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PNNL-31497

Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for District of Columbia

July 2021

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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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Pacific Northwest National Laboratory
Richland, Washington 99354

Acronyms and Abbreviations

AVERT	U.S. EPA AVoided Emissions and geneRation Tool
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CH_4	Methane
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
E.O.	Executive Order
eGRID	EPA Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
HVAC	Heating, Ventilating, and Air-Conditioning
LCC	Life-Cycle Cost
MMT	Million Metric Tons
N_2O	Nitrous Oxide
NOx	Nitrogen Oxides
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
SOx	Sulfur Oxides
UPV	Uniform Present Value

1.0 Highlights

Moving to the ASHRAE Standard 90.1-2019 (ASHRAE 2019) edition from Standard 90.1-2016 (ASHRAE 2016) is cost-effective for District of Columbia. Standard 90.1-2019 will provide an annual energy cost savings of $0.050 per square foot on average across the state. It will reduce statewide CO_2 emissions by .5 MMT (30 years cumulative), equivalent to the CO_2 emissions of 116,600 cars driven for one year.

Updating the state energy code based on Standard 90.1-2019 will also stimulate the creation of high-quality jobs across the state. Standard 90.1-2019 is expected to result in buildings that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort, and resilience.

The tables below show the expected impact of upgrading to Standard 90.1-2019 from a consumer perspective and statewide perspective. These results are weighted averages for all building types in all climate zones in the state, based on weightings shown in Table 4. The methodology used for this analysis is consistent with the methodology used in the national cost-effectiveness analysis.[1] Additional results and details on the methodology are presented in the following sections.

Consumer Impact	
Annual (first year) energy cost savings, $/ft^2	$0.050
Added construction cost, $/ft^2	-$1.414
Publicly-owned scenario LCC Savings, $/ft^2	3.47
Privately-owned scenario LCC Savings, $/ft^2	2.91

Statewide Impact - Emissions	First Year	30 Years Cumulative
Energy cost savings, 2020$	100,100	44,060,000
CO_2 emission reduction, Metric tons	763	535,900
CH_4 emissions reductions, Metric tons	0.01	8
N_2O emissions reductions, Metric tons	0.001	1
NOx emissions reductions, Metric tons	0.38	266
SOx emissions reductions, Metric tons	0.58	405

Statewide Impact - Jobs Created	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	5	156
Jobs Created Construction Related Activities	4	122

[1] National cost-effectiveness report: https://www.energycodes.gov/development/commercial/cost_effectiveness

The report provides analysis of two LCC scenarios:

- **Scenario 1**, representing *publicly-owned* buildings, considers initial costs, energy costs, maintenance costs, and replacement costs—without borrowing or taxes.
- **Scenario 2**, representing *privately-owned* buildings, adds borrowing costs and tax impacts.

Figure 1 compares annual energy cost savings, first cost for the upgrade, and net annualized LCC savings. The net annualized LCC savings per square foot is the annual energy savings minus an allowance to pay for the added cost under scenario 1. Figure 2 shows overall state weighted net LCC results for both scenarios. When net LCC is positive, the updated code edition is considered cost-effective.

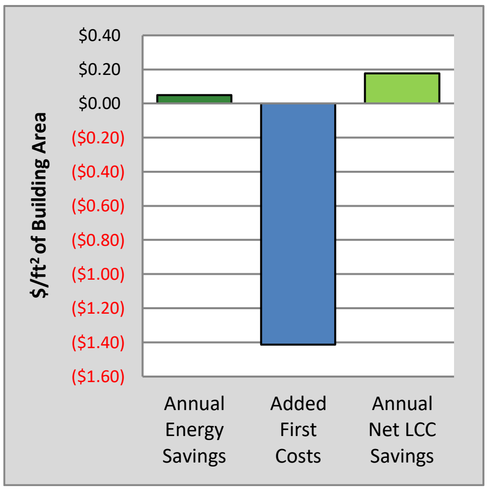

Figure 1. Statewide Weighted Costs and Savings

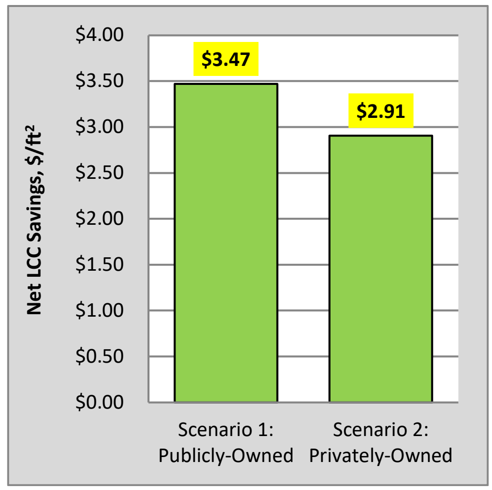

Figure 2. Overall Net Life-Cycle Cost Savings

2.0 Cost-Effectiveness Results for ASHRAE Standard 90.1-2019 in District of Columbia

This section summarizes the cost-effectiveness analysis results applicable to the building owner. Life Cycle Cost (LCC) savings is the primary measure established by the U.S. Department of Energy to assess the cost effectiveness and economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The non-energy incremental costs include initial equipment and construction costs, and maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective. Savings are computed for two scenarios:

- **Scenario 1:** represents *publicly-owned buildings*, includes costs for initial equipment and construction, energy, maintenance and replacement and does not include loans or taxes.
- **Scenario 2:** represents *privately-owned buildings*, includes the same costs as Scenario 1, with the initial investment financed through a loan amortized over 30 years and federal and state corporate income tax deductions for interest and depreciation.

Both scenarios include the residual value of equipment with remaining useful life at the end of the 30-year assessment period. Totals for building types, climate zones, and the state overall are averages based on Table 4 construction weights. Factors such as inflation and discount rates are different between the two scenarios, as described in the Cost-Effectiveness Methodology section.

LCC is affected by many variables, including the applicability of individual measures in the code, measure costs, measure lifetime, replacement costs, state cost adjustment, energy prices, and so on. In some cases, the LCC can be negative for a given building type or climate zone based on the interaction of these variables. However, the code is considered cost-effective if the weighted statewide LCC is positive.

Table 1 shows the present value of the net LCC savings over 30 years for buildings in scenario 1 averages $3.47 per square foot for Standard 90.1-2019.

Table 1. Net LCC Savings for District of Columbia, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	$4.07	$4.20	$4.22	$4.93	$13.53	$1.97	$3.47
State Average	$4.07	$4.20	$4.22	$4.93	$13.53	$1.97	**$3.47**

Table 2 shows the present value of the net LCC savings over 30 years averages $2.91 per square foot for scenario 2.

Table 2. Net LCC Savings for District of Columbia, Scenario 2 ($/ft^2)

DoEvents

2.1 Energy Cost Savings

Table 3 shows the economic impact of upgrading to Standard 90.1-2019 by building type and climate zone in terms of the annual energy cost savings in dollars per square foot. The annual energy cost savings across the state averages $0.050 per square foot.

Table 3. Annual Energy Cost Savings for District of Columbia ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	$0.050	$0.064	$0.085	$0.074	$0.090	$0.019	$0.050
State Average	$0.050	$0.064	$0.085	$0.074	$0.090	$0.019	**$0.050**

2.2 Construction Weighting of Results

Energy and economic impacts were determined and reported separately for each building type and climate zone. Cost-effectiveness results are also reported as averages for all prototypes and climate zones in the state. To determine these averages, results were combined across the different building types and climate zones using weighting factors shown in Table 4. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes in state-specific climate zones. The weighting factors were developed from construction start data from 2003 to 2018 (Dodge Data & Analytics) based on an approach documented in Lei, et al.

Table 4. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	1.2%	56.1%	4.9%	2.8%	0.3%	34.8%	100.0%
State Average	1.2%	56.1%	4.9%	2.8%	0.3%	34.8%	100.0%

2.3 Incremental Construction Cost

Cost estimates were developed for the differences between Standard 90.1-2016 and Standard 90.1-2019 as implemented in the six prototype models. Costs for the initial construction include material, labor, commissioning, construction equipment, overhead and profit. Costs were also estimated for replacing equipment or components at the end of the useful life. The costs were developed at the national level for the national cost-effectiveness analysis and then adjusted for local conditions using a state construction cost index (Hart et al. 2019, Means 2020a,b).

Table 5 shows incremental initial cost for individual building types in state-specific climate zones and weighted average costs by climate zone and building type for moving to Standard 90.1-2019 from Standard 90.1-2016.

The added construction cost can be negative for some building types, which represents a reduction in first costs and a savings that is included in the net LCC savings. This is typically due to the interaction between measures and situations such as the following:

- Fewer light fixtures are required when the allowed lighting power is reduced. Also, changes from fluorescent to LED technology result in reduced lighting costs in many cases and longer lamp lives, requiring fewer lamp replacements.

- Smaller heating, ventilating, and air-conditioning (HVAC) equipment sizes can result from the lowering of heating and cooling loads due to other efficiency measures, such as better building envelopes. For example, Standard 90.1-2019 has more stringent fenestration U-factors for some climate zones. This results in smaller equipment and distribution systems, resulting in a negative first cost.

Table 5. Incremental Construction Cost for District of Columbia ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	($1.769)	($2.048)	($1.313)	($2.005)	$0.654	($0.362)	($1.414)
State Average	($1.769)	($2.048)	($1.313)	($2.005)	$0.654	($0.362)	**($1.414)**

2.4 Simple Payback

Simple payback is the total incremental first cost divided by the annual savings, where the annual savings is the annual energy cost savings less any incremental annual maintenance cost. Simple payback is not used as a measure of cost-effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any replacement costs that occur after the initial investment. However, it is included in the analysis for states who wish to use this information. Table 6 shows simple payback results in years.

Table 6. Simple Payback for District of Columbia (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
4A	Immediate	Immediate	Immediate	Immediate	7.3	Immediate	Immediate
State Average	Immediate	Immediate	Immediate	Immediate	7.3	Immediate	**Immediate**

3.0 Societal Benefits

3.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process. Making this early investment in energy efficiency will pay dividends to residents of District of Columbia for years into the future.

3.2 Greenhouse Gas Emissions

The urban built environment is responsible for 75% of annual global greenhouse gas (GHG) emissions while buildings alone account for 39%.[2] While carbon dioxide emissions represent the largest share of greenhouse gas emissions, building electricity use and on-site fossil fuel consumption also contribute to other emissions, two of which, methane (CH_4) and nitrous oxide (N_2O), are significant greenhouse gases in their own right.

For natural gas combusted on site, emission metrics are developed using nationwide emission factors from U.S. Environmental Protection Agency publications for CO_2, NOx, SO_2, CH_4 and N_2O (EPA 2014).

For electricity, marginal carbon emission factors are provided by the U.S. Environmental Protection Agency (EPA) AVoided Emissions and geneRation Tool (AVERT) version 3.0 (EPA 2020). The AVERT tool forms the basis of the national marginal emission factors for electricity also published by EPA on its Greenhouse Gas Equivalencies Calculator website and are based on a portfolio of energy efficiency measures examined by EPA. AVERT is used here to provide marginal CO_2 emission factors at the State level.[3] AVERT also provides marginal emission factor estimates for gaseous pollutants associated with electricity production, including NOx and SO_2 emissions. While not considered significant greenhouse gases, these are EPA tracked pollutants. The current analysis uses AVERT to provide estimates of corresponding emission changes for NOx and SO_2 in physical units but does not monetize these.

AVERT does not develop associated marginal emissions factors for CH_4 or N_2O. To provide estimates for the associated emission reductions for CH_4 and N_2O, this report uses emission factors separately provided through the U.S. Environmental Protection Agency (EPA) Emissions

[2] Architecture 2030, https://architecture2030.org/2030_challenges/2030-challenge

[3] AVERT models avoided emissions in 14 geographic regions of the 48 contiguous United States and includes transmission and distribution losses. Where multiple AVERT regions overlap a state's boundaries, the emission factors are calculated based on apportionment of state electricity savings by generation across generation regions. The most recent AVERT 3.0 model uses EPA emissions data for generators from 2019. Note that AVERT estimates are based on marginal changes to demand and reflect current grid generation mix. Emission factors for electricity shown in Table 7 do not take into account long term policy or technological changes in the regional generation mix that can impact the marginal emission benefits from new building codes.

& Generation Resource Integrated Database (eGRID) dataset. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States and the emission characteristics for electric power generation for each of the above emissions can also be found aggregated down to the state level in eGRID (EPA 2021a). The summary emission factor data provided by eGRID does not provide marginal emission factors, but instead summarizes emission factors in terms of total generation emission factors and non-baseload generation emission factors. Non-baseload emission factors established in eGRID are developed based on the annual load factors for the individual generators tracked by the EPA (EPA 2021b). Because changes in building codes are unlikely to significantly impact baseload electrical generators, the current analysis uses the 2019 non-baseload emission factors established in eGRID by state to estimate CH_4 or N_2O emission reductions due to changes in electric consumption.

Table 7 summarizes the marginal emission factors available from AVERT, eGRID and the EPA Greenhouse Gas Equivalencies Calculator.

Table 7. Greenhouse Gas Emission Factors by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)
CO_2	1,567	120,000
SO_2	1.194	0.6
NO_X	0.774	96
N_2O	0.002	0.23
CH_4	0.022	2.3

Table 8 shows the annual first year and projected 30-year energy cost savings. This table also shows first year and projected 30-year greenhouse gas (CO_2, CH_4, and N_2O) emission reductions, in addition to NOx and SO_2 reductions.

Table 8. Societal Benefits of Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, 2020$	100,100	44,060,000
CO_2 emission reduction, Metric tons	763	535,900
CH_4 emissions reductions, Metric tons	0.01	8
N_2O emissions reductions, Metric tons	0.001	1
NOx emissions reductions, Metric tons	0.38	266
SOx emissions reductions, Metric tons	0.58	405

3.3 Jobs Creation through Energy Efficiency

Energy-efficient building codes impact job creation through two primary value streams:

1. Dollars returned to the economy through reduction in utility bills and resulting increase in disposable income, and;
2. An increase in construction-related activities associated with the incremental cost of construction that is required to produce a more energy efficient building.

When a building is built to a more stringent energy code, there is the long-term benefit of the ratepayer paying lower utility bills.

- This is partially offset by the increased cost of that efficiency, establishing a relationship between increased building energy efficiency and additional investments in construction activity.
- Since building codes are cost-effective, (i.e., the savings outweigh the investment), a real and permanent increase in wealth occurs that can be spent on other goods and services in the economy, just like any other income, generating economic benefits and creating additional employment opportunities.

Table 9 shows the number of jobs created because of efficiency gains in Standard 90.1-2019.

Table 9. Jobs Created from Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	5	156
Jobs Created Construction Related Activities	4	122

4.0 Overview of the Cost-Effectiveness Methodology

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the DOE Building Energy Codes Program. DOE is directed by federal law to provide technical assistance supporting the development and implementation of residential and commercial building energy codes. The national model energy codes – the International Energy Conservation Code (IECC) and ANSI/ASHRAE/IES Standard 90.1 – help adopting states and localities establish minimum requirements for energy-efficient building design and construction, as well as mitigate environmental impacts and ensure residential and commercial buildings are constructed to modern industry standards.

The current analysis evaluates the cost-effectiveness of Standard 90.1-2019 relative to Standard 90.1-2016. The analysis covers six commercial building types. The analysis is based on the current prescriptive requirements of Standard 90.1. The simulated performance rating method is not in the scope of this analysis, as it is generally based on the core prescriptive requirements of Standard 90.1, and due to the unlimited range of building configurations that are allowed. Buildings complying via this path are generally considered to provide equal or better energy performance compared to the prescriptive requirements, as the intent of these paths is to provide additional design flexibility and cost optimization, as dictated by the builder, designer, and owner.

The current analysis is based on the methodology by DOE for assessing building energy codes (Hart and Liu 2015). The LCC analysis perspective described in the methodology appropriately balances upfront costs with longer term consumer costs and savings and is therefore the primary economic metric by which DOE evaluates the cost-effectiveness of building energy codes.

4.1 Cost-Effectiveness

DOE has established standard economic LCC cost-effectiveness analysis methods in comparing Standard 90.1-2019 and Standard 90.1-2016, which are described in *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes* (Hart and Liu 2015). Under this methodology, two metrics are used:

- **Net LCC Savings:** This is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The costs include initial equipment and construction costs, maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective.
- **Simple Payback:** While not a true cost-effectiveness metric, simple payback is also calculated. Simple payback is the number of years required for accumulated annual energy cost savings to exceed the incremental first costs of a new code.

Two cost scenarios are analyzed:

- **Scenario 1** represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes.
- **Scenario 2** represents privately-owned buildings and includes the same costs as Scenario 1 plus financing of the incremental first costs through increased borrowing with tax impacts including mortgage interest and depreciation deductions. Corporate tax rates are applied.

The cost-effectiveness analysis compares the cost for new buildings meeting Standard 90.1-2019 versus new buildings meeting Standard 90.1-2016. The analysis includes energy savings estimates from building energy simulations and LCC and simple payback calculations using standard economic analysis parameters. The analysis builds on work documented in *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019* (DOE 2021), and the national cost-effectiveness analysis documented in *National Cost-effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019* (Tyler et al. 2021).

4.2 Building Prototypes and Energy Modeling

The cost-effectiveness analysis uses six building types represented by six prototype building energy models. These six models represent the energy impact of five of the eight commercial principal building activities that account for 74% of the new construction by floor area covered by the full suite of 16 prototypes. These models provide coverage of the significant changes in ASHRAE Standard 90.1 from 2016 to 2019 and are used to show the impacts of the changes on annual energy usage. The prototypes represent common construction practice and include the primary conventional HVAC systems most commonly used in commercial buildings.[4]

Each prototype building is analyzed for each of the climate zones found within the state. Using the U.S. DOE EnergyPlus software, the six building prototypes summarized in Table 10 are simulated with characteristics meeting the requirements of Standard 90.1-2016 and then modified to meet the requirements of the next edition of the code (Standard 90.1-2019). The energy use and energy cost are then compared between the two sets of models.

Table 10. Building Prototypes

Building Prototype	Floor Area (ft²)	Number of Floors
Small Office	5,500	1
Large Office	498,640	13
Stand-Alone Retail	24,690	1
Primary School	73,970	1
Small Hotel	43,210	4
Mid-Rise Apartment	33,740	4

4.3 Climate Zones

Climate zones are defined in ASHRAE Standard 169, as specified in ASHRAE Standard 90.1, and include eight primary climate zones in the United States, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating humid, B indicating dry, and C indicating marine. Figure 3 shows the national climate zones. For this state analysis, savings are analyzed for each climate zone in the state using weather data from a selected city within the climate zone and state, or where necessary, a city in an adjoining state with more robust weather data.

[4] More information on the prototype buildings and savings analysis can be found at www.energycodes.gov/development/commercial/90.1_models

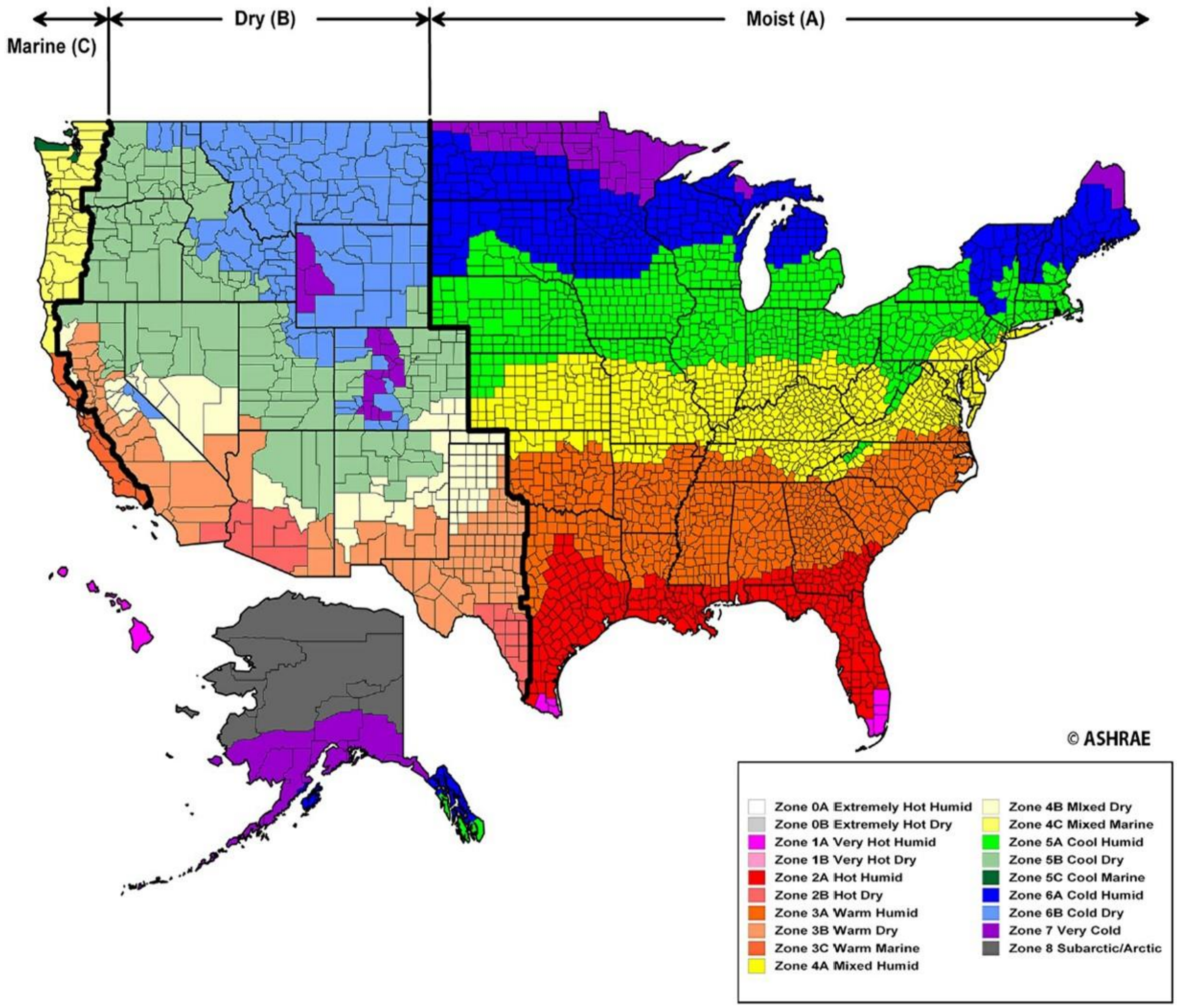

Figure 3. National Climate Zones

4.4 Cost-Effectiveness Method and Parameters

The DOE cost-effectiveness methodology accounts for the benefits of energy efficient building construction over a multi-year analysis period, balancing initial costs against longer term energy savings. DOE evaluates energy codes and code proposals based on LCC analysis over a multi-year study period, accounting for energy savings, incremental investment for energy efficiency measures, and other economic impacts. The value of future savings and costs are discounted to a present value, with improvements deemed cost-effective when the net LCC savings (present value of savings minus cost) is positive.

The U.S. DOE Building Energy Codes Program has established LCC analysis criteria similar to the method used for many federal building projects, as well as other public and private building projects (Fuller and Petersen 1995). The LCC analysis method consists of identifying costs (and revenues if any) and in what year they occur; then determining their value in today's dollars (known as the present value). This method uses economic relationships about the time value of money. Money in-hand today is normally worth more than money received in the future, which is why we pay interest on a loan and earn interest on savings. Future costs are discounted to the present based on a discount rate. The discount rate may reflect the interest rate at which money can be borrowed for projects with the same level of risk or the interest rate that can be earned on other conventional investments with similar risk.

The LCC includes incremental initial costs, repairs, maintenance, and replacements. Scenario 2 also includes loan costs and tax impacts including mortgage interest and depreciation deductions. The residual value of equipment (or other component such as roof membrane) that has remaining useful life at the end of the 30-year study period is also included for both scenarios. The residual value is calculated by multiplying the initial cost of the component by the years of useful life remaining for the component at year 30 divided by the total useful life, a simplified approach included in the Federal Energy Management Program (FEMP) LCC method (Fuller and Petersen 1995). A component will have zero residual value at year 30 only if it has a 30-year life, or if it has a shorter than 30-year life that divides exactly into 30 years (for example, a 15-year life).

The financial and economic parameters used for the LCC calculations are shown in Table 11.

Table 11. LCC Economic Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years[1]	30	30
Nominal Discount Rate[2]	3.10%	5.25%
Real Discount Rate[2]	3.00%	3.34%
Effective Inflation Rate[3]	0.10%	1.85%
Electricity Prices[4] (per kWh)	$0.1195	$0.1195
Natural Gas Prices[4] (per therm)	$1.0728	$1.0728
Energy Price Escalation Factors[5]	*Uniform present value factors*	*Uniform present value factors*
Electricity Price UPV[5]	19.17	17.37
Natural Gas Price UPV[5]	23.45	21.25
Loan Interest Rate[6]	NA	5.25%
Federal Corporate Tax Rate[7]	NA	21.00%
State Corporate Tax Rate[8]	NA	8.25%
Combined Income Tax Impact[9]	NA	27.52%
State and Average Local Sales Tax[10]	6.00%	6.00%
State Construction Cost Index[11]	0.952	0.952

[1] A 30-year study period captures most building components useful lives and is a commonly used study period for building project economic analysis. This period is consistent with previous and related national 90.1 cost-effectiveness analysis. It is also consistent with the cost-effectiveness analysis that was done for the residential energy code as described in multiple state reports and a summary report (Mendon et al. 2015). The federal building LCC method uses 25 years and the ASHRAE Standard 90.1 development process uses up to 40 years for building envelope code improvement analysis. Because of the time value of money, results are typically similar for any study periods of 20 years or more.

[2] The Scenario 1 real and nominal discount rates are from the National Institute of Standards and Technology (NIST) 2019 annual update in the *Report of the President's Economic Advisors, Analytical Perspectives* (referenced in the NIST 2019 annual supplement without citation) (Lavappa and Kneifel 2019). The Scenario 2 nominal discount rate is taken as the marginal cost of capital, which is set equal to the loan interest rate (see footnote 6). The real discount rate for Scenario 2 is calculated from the nominal discount rate and inflation.

[3] The Scenario 1 effective inflation rate is from the NIST 2019 annual update for the federal LCC method (Lavappa and Kneifel 2019). The Scenario 2 inflation rate is the 30-year average Producer Price Index for non-residential construction, June 1990 to June 2020 (Bureau of Labor Statistics 2021).

[4] Scenario 1 and 2 electricity and natural gas prices are state average annual prices for 2020 from the United States Energy Information Administration (EIA) *Electric Power Monthly* (EIA 2021a) and *Natural Gas Monthly* (EIA 2021b).

[5] Scenario 1 energy price escalation rates are from the NIST 2019 annual update for the FEMP LCC method (Lavappa and Kneifel 2019). The NIST uniform present value (UPV) factors are multiplied by the first-year annual energy cost to determine the present value of 30 years of energy costs and are based on a series of different annual escalation rates for 30 years. Scenario 2 UPV factors are based on NIST UPVs with an adjustment made for the scenario difference in discount rates.

[6] The loan interest rate is estimated from multiple online sources listed in the references (Commercial Loan Direct 2021; Realty Rates 2021).

[7] The highest federal marginal corporate income tax rate is applied.

[8] The highest marginal state corporate income tax rate is applied from the Federation of Tax Administrators (FTA 2021).

[9] The combined tax impact is based on state tax being a deduction for federal tax and is applied to depreciation and loan interest.

[10] The combined state and average local sales tax is included in material costs in the cost estimate (Tax Foundation 2020).

[11] The state construction cost index is based on weighted city indices from the state (Means 2020b).

5.0 Detailed Energy Use and Cost

On the following pages, specific detailed results for District of Columbia are included:

- Table 12 shows the average energy rates used.
- Table 13 shows the per square foot energy costs for Standard 90.1-2016 and Standard 90.1-2019 and the cost savings from Standard 90.1-2019.
- Table 14 shows the per square foot energy use for Standard 90.1-2016 and Standard 90.1-2019 and the energy use savings from Standard 90.1-2019.
- Table 15.A shows the energy end use by energy type for each climate zone in the state.

Table 12. Energy Rates for District of Columbia, Average $ per unit

Electricity	$0.1195	kWh
Gas	$1.0728	Therm

Source: Energy Information Administration, annual average prices for 2020 (EIA 2021a,b)

Table 13. Energy Cost Saving Results in District of Columbia, $ per Square Foot

Climate Zone:	4A			
Code:	90.1-2016	90.1-2019	Savings	
Small Office				
Electricity	$0.892	$0.842	$0.050	5.6%
Gas	$0.005	$0.006	$0.000	0.0%
Totals	$0.898	$0.848	$0.050	5.6%
Large Office				
Electricity	$1.828	$1.765	$0.063	3.4%
Gas	$0.026	$0.025	$0.001	3.8%
Totals	$1.854	$1.790	$0.064	3.5%
Stand-Alone Retail				
Electricity	$1.134	$1.041	$0.093	8.2%
Gas	$0.169	$0.177	-$0.008	-4.7%
Totals	$1.303	$1.218	$0.085	6.5%
Primary School				
Electricity	$1.115	$1.042	$0.072	6.5%
Gas	$0.108	$0.106	$0.002	1.9%
Totals	$1.223	$1.148	$0.074	6.1%
Small Hotel				
Electricity	$1.085	$0.995	$0.090	8.3%
Gas	$0.251	$0.251	$0.000	0.0%
Totals	$1.336	$1.247	$0.090	6.7%
Mid-Rise Apartment				
Electricity	$1.204	$1.181	$0.023	1.9%
Gas	$0.022	$0.026	-$0.004	-18.2%
Totals	$1.226	$1.206	$0.019	1.5%

Table 14. Energy Use Saving Results in District of Columbia, Energy Use per Square Foot

Climate Zone:	4A			
Code:	90.1-2016	90.1-2019	Savings	
Small Office				
Electricity, kWh/ft^2	7.468	7.048	0.420	5.6%
Gas, therm/ft^2	0.005	0.005	0.000	0.0%
Totals, kBtu/ft^2	25.973	24.575	1.398	5.4%
Large Office				
Electricity, kWh/ft^2	15.296	14.771	0.525	3.4%
Gas, therm/ft^2	0.024	0.023	0.001	4.2%
Totals, kBtu/ft^2	54.615	52.700	1.914	3.5%
Stand-Alone Retail				
Electricity, kWh/ft^2	9.489	8.711	0.778	8.2%
Gas, therm/ft^2	0.157	0.165	-0.008	-5.1%
Totals, kBtu/ft^2	48.118	46.238	1.880	3.9%
Primary School				
Electricity, kWh/ft^2	9.327	8.722	0.605	6.5%
Gas, therm/ft^2	0.101	0.099	0.002	2.0%
Totals, kBtu/ft^2	41.933	39.664	2.270	5.4%
Small Hotel				
Electricity, kWh/ft^2	9.081	8.330	0.751	8.3%
Gas, therm/ft^2	0.234	0.234	0.000	0.0%
Totals, kBtu/ft^2	54.397	51.840	2.556	4.7%
Mid-Rise Apartment				
Electricity, kWh/ft^2	10.074	9.881	0.193	1.9%
Gas, therm/ft^2	0.020	0.024	-0.003	-15.0%
Totals, kBtu/ft^2	36.430	36.111	0.319	0.9%

Table 15.A. Annual Energy Usage for Buildings in District of Columbia in Climate Zone 4A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.441	0.005	0.731	0.013	0.000	0.121	0.000	0.039	0.482	0.012	0.000	0.020
Cooling	0.901	0.000	1.940	0.000	1.895	0.000	1.653	0.000	1.831	0.000	0.965	0.000
Fans, Pumps, Heat Recovery	0.883	0.000	1.399	0.000	1.571	0.000	1.557	0.000	1.061	0.000	0.637	0.000
Lighting, Interior & Exterior	1.894	0.000	1.957	0.000	3.837	0.000	1.418	0.000	2.120	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.187	0.000	4.601	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.036	0.097	0.015	0.000	0.130	3.209	0.000
Total	7.468	0.005	15.296	0.024	9.489	0.157	9.327	0.101	9.081	0.234	10.074	0.020
ASHRAE 90.1-2019												
Heating, Humidification	0.450	0.005	0.731	0.012	0.000	0.129	0.000	0.037	0.560	0.012	0.000	0.024
Cooling	0.855	0.000	1.803	0.000	1.776	0.000	1.589	0.000	1.715	0.000	0.938	0.000
Fans, Pumps, Heat Recovery	0.813	0.000	1.339	0.000	1.618	0.000	1.407	0.000	1.007	0.000	0.625	0.000
Lighting, Interior & Exterior	1.582	0.000	1.629	0.000	3.130	0.000	1.170	0.000	1.461	0.000	0.901	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.187	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.011	0.000	0.036	0.097	0.015	0.000	0.130	3.210	0.000
Total	7.048	0.005	14.771	0.023	8.711	0.165	8.722	0.099	8.330	0.234	9.881	0.024
Total Savings	0.420	0.000	0.525	0.001	0.778	-0.008	0.605	0.002	0.751	0.000	0.193	-0.003

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