than 0.1 W/sf. Additional egress lighting must be controlled by an occupancy sensor.	y	n	Egress lighting power will be lowered to meet requirement	No impact because building operates continuously
9.5.2.4	Adds exterior sign lighting control	Sign lighting operating for more than one hour during daylight hours shall automatically reduce input power to 35% of full power for a period from one hour after sunset to one hour before sunrise.	n	n	No sign lighting in prototypes	
9.5.1/9.6.1	Lowers interior lighting power densities	Reduces interior lighting power allowance when using both the	y	y	Interior LPDs will be recalculated based on new requirements	

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
		building area method and the space-by-space method.				
9.6.2.a	Additional allowance	Changes decorative lighting allowance from 1.0 W/sf to 5% of the total interior lighting power allowance.	n	n	This decorative lighting allowance is not used in the prototypes	
9.6.2.b	Changes additional retail allowance	Changes retail area allowance to use a percentage basis instead of a W/sf basis.	n	n	No retail spaces in prototypes	
10.5	Adds Energy Star Requirements	Requires all buildings to comply with ENERGY STAR requirements for new equipment not covered by federal appliance efficiency regulations. For projects using the alternate renewables approach, ENERGY STAR requirements for equipment covered by federal appliance efficiency regulations shall also be met.	n	y	No requirements applicable	Smart thermostats and ENERGY STAR fans will be accounted for
11	Adds commissioning requirements	Whole building air leakage shall not exceed 0.25 cfm/sf of above- and below-grade building envelope area.	y	y	Infiltration rate shall be reduced to 0.25 cfm/sf	

Section Modified Beyond 90.1-2013	Change Title	Changes Summary	Applicable to Prototypes? LO	MA	Comments Large Office	Mid-Rise Apartment
13	Prescriptive Renewables	One of two approaches shall be chosen for compliance: a. Standard approach: Renewable systems shall provide annual energy production of at least 6.0 kBtu/sf of roof area for single-story buildings, and 10.0 kBtu/sf of roof area for all other buildings b. Alternate approach: Renewable systems shall provide annual energy production of at least 4.0 kBtu/sf of roof area for single-story buildings, and 7.0 kBtu/sf of roof area for all other buildings. In addition, buildings are required to comply with various other high-efficiency equipment requirements (HVAC, SWH, ENERGY STAR).	y	y	Assuming standard renewables approach	

Appendix B

Energy End Use Savings

Appendix B

Energy End Use Savings

Table B.1. Large Office Energy End Use Savings

Large Office End Uses	90.1-2010	D.C. EC-2017	90.1-2010	%
Electricity (kWh):				
Heating	17,436	5,575	11,861	*68.0%*
Cooling	1,084,375	897,261	187,114	*17.3%*
Interior Lighting	1,053,042	912,753	140,289	*13.3%*
Exterior Lighting	189,183	127,158	62,025	*32.8%*
Interior Equipment	4,082,031	4,076,753	5,278	*0.1%*
Exterior Equipment	551,464	550,189	1,275	*0.2%*
Fans	553,347	422,844	130,503	*23.6%*
Pumps	149,892	104,703	45,189	*30.1%*
Heat Rejection	113,369	80,119	33,250	*29.3%*
Humidification	8,444	8,081	363	*4.3%*
Heat Recovery	0	29,414	-29,414	*NA*
Photovoltaic Power	0	-116,617	116,617	*NA*
Total kWh/year	7,802,583	7,098,233	704,350	*9.0%*
Total kWh/ft^2-year	15.65	14.24	1.41	
Natural Gas (therms):				
Heating	42,521	31,686	10,835	*25.5%*
Water Systems	5,583	5,584	-1	*0.0%*
Total therms/year	48,104	37,270	10,834	*22.5%*
Total therms/ft^2-year	0.096	0.075	0.022	
Summary:				
Total Electric $/year	$937,117	$852,522	$84,595	*9.0%*
Total Natural Gas $/year	$50,990	$39,506	$11,484	*22.5%*
Total Energy $/year	$988,108	$892,029	$96,079	*9.7%*
Total Energy $/ft^2-year	$1.98	$1.79	$0.19	
Total site energy kBtu/ft^2-yr	63.1	56.1	7.0	*11.1%*
Total source energy kBtu/ft^2-yr	168.1	151.5	16.6	*9.9%*

Table B.2. Mid-Rise Apartment Energy End Use Savings

Mid-Rise Apartment End Uses	90.1-2010	D.C. EC-2017	90.1-2010	%
Electricity (kWh):				
Heating	0	5,422	-5,422	*NA*
Cooling	43,069	32,403	10,666	*24.8%*
Interior Lighting	45,833	25,647	20,186	*44.0%*
Exterior Lighting	10,950	9,631	1,319	*12.0%*
Interior Equipment	142,061	141,969	92	*0.1%*
Fans	65,078	48,106	16,972	*26.1%*
Water Systems	109,794	109,522	272	*0.2%*
Heat Recovery	0	15,136	-15,136	*NA*
Photovoltaic Power	0	-25,667	25,667	*NA*
Total kWh/year	416,785	362,169	54,616	*13.1%*
Total kWh/ft^2-year	12.35	10.73	1.62	
Natural Gas (therms):				
Heating	2,600	0	2,600	*100.0%*
Total therms/year	2,600	0	2,600	*100.0%*
Total therms/ft^2-year	0.077	0.000	0	
Summary:				
Total Electric $/year	$50,057	$43,498	$6,560	*13.1%*
Total Natural Gas $/year	$2,756	$0	$2,756	*100.0%*
Total Energy $/year	$52,813	$43,498	$9,316	*17.6%*
Total Energy $/ft^2-year	$1.57	$1.29	$0.28	
Total site energy kBtu/ft^2-yr	49.9	36.6	13.2	*26.5%*
Total source energy kBtu/ft^2-yr	132.8	108.1	24.7	*18.6%*

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