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# 2019 Oregon Commercial Energy Code – Energy Savings Analysis

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## Glossary of Acronyms

| | |
|---|---|
| 4C | Climate zone 4C (western Oregon) |
| 5B | Climate zone 5B (eastern Oregon) |
| ASHRAE | American Society of Heating, Refrigeration, and Air-Conditioning Engineers |
| CFA | Conditioned floor area |
| DCV | Demand control ventilation |
| HVAC | Heating, Ventilation and Air Conditioning |
| IES | Illuminating Engineering Society |
| LPD | Lighting power density (W/$ft^2$) |
| NC | New construction |
| NEEA | Northwest Energy Efficiency Alliance |
| NPCC | Northwest Power and Conservation Council |
| OCEC 2019 | Oregon Commercial Energy Code 2019 |
| OCCE | Oregon Code Compliance Evaluation Study |
| OEESC 2014 | Oregon Energy Efficiency Specialty Code 2014 |
| OR14 | OEESC 2014 |
| OR19 | OCEC 2019 |
| RBSA | Residential Building Stock Assessment |
| SHGC | Solar heat gain coefficient of fenestration |
| SHGCA | Solar heat gain coefficient times fenestration area |
| TMY3 | Typical Meteorological Year 3 |
| UA | Building heat loss expressed as U-value times area |
| VAV | Variable air volume |
| WSEC | Washington State Energy Code |

## Glossary of Units

| | |
|---|---|
| aMW | Average megawatt |
| Btu | British thermal unit |
| Btuh | British thermal unit per hour |
| $ft^2$ | square feet |
| kBtu | British thermal unit (1000s) |
| kBtuh | British thermal unit (1000s) per hour |
| kWh | kilowatt-hour |
| MMBtu | British thermal unit (1000000s) |
| mWh | megawatt-hour |
| W | Watt |

# Executive Summary

The 2019 Oregon Commercial Energy Code (OCEC 2019) is the most recent iteration of Oregon commercial building energy code. The code was developed by the Oregon Building Codes Division and adopted statewide for construction permitted as of January 1, 2020. It replaces the previous 2014 Oregon Energy Efficiency Specialty code (OEESC 2014). The code impacts all types of commercial buildings and multifamily buildings over three stories tall. The OCEC 2019 requires that buildings demonstrate compliance with the ASHRAE 90.1-2016 building energy code. ASHRAE 90.1-2016 changes lighting and envelope efficiency requirements, has more HVAC control requirements, and significantly expands the building systems that are regulated (e.g., refrigeration, plug loads, metering).

The Northwest Energy Efficiency Alliance (NEEA) has played a pivotal role in aiding states to deliver more effective and efficient energy codes. The main objective of this report is to quantify the energy use and energy savings resulting from adoption of the 2019 Oregon Commercial Energy Code (OCEC 2019) in new buildings and additions.

## Methodology

The study was developed in two phases. The first phase involved identifying all code changes that resulted in possible energy changes and making a qualitative assessment of whether the measure warranted quantitative evaluation. All major code changes were selected for quantification except for metering and commissioning changes that impact building operations. The major code changes identified for evaluation include a 10.6% decrease in interior lighting power allowances, a 29% decrease in exterior lighting allowance, interior and exterior lighting controls, plug load equipment control savings, HVAC fan controls, and improved envelope efficiency. Only changes in the code prescriptive path were evaluated. Many smaller code changes were not selected for evaluation due to limited evaluation resources and diminishing returns of evaluating changes that impact very narrow slices of new construction.

The second phase involved development of energy use and savings estimates for the selected changes. The building energy modeling software EnergyPlus (DOE 2018) was utilized and supplemented with engineering calculations. A suite of 16 prototype buildings, derived from the Bonneville Power Administration (BPA) new vintage existing building models (Navigant, 2016) and modified for code evaluation, were utilized. The BPA models share many characteristics with the national reference models but have been modified to capture region-specific construction practices. Specific model inputs representing code values were developed based in some cases on impacts estimated from those same regional building data sets, and in other cases on Pacific Northwest National Laboratory (PNNL) 90.1 modeling inputs (Thorton et al. 2011, PNNL 2014a, PNNL 2014b, 2017).

Two estimates of code energy savings are made on a unit area basis for each code, building type and climate combination. First, the prototype energy use is calculated for each code and the difference is taken as the change in code stringency.[1] The second estimate includes current practice adjustments to improve its representation of actual energy savings. The adjustments account for areas of code for which current practice is always better than code, as well as new provisions for which substantial portions of the commercial sector are already implementing the provision.

Total state estimates combine the unit area savings estimate with the new construction/addition floor area forecasts from the Northwest Power and Conservation Council (NPCC) Seventh Power Plan.[2] The prototype models directly represent 64% of Oregon commercial sector floor area. Where absolute savings are presented, it is assumed that the average of the modeled sectors can be used to represent those sectors not modeled.

## Results

In total, 108 changes were noted in the new code, of which 72 were determined to likely impact energy use, 57 decreasing energy use and 15 increasing it. A total of 27 measures were evaluated to quantify the energy savings. The unevaluated measures included many niche provisions (e.g., lowering leakage allowed in high pressure ducts) as well as some larger measures such as commissioning, metering, and refrigeration provisions.

**Code Stringency**

New commercial buildings meeting the requirements of the OCEC 2019 analyzed in the prototypes exhibit significant reduced electric usage, slightly increased natural gas usage, and overall reduction in site energy usage. The weighted average changes in prototype energy use are:

- 9.0% reduction in site energy
- 10.8% reduction in source energy
- 12.3% reduction in electricity usage
- 1.2% reduction in gas usage

The relatively small reduction in gas usage is the result of increased heating that results from interior lighting and equipment provision measures which reduce interior electric use and the resulting internal heat gains. The change in prototype energy use by building type is presented in Table 1. These values represent the change in code stringency and are comparable to savings numbers from national energy code determinations (Thorton et al. 2011, PNNL, 2014a, PNNL 2017). Energy use indices (EUI) by prototype are presented for each code in Table 2.

[1] While this quantity is typically referred to as energy savings in national code determinations, this report refers to it as code-to-code savings.

[2] Supporting data files from: Seventh Northwest Electric Power and Conservation Plan, Northwest Power and Conservation Council

**Table 1. Prototype Energy Use Change (Code-to-Code)**

| **Building Type** | **Energy Savings (%)** | | | |
|---|---|---|---|---|
| | **Site Energy** | **Source Energy** | **Electric** | **Gas** |
| Apartment Midrise | 6.4% | 7.7% | 8.8% | 0.7% |
| Apartment Highrise | 7.8% | 9.0% | 10.1% | 2.3% |
| Hospital | 2.6% | 1.8% | 1.0% | 4.9% |
| Lodging – Hotel | 6.7% | 6.4% | 6.0% | 7.8% |
| Lodging – Motel | 8.3% | 8.6% | 8.8% | 7.7% |
| Office – Large | 10.1% | 10.4% | 10.6% | -1.1% |
| Office – Medium | 16.0% | 16.4% | 16.7% | 1.3% |
| Office – Small | 12.9% | 12.7% | 12.5% | 15.5% |
| Residential Care | 1.2% | 0.3% | -0.9% | 3.2% |
| Restaurant - Full Serve | 1.6% | 2.4% | 3.6% | 0.6% |
| Restaurant - Fast Food | 1.2% | 1.7% | 2.5% | 0.6% |
| Retail – Large | 9.8% | 12.1% | 14.3% | 2.6% |
| Retail – Small | 12.7% | 14.2% | 15.6% | 7.4% |
| School – Primary | 11.5% | 15.8% | 19.4% | -5.7% |
| School – Secondary | 7.7% | 11.7% | 14.8% | -13.8% |
| Warehouse | 17.1% | 24.1% | 30.1% | -11.5% |
| **Avg All Models** | **9.0%** | **10.8%** | **12.3%** | **1.2%** |

**Table 2. Prototype Annual Energy Use Indices**

| Building Type | OEESC 2014 | | | | OCEC 2019 | | | |
|---|---|---|---|---|---|---|---|---|
| | Site Energy (kBtu/sf) | Source Energy (kBtu/sf) | Electric (kWh/sf) | Gas (therm/sf) | Site Energy (kBtu/sf) | Source Energy (kBtu/sf) | Electric (kWh/sf) | Gas (therm/sf) |
| Apartment Midrise | 48.9 | 117.3 | 10.1 | 0.144 | 45.7 | 108.2 | 9.2 | 0.143 |
| Apartment Highrise | 43.2 | 103.3 | 8.9 | 0.129 | 39.8 | 94.0 | 8.0 | 0.126 |
| Hospital | 156.9 | 347.2 | 27.8 | 0.621 | 152.9 | 341.0 | 27.5 | 0.591 |
| Lodging - Hotel | 78.8 | 174.6 | 14.0 | 0.310 | 73.5 | 163.5 | 13.2 | 0.286 |
| Lodging - Motel | 55.9 | 117.7 | 9.0 | 0.253 | 51.2 | 107.7 | 8.2 | 0.233 |
| Office - Large | 54.3 | 156.7 | 15.4 | 0.019 | 48.8 | 140.4 | 13.7 | 0.019 |
| Office - Medium | 38.0 | 108.5 | 10.6 | 0.019 | 31.9 | 90.6 | 8.8 | 0.019 |
| Office - Small | 31.1 | 83.7 | 7.8 | 0.044 | 27.1 | 73.1 | 6.9 | 0.037 |
| Residential Care | 64.6 | 127.0 | 8.9 | 0.341 | 63.8 | 126.6 | 9.0 | 0.330 |
| Restaurant - Full Serve | 349.6 | 611.4 | 36.4 | 2.255 | 343.9 | 596.9 | 35.1 | 2.242 |
| Restaurant - Fast Food | 499.3 | 839.1 | 46.6 | 3.405 | 493.2 | 825.0 | 45.4 | 3.383 |
| Retail - Large | 56.1 | 125.3 | 10.1 | 0.216 | 50.6 | 110.1 | 8.7 | 0.210 |
| Retail - Small | 54.7 | 125.9 | 10.4 | 0.191 | 47.8 | 108.0 | 8.8 | 0.177 |
| School - Primary | 50.2 | 118.5 | 10.1 | 0.158 | 44.4 | 99.9 | 8.1 | 0.167 |
| School - Secondary | 35.8 | 88.9 | 7.9 | 0.089 | 33.0 | 78.5 | 6.7 | 0.101 |
| Warehouse | 19.2 | 45.4 | 3.9 | 0.060 | 15.9 | 34.5 | 2.7 | 0.067 |
| **Avg All Models** | **48.9** | **116.9** | **10.0** | **0.147** | **44.5** | **104.3** | **8.8** | **0.145** |

## Energy Savings Estimates

Table 3 presents the estimated energy savings after adjustment for current practice on a floor area normalized basis and forecast sector savings. The forecast sector savings combine the floor area normalized savings with forecast annual new floor area in the state. The evaluation found significant electric savings and a small amount of gas savings. The savings are steady across building types.

Table 4 presents adjusted current practice savings by major code provision. Electric savings are dominated by provisions reducing lighting and plug-load equipment energy use. These same provisions result in increased heating energy use much of which is provided by gas. The net difference of all the provisions is a small change in gas use, with gas savings resulting from new envelope and HVAC provisions in the code largely offset by this increased gas use of the lighting and equipment provisions. Gas savings comprise all fuels including natural gas, propane, and oil consumption.

The savings estimates come with some limitation and uncertainty. Only the primary code provisions are evaluated. Code provisions not quantified include those based upon DOE Federal appliance and equipment standards, those with small expected savings, and a few with uncertainty about current practice and application. Savings from code provisions based upon DOE Federal appliance and equipment standards are captured in NEEA evaluations of the individual standards.

Another source of uncertainty is the operation assumptions assumed for lighting and plug load control provisions. Estimates attributing savings to specific fuels have additional uncertainty due to the limited data on current HVAC system and fuel type choices. Differences between assumed system and fuel type and future installed system and fuel types will directly impact electric and gas savings from envelope provisions and, due to HVAC interaction, the savings associated with interior lighting and receptacles.

In addition to the above limitations, the forecast sector savings do not include savings from code remodel provisions and activity. Thus, significant additional savings occur but are not quantified. As such, this work forms a conservative estimate of improvement in energy efficiency as a result of the code and market changes.

**Table 3. Estimated Annual Energy Savings by Building Type - Current Practice**

| **Building Type** | **Normalized Savings** | | | | **Forecast Sector Savings** | |
|---|---|---|---|---|---|---|
| | **Site Energy kBtu/sf** | **Source Energy kBtu/sf** | **Electric kWh/sf** | **Gas therm/sf** | **Electric aMW** | **Gas MMBtu** |
| Assembly | 3.75 | 10.41 | 1.00 | 0.004 | 0.15 | 478 |
| Hospital | 3.10 | 4.81 | 0.23 | 0.023 | 0.01 | 510 |
| K-12 School | 4.12 | 12.35 | 1.24 | -0.001 | 0.13 | -100 |
| Lodging | 3.36 | 8.12 | 0.70 | 0.010 | 0.03 | 303 |
| Multifamily | 3.11 | 8.87 | 0.86 | 0.002 | 0.16 | 260 |
| Office – Large | 3.64 | 10.81 | 1.08 | 0.000 | 0.20 | -75 |
| Office – Medium | 4.35 | 12.76 | 1.26 | 0.000 | 0.22 | 49 |
| Office – Small | 3.76 | 9.85 | 0.91 | 0.007 | 0.04 | 290 |
| Other | 3.75 | 10.41 | 1.00 | 0.004 | 0.58 | 1799 |
| Other Health | 1.38 | 2.35 | 0.13 | 0.009 | 0.02 | 908 |
| Restaurant | 4.07 | 11.57 | 1.12 | 0.002 | 0.02 | 37 |
| Retail – Big Box/Anchor | 5.09 | 13.62 | 1.27 | 0.007 | 0.09 | 475 |
| Retail – Small/High End | 6.31 | 15.99 | 1.44 | 0.014 | 0.13 | 1142 |
| University | 3.66 | 10.51 | 1.03 | 0.002 | 0.01 | 15 |
| Warehouse | 3.25 | 9.85 | 0.99 | -0.001 | 0.26 | -341 |
| **Total** | **3.71** | **10.35** | **0.99** | **0.003** | **2.05** | **5750** |

**Table 4. Annual Energy Savings by Measure – Current Practice**

| | Normalized Savings | | Forecast Sector Savings | |
|---|---|---|---|---|
| **Code Item** | **Electric kWh/ft²** | **Gas therms/ft²** | **Electric aMW** | **Gas MMBtu/yr** |
| Envelope Changes | 0.079 | 0.0076 | 0.16 | 13703 |
| Minimum Skylight Area | 0.060 | -0.0007 | 0.12 | -1200 |
| Interior Lighting Power | 0.221 | -0.0021 | 0.46 | -3741 |
| Interior Lighting Controls | 0.205 | -0.0009 | 0.42 | -1601 |
| Exterior Lighting Power | 0.152 | 0.0000 | 0.31 | 0 |
| Exterior Lighting Controls | 0.128 | 0.0000 | 0.26 | 0 |
| Receptacles | 0.146 | -0.0008 | 0.30 | -1360 |
| Air Cooled Chiller Limit elimination | -0.011 | 0.0000 | -0.02 | 0 |
| Economizer Control Requirements | 0.007 | 0.0000 | 0.01 | -16 |
| VAV Optimization | 0.006 | -0.0002 | 0.01 | -451 |
| DCV Kitchen Hood Req. Threshold Increase | -0.001 | -0.0001 | 0.00 | -268 |
| New DCV Exception | 0.000 | -0.0001 | 0.00 | -175 |
| High Input Rated Hot Water | 0.000 | 0.0004 | 0.00 | 674 |
| DHW Pipe insulation | 0.001 | 0.0001 | 0.00 | 185 |
| **Total** | **0.994** | **0.0032** | **2.05** | **5750** |

# 1. Introduction

This work evaluates energy savings from the 2019 Oregon Commercial Energy Code (OCEC 2019) in commercial buildings and in multifamily buildings that are four or more stories tall. The previous code, the 2014 Oregon Energy Efficiency Specialty Code (OEESC), is published as Chapter 13 of the 2014 Oregon Structural Specialty Code (OSSC). In March 2019, the Oregon Building Codes Division (BCD) voted to change the energy provisions of OSSC Chapter 13 and renamed the code to the Oregon Commercial Energy Code (OCEC). The new provisions will follow the current Statewide Alternate Method 18-02, entitled the Oregon Zero Code Efficiency Standard, and will encompass:

- Compliance with ASHRAE 90.1-2016 as shown by COM*check*™[3]
- Estimating the energy use of the proposed building
- Identifying required onsite or offsite renewables to achieve a net zero building

The last two items are to be determined using the Architecture 2030 Zero Code Calculator. At this time, there is no requirement for actual installation or purchase of renewables, so effectively the 2019 OCEC is the ASHRAE 90.1-2016 energy code.

The effective date of the new provisions was January 1, 2020. There was a phase-in period from October 1, 2019 to January 1, 2020 in which buildings could be submitted under either code. The BCD also committed to adopting future ASHRAE 90.1 codes soon after they are published. The adoption process will start within 12 months of the 90.1 publication date, subject to COMcheck availability.

The clear advantages of this approach are that it provides predictability and ready-made compliance tools with COM*check*™ and 90.1 User Manuals. In addition, being an early adopter of 90.1 will keep the state abreast or ahead of the International Energy Conservation Code (IECC) energy code. Adding the Zero Code Calculator into the code process may facilitate future movement down the path toward net zero buildings.

State Alternate Method 19-01 was adopted in October 2019; it creates a parallel compliance path utilizing the 2018 IECC. This alternate method code is missing the 90.1 interior lighting control and receptacle control improvements. This alternate method is intended to remain available until the 90.1-2019 code is adopted.

The primary difference between the OEESC 2014 and OCEC 2019 codes is one of detail and scale. OEESC 2014 is concise, while OCEC 2019 is specific and detailed. OCEC 2019 updates lighting and envelope efficiency requirements, includes more HVAC control requirements,

[3] COMcheck is a software used to determine whether new commercial or high rise residential buildings, additions and alterations meet the requirements of ASHRAE standard 90.1. More details can be found at https://www.energycodes.gov/comcheck

and significantly expands the building systems that are regulated (e.g., refrigeration, plug loads, metering). It also addresses more special cases and exceptions in the requirement language, thus leaving less room for uncertainty in code requirements.

This work estimates two metrics. The first is a code-to-code estimate, which compares the codes directly; the change in energy use is referred to in this report as the code-to-code estimate or savings. The second estimate is referred to in this report as current practice estimate or current practice savings. Energy codes follow practice, extending best practices and in some cases standard practices to all buildings. The current practice savings are adjusted for actual building conditions in an attempt to better capture the actual impacts of the codes and market forces by fuel type.

Savings are projected to new building floor area forecast by the Northwest Power Planning Council for completion starting in 2021, one year after the code effective date. Savings are not quantified for changes to existing buildings. While doing so might involve large additional savings, it would also involve significant interactions with utility programs and issues related to enforcement and code applicability.

The savings estimates associated with this work come with some limitation and uncertainty. Only the primary code provisions are evaluated. Many other code provisions are not quantified, mostly due to expected small overall savings, or occasionally to uncertainty about current practice and application. Adding this to remodeling activity means that significant additional savings occur but are not quantified. As such, this work forms a conservative estimate of improvement in energy efficiency as a result of the code and market changes.

Previous Northwest Energy Efficiency Alliance (NEEA) reports evaluated energy savings associated with regional non-residential code changes made between 1996 and 2015 (Kennedy, 2005-2018).[4] This work relies heavily upon the methods used in this earlier work and upon work by Pacific Northwest National Laboratory (PNNL) (Thorton et al. 2011, PNNL 2014a, PNNL 2014b, PNNL 2017).

[4] Residential code energy savings for the same period were estimated by the Northwest Power & Conservation Council.

# 2. Methodology and Data Sources

The analysis method used in this report estimates the incremental energy savings from the recently-adopted code by comparing to previous code. This method has been used by the Northwest Energy Efficiency Alliance (NEEA) and the Northwest Power and Conservation Council (NPCC) for more than 20 years to estimate regional energy savings potential from improvements to new and existing buildings.

The process utilizes a hybrid simulation and engineering calculation approach with baseline characteristics derived from regional building characteristic data as follows:

- Estimate the maximum heat loss rate (UA/ft$^2$), and cooling efficiency performance requirements for the base code (e.g., OEESC 2014) and the newly adopted code (e.g., OCEC 2019). This is primarily done about applying the code to each building in a sample of recently-constructed buildings to utilize real building traits to weight the occurrence of space, construction, and equipment types. The current evaluation utilized primary data sets that included 350 commercial buildings (NEEA 2004 NC discussed in Section 2.1) and 23 mid- and high-rise residential buildings (RBSA 2014).
- Estimate of lighting power density (LPD) for each building type by applying code allowances to each space type assumed by ASHRAE/IES space type.
- Determine the current practice condition. For LPD, UA/ft$^2$, and other traits that apply to every building, it is a deration for the fact that buildings have always been better than code since the first evaluation. The starting LPD is better than code minimum, the percent change in code value is applied to that LPD, so the final LPD is better than code and the change is slightly reduced. For certain discrete provisions such as the minimum skylight provision, the fraction of floor area that already has skylights is determined from available data and removed from the savings pool.
- Estimate energy savings for the code-to-code changes and the current practice changes in representative prototype buildings by climate zone using EnergyPlus 8.9 building energy simulation software and, where needed, engineering calculations.
- Measures with broad applicability and generally positive savings were modeled both individually and as a package. Individual savings were then adjusted uniformly so the sum of individual savings matched the package. Additional measures were simulated incrementally from the final package.
- Measures not modeled were determined using engineering calculations typically based on model predictions of end-use consumption. This evaluation has no example of this step.
- Engineering calculations adjust savings for other heating fuel types and, where warranted, for applicability and current saturation.
- The savings results were normalized per unit floor area and were combined with the expected new construction/addition floor area forecast from the Northwest

Power and Conservation Council (NPCC) Seventh Power Plan[5] to provide a weighted savings for each building prototype and a weighted result for all commercial buildings.

## 2.1. Primary Data Sources

Primary sources of building data used in this project are listed in this section. These data were used to establish typical building traits such as HVAC system type and heating fuel, building envelope proportions and construction types, and many other traits. Three of the data sources were regional studies and contain data for buildings in Idaho, Montana, Oregon, and Washington. In general, these studies do not contain adequate sample within each state to characterize individual building types. For these data sets the regional averages were used to represent Oregon on the presumption that issues related to variation between states were less significant than the gains in statistical significance when looking at individual building types.

### 2.1.1. NEEA Baseline Characteristics of the 2002-2004 Non-Residential Sector (NEEA 2004 NC)

The primary characteristics data used in this work are derived from data collected as part of the NEEA Baseline Characteristics of the 2002-2004 Non-Residential Sector (NEEA 2004 NC) study (Baylon and Kennedy, 2008).[6] The data set include data on 350 buildings constructed between 2002 and 2004 in Washington, Oregon, Idaho, and Montana. These data were used to determine space and water heating fuel saturations, HVAC system and equipment types and associated minimum code performance, and building envelope characteristics and geometry. This data set is referred to as the NEEA 2004 NC data.

### 2.1.2. 2019 Oregon New Commercial Construction Code Evaluation Study (OCCE)

The 2019 Oregon New Commercial Construction Code Evaluation study (Larson et al. 2019)[7] examined 46 office, multifamily, retail, and school buildings in Oregon with construction starts between 2013 and 2016. The study was primarily intended as a check of assumptions based on the previous NEEA 2004 NC and Residential Building Stock Assessment (RBSA 2014) data. This data set is referred to as the OCCE data; Appendix D provides more detail on this study.

### 2.1.3. Commercial Building Stock Assessment (CBSA) 2014

The 2014 Commercial Building Stock Assessment (Navigant Consulting 2014) data are used as auxiliary characteristics data, filling in where the NEEA 2004 NC data are missing or incomplete. The new cohort in the 2014 CBSA is slightly newer than the NEEA 2004 NC data (2004–2012 vs. 2003–2005 completion years); however, it has a few shortcomings

[5] Supporting data file 7P Forecasts D2.xlsx from: Seventh Northwest Electric Power and Conservation Plan, Northwest Power and Conservation Council, 2016. Currently can be found under Conservation Supply Curve Workbooks, crosscutting at: https://www.nwcouncil.org/reports/technical-information-and-data

[6] http://www.nwalliance.org/resources/reportdetail.asp?RID=134

[7] https://neea.org/resources/2019-oregon-new-commercial-construction-code-evaluation-study

that negate some of this value. It spans three code cycles, which makes interpreting the data difficult, and is based primarily on site visits. The NEEA 2004 NC data made heavy use of plans and building O&M manuals in addition to site visits. Because extracting data from the NEEA 2004 NC data was easier, it was chosen as the primary data set and CBSA 2014 as the secondary data set.

### 2.1.4. NEEA Residential Building Stock Assessment (RBSA 2011) Characteristics

The primary characteristics data used for the mid- and high-rise multifamily buildings work are derived from data collected as part of the NEEA Residential Building Stock Assessment (RBSA), which surveyed existing multifamily building characteristics (Baylon et al., 2013). A total of 79 mid-rise and high-rise multifamily buildings were surveyed, of which 23 were built between 2001 and 2012. Table 5 presents a break down of the sampled buildings. The RBSA sample was not segmented to isolate new mid-rise and high-rise buildings and the resulting sample has a large uncertainty when looking at these building types in isolation. Most notable is that while the overall multifamily sample is a regional sample, most all of the mid-rise and high-rise occur in Seattle.

Despite concerns about the small number of new mid-rise and high-rise buildings in the sample, these data were used to determine building and unit code maximum lighting power densities (LPD), and building envelope characteristics, geometry, and code minimum performance. The data were also considered in selecting the HVAC system and fuel type and the service hot water heating fuel types. The study buildings were built to the standards current during the construction year. The forms of the buildings (e.g., the distribution of lighting space types) built in the 2001–2012 period were considered typical of new buildings. For each code, the codes were applied to each of the buildings to determine code allowances and the average values used as inputs in the simulation models.

**Table 5. RBSA Multifamily Building Sample**

| | 2001–2007 | 2008–2012 | Total |
|---|---|---|---|
| **Audited Buildings (count)** | | | |
| High-rise | 5 | 5 | 10 |
| Mid-rise | 7 | 6 | 13 |
| Total | 12 | 11 | 23 |
| **Sector Building Distribution (%)** | | | |
| High-rise | 5.49 | 21.34 | 26.82 |
| Mid-rise | 6.95 | 56.22 | 73.18 |
| Total | 2.44 | 77.56 | 100.00 |
| **Sector Floor Area Distribution (%)** | | | |
| High-rise | 0.68 | 41.21 | 51.89 |
| Mid-rise | 6.48 | 31.64 | 48.11 |
| Total | 7.15 | 72.85 | 100.00 |

Mid-rise and high-rise multifamily buildings are characterized by RBSA as being comprised of unit areas, common areas, and commercial non-residential floor area. The commercial non-residential floor area found in residential buildings is typically retail and other commercial occupancies located on the first floor of the building. The current evaluation is limited to the residential dwelling unit areas and the common areas serving the dwelling unit areas. Commercial floor area found in RBSA, and code energy savings associated with it, are covered by the NPCC commercial floor area forecast and the energy code savings determined in previous evaluations of commercial buildings; they are therefore not addressed here. This data set is referred to as RBSA 2014.

### 2.1.5. NPCC Seventh Plan and Floor Area Forecast

The Northwest Power and Conservation Council (NPCC) Seventh Power Plan developed a regional state-by-state floor area forecast for a range of building types. This data set forms the basis of all floor area estimates used in weighting between states and building types.

### 2.1.6. Bonneville Power Administration (BPA) Future Codes Analysis

Building population distribution among climate zones within the state uses work conducted by Bonneville Power Administration (BPA) (Kennedy 2012) to map the distribution of new commercial buildings to these zones based on Dodge construction data from 2002–2008. The available data set did not include mid-rise and high-rise residential buildings and climate zone distribution was not available. The NPCC forecast assumes 18% of multifamily units are in mid-rise and high-rise buildings. A weighted average of the weights used for all other building types was used for multifamily buildings, which may overweight the proportion of mid-rise and high-rise multifamily buildings assigned to the 5B climate zone (described in the following section).

## 2.2. OCEC 2019 Code Changes

The base code for this evaluation is the 2014 Oregon Energy Efficiency Specialty Code (OEESC 2014) and the newly adopted code is the 2019 Oregon Commercial Energy Code (OCEC 2019). This evaluation compares changes in the code prescriptive paths only. No attempt is made to compare performance paths or to evaluate the alternative 2018 International Energy Conservation Code (IECC 2018).

Given the much greater level of detail in the OCEC 2019 code and the very different origins of the code language, the differences between the two codes are substantial. Virtually every requirement in the 2019 code has some element (requirement, threshold, or exception) that is changed. Table 6 presents the evaluated measures in this study; Table 7 identifies some of major provisions not evaluated. However, many more provisions are not evaluated, and an in-depth listing of code differences can be found in Appendix B.

The OCEC 2019 addresses two Oregon climate zones, 4C and 5B. Envelope provisions constitute the primary differences between the two zones, though a couple mechanical provisions also change. This study evaluates the envelope of each climate zone independently.

**Table 6. Evaluated Code Changes**

| OCEC 2019 Section | Code Provisions |
|---|---|
| 5.1.2 & Tables 5.5-4 & 5.5-5 | Semi-heated threshold and requirements, envelope maximum conductance, maximum WWR increase, SHGC decrease |
| 5.5.4.2.3 | Minimum skylight area |
| OEESC 2014 503.4.6 | Elimination of air-cooled chiller capacity limit |
| 6.5.3.2.1 | Air flow control hydronic fan coils– two speed fans |
| 6.4.3.8 | Increased applicability of DCV exception |
| 6.5.1.1.3 | Economizer high limit |
| 6.5.3.3 | VAV optimization |
| 6.5.7.2 | New kitchen DCV hood exception |
| 7.5.3 | High input hot water |
| 8.4.2 | Receptacle OS control |
| 9.4.4, 9.5, 9.6 | Interior lighting power |
| 9.4.2 | Exterior lighting power |
| 9.4.1.1, 9.4.1.3 | Interior lighting control |
| 9.4.1.2, 9.4.1.4 | Exterior and parking garage light control |

*Notes:* WWR = window-wall ratio; SHGC = solar heat gain coefficient of fenestration

**Table 7. Key Provisions Not Evaluated**

| OCEC 2019 Section | Code Provisions | Reason |
|---|---|---|
| 6.4.5, 6.4.6, 6.5.11 | Refrigeration changes | Grocery prototype is not adequate; most of code changes are an echo of US Department of Energy (DOE) standards which NEEA is claiming separately. |
| 6.5.3.2.1 | Air flow control DX – two speed fans | Savings for DOE IEER standards claimed by NEEA separately.* |
| 6.7.2.3, 6.7.2.4, 9.4.3 | Commissioning | High uncertainty of savings. |
| 8.4.3, 10.4.5 | Metering | |
| 6.5.6.1 | Energy recovery for 8000+ hour systems | Hospital prototype not set up to handle provision. |
| 10.4.1 | New electric motor efficiency tables | Savings for electric motor efficiency claimed by NEEA separately. * |
| 6.8.1 | Small boiler, packaged terminal heat pumps (PTHP) | Small boilers and PTHP savings were accounted in OCEC 2014 analysis prior to NEEA's involvement. * |
| 6.8.1 | Separated vertical package equipment, room AC, pool dehumidifier, computer room AC, and DX-DOAS efficiency | Equipment efficiency not evaluated since savings for those standards claimed by NEEA separately.* |

*Refer to Section 2.3.4 Federal Appliance and Equipment Standards for details.

## 2.3. Savings Estimation

Energy savings from code provisions are estimated using building energy simulation supplemented with engineering calculations. Savings estimates are made on a unit area basis for each building type and climate combination. Total state and regional savings estimates combine the unit area savings estimate with the new construction/addition floor area forecasts from the Northwest Power and Conservation Council (NPCC) Seventh Power Plan.[8]

Prototype building descriptions were modeled to determine savings. For code-to-code estimates, OEESC 2014 and OCEC 2019 models were run in the two climates. For the current practice estimates, individual simulations were completed for incremental changes in the primary performance variables (e.g., lighting LPD, equipment efficiency, and envelope component efficiency) and for the other evaluated code provisions. The results from the various runs are post-processed to achieve final savings estimates.

This section provides a generalized discussion of the savings calculations. Details on the evaluated measures and individual savings calculations can be found in Appendix A and in the calculation spreadsheets.

### 2.3.1. Prototype Buildings and Simulations

Simulations were conducted using EnergyPlus V8.9, a building energy simulation program developed by the US DOE. The prototype building descriptions are derived from the BPA new vintage existing building models (Navigant 2016). The BPA models are based on the DOE reference buildings with several modifications to make them more applicable to NW buildings. The BPA descriptions are implemented in the Params framework developed by Big Ladder Software.[9] This framework assembles building descriptions dynamically from templates based on predefined parameters.

Part of an evaluation of the 2015 Washington State Energy Code (WSEC) (Kennedy, 2018) consisted of a major effort to upgrade the BPA templates and inputs to better represent new construction, allow dynamic changes to windows and skylight fractions, and to streamline several aspects of the HVAC specification. Some elements of this work are discussed in Appendix C of this report.

This evaluation was conducted under the notable constraint that the prototypes utilize HVAC systems typical 10–15 years ago, prior to substantial changes in the marketplace. Regional data sources are generally lacking for the recent time period. While variable refrigerant flow (VRF) and chilled beam systems were not present during the NEEA 2004 NC study, they are clearly present now; anecdotally, interest in water source heat pumps seems to be growing. For medium office, retail, schools and multifamily buildings, the OCCE

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[8] Supporting data files : Seventh Northwest Electric Power and Conservation Plan, Northwest Power and Conservation Council, available at https://www.nwcouncil.org/reports/seventh-power-plan.

[9] https://bigladdersoftware.com/projects/params/

data set provides newer data for a small sample of projects; however, the system type trends are not clear, as discussed in Appendix D. Because this evaluation utilizes engineering adjustments to provide estimates for all fuel types, the primary impact of different systems and fuel selection is captured to the extent that the new systems are replacing systems with similar fuel types (e.g., VRF in place of air source heat pump).

As discussed in Appendix D, the fuel saturations used are updated for multifamily space and water heat and large office water heat. The modeled HVAC system types remain the same except for the residential properties, which are modeled with package terminal heat pumps (PTHP), a poor-performing heat pump with some units lacking defrost capabilities. Table 7 of the OCCE study indicates that 48% of multifamily floor area is heated by zonal electric resistance, 38% by VRF, WSHP, and DHP, and 15% by PTHP. PTHP was chosen as representing the middle ground between electric resistance and a good heat pump. Table 8 lists the modeled prototype buildings and the selected HVAC system types.

The prototype base characteristics for LPD, window-to-wall ratio, envelope heat loss, and equipment efficiency for each prototype were updated for the evaluated codes. The prototype LPD and heat loss rate are scaled so that the modeled building traits are the same as the average found by the code change increment process described in the next section.

For the code-to-code estimates individual simulations were conducted for the OEESC 2014 and OCEC 2019 codes. For the current practice estimates the code provisions are modeled individually or, in the case of the envelope, as a group. This allows the attribution of savings to individual provisions and also allows applicability and current practice adjustments. The major generally-applicable measures (e.g., lighting, envelope, motor control) are modeled first individually and then as a group. The group run is used to adjust the individual runs for interactive effects. Subsequent measures are modeled incrementally.

**Table 8. Prototype Descriptions**

| Building Type | Baseline System/Fuel* |
|---|---|
| Mid-Rise Residential | PNNL 90.1 determination-derived model with packaged terminal heat pump in the dwelling units and single-zone package AC/gas furnace in the common area |
| High-Rise Residential | Same geometry as the mid-rise model but with 8 floors rather than 10 floors. Dwelling unit HVAC is packaged terminal heat pump and common areas have single-zone package AC/furnace. |
| Office – Large | VAV with series fan-powered terminals on perimeter and pinch boxes in the core with electric resistance reheat. |
| Office – Medium | Package single-zone AC/gas furnace |
| Office – Small | Package single-zone AC/gas furnace |
| Retail – Large | Package single-zone AC/gas furnace |
| Retail – Small | Package single-zone AC/gas furnace |
| School – Secondary | Single zone air handlers with hydronic heating and cooling |
| School – Primary | VAV with pinch boxes and electric hydronic reheat in classrooms. Single-zone air handlers with hydronic heating and cooling for common areas. |
| Warehouse | Package single-zone AC, gas furnace in office. Gas fired unit heaters in storage |
| Hospital | CAV and VAV with pinch terminals. Gas boiler, hot water reheats. |
| Residential Care | Sleeping unit HVAC is packaged terminal AC with electric resistance heat and common areas have single-zone package AC/furnace. |
| Restaurant – Sit Down | Package single-zone AC, gas furnace in dining. Gas fired make-up air units for kitchen. |
| Restaurant – Fast Food | Package single-zone AC, gas furnace in dining. Gas fire make-up air units for kitchen. |
| Lodging – Hotel | Common areas: single-zone air handlers; rooms: four pipe fan coils |
| Lodging – Motel | Common areas: package single-zone AC, gas furnace; rooms: PTHP |

* This is the modeled fuel type. Conversion of results to other heating fuel types is done as part of the engineering calculations to capture first order effects of other fuels.

The weather files used in this work are shown in Table 9. Boise, ID was selected to represent the Oregon 5B climate zone because previous regional and national commercial code savings evaluations have utilized Boise, ID to represent zone 5B. It is both similar to and geographically close to eastern Oregon zone 5B.

**Table 9. TMY3 Weather Data**

| State | Climate Zone | Weather Station | Heating Degree Days | Cooling Degree Days |
|---|---|---|---|---|
| Oregon | Zone 4C | Portland, OR | 4230 | 446 |
| Oregon | Zone 5B | Boise, ID | 5416 | 1008 |

### 2.3.2. Determining Model Inputs

This study relied heavily on characteristics from the actual NW building stock to determine OSEEC 2014 and OCEC 2019 inputs.

The code envelope heat loss, window area, and cooling efficiency for each code were estimated by applying the codes to the construction types and areas, and equipment types found in each building of the NEEA 2004 NC commercial building and RBSA new mid-rise and high-rise data sets. The resulting estimated building characteristics (e.g., envelope heat loss, cooling efficiency) are averaged by building type for each code.

The code interior lighting power allowance for each prototype was calculated as the weighted average of the code space-by-space allowances using weights taken from the ASHRAE/IES building area allowance calculations.

The prototype characteristics are then scaled so the model average matches the average characteristic determined, either code-to-code or current practice. Using the average for many buildings implicitly weights the various lighting area types, envelope component types, and equipment sizes so that the efficiency increase (or decrease) represents the sector response rather than that found for just the few situations represented in the models.

The minimum skylight provision is a unique case. For the code-to-code estimate, the number of spaces to model with skylights was based on the percentage of floor area in the 2005 NEEA 2004 NC buildings that would be required to have skylights. The current practice estimate was also adjusted for the current saturation of skylights in buildings. Skylights with top daylight harvest controls predate the code requirements by a decade or more in many building types. The current practice estimate was based on the assumption that code requirements to have skylights do not save energy for the fraction of floor area found to have skylights in the NEEA 2004 NC data.

For other code provisions, exterior lighting, power lighting, lighting and equipment control measure increments, inputs were derived utilizing inputs from the national 90.1 determinations (Thorton et al. 2011, PNNL2014a, PNNL 2014b, PNNL 2017). The code-to-code and current practice inputs were the same for these provisions.

Provision-by-provision details are presented in Appendix A.

### 2.3.3. LPD & UA/ft$^2$ Current Practice Adjustments

The code-to-code increment produces an estimate of the upper bound of possible savings. Every field study of Northwest buildings in which building and code data are collected has found that average new building characteristics exceed the average code requirements. For example, in the NEEA 2004 NC data, the average office building LPD is 1.03 W/ft$^2$, 18% lower than the 1.257 W/ft$^2$ average code-allowed LPD for those buildings at the time of construction. Using the arithmetic code-to-code change takes credit for saving the lighting power between the base code maximum power and actual installed power.

To account for this and ensure estimates are conservative, current practice adjustments are made to reduce savings where current practice typically exceeds code in the base code (OEESC 2014). For maximum LPD and envelope thermal performance, this adjustment is made to the model input values. A percent reduction is applied to both the base code (OEESC 2014) and new code (OCEC 2019) input assumptions. The primary impact is that the difference between the base and new code inputs modeled is reduced as are the resulting savings.

In previous NEEA commercial code savings studies, the adjustment was based upon the average LPD and code allowances at time of construction for the buildings in the NEEA 2004 NC data. Due to some concern about the reliability of the NEEA 2004 NC code allowance and a desire to move away from the NEEA 2004 NC data it was decided to use fixed percentages across all building types. A 5% adjustment was applied to code envelope UA/ft$^2$ and 10% adjustment was applied to code LPD. These values are conservative estimates based on the 2004 NEEA NC Data. The 10% lighting adjustment is smaller than the 15% average adjustment based upon the 2004 NEEA NC data. The envelope value is fairly close to the average for envelope found in the 2004 NEEA NC data.

A more complete discussion of the code-to-code versus current practice adjustment can be found in the 2011 NEEA Energy Code Evaluation (Kennedy, 2011, Appendix E) along with the implied after-code LPD for the NEEA New Construction Survey buildings for each scenario and code.

#### 2.3.4. Federal Appliance and Equipment Standards

Previous NEEA energy code savings evaluations made no attempt to separate energy savings due to regional energy codes from those due to federally covered appliance and equipment energy efficiency standards (hereafter referred to as DOE standards). Savings for items in the energy code were counted as savings even if they occurred as part of DOE standards.

Starting in 2015, NEEA has worked to influence DOE standards in addition to regional codes and is evaluating savings for DOE standards separately from codes. This necessitates excluding savings from recent DOE standards which have been incorporated into energy codes. DOE standards regulate efficiency in most classes of HVAC and hot water heating equipment as well as electric motor efficiency, lighting, and refrigeration equipment. This overlap can be direct in that energy codes regulated the efficiency in the same way as DOE standards ( i.e. HVAC equipment rated efficiency). It can also be indirect with codes regulating one aspect and standards another (i.e. lighting efficacy vs lighting power density and unitary DX IEER vs two-speed fan). Where code changes resulted from DOE standards being included in code the inputs for the OEESC 2014 models were set to reflect the current DOE standard so no savings would accrue that were also included in standards evaluations.

This was more difficult in cases where codes and standards regulate the same item but in different ways. The details are presented in the code provision input discussions in Appendix A.

#### 2.3.5. Savings Calculation Spreadsheets

All savings calculations are processed through spreadsheets that combine simulation results, end use fuel saturations, current practice adjustments, and new construction floor area estimates to produce energy use estimates. Within each climate workbook are worksheets with OEESC 2014 and OCEC 2019 code-to-code results as well a current practice worksheet.

The calculation worksheets calculate electric, gas, and heat pump space heating and water heating from the modeled system consumption using simplified conversion factors and heating fuel saturation factors determined from the NEEA 2004 NC and OCCE data. This method provides better estimates of changes in electric vs. gas without the need to model each fuel type.

The current practice worksheets make additional applicability and saturation adjustments. There is a current practice worksheet for each evaluated code provision. The simulation results for each measure are normalized by floor area or sometimes by other factors. Normalized savings are estimated for the two non-modeled fuels. These results are then combined with an applicability factor reducing savings based on the estimated applicability of the code language to the given building type, heating fuel, system type, or other factor. A current saturation factor further reduces savings for measures with extensive saturation prior to code adoption (e.g., minimum skylight in retail). Total saturation is the assumed end result. All applicable buildings that lack a particular required technology are assumed to have installed it. The applicability and saturation factors are determined from field data and study results where possible.

The current practice estimates are rolled up into an overall current practice savings estimate by building type. To arrive at sector savings, the normalized energy use and savings estimates for each worksheet are combined with the applicable floor area for the given region and building type.

#### 2.3.6. Overall Sector Energy Use and Performance

For the code-to-code runs and for each code provision analyzed, the simulation and engineering calculations produced estimates of energy use and savings per square foot by building type and state. The normalized savings were weighted by the new construction square footage in each climate zone to develop statewide averages. The overall state floor area by building type is taken from the Northwest Power Planning Council's medium growth scenario. The Council's forecast provides square footage estimates for each year through 2035. OCEC 2019 went into effect on January 1, 2020 and buildings built to that codes will be completed and start accruing savings in 2021. The average projected annual floor area for 2021–2030 is used to weight code-to-code and current practice energy savings estimates. Weighting within the state between the two climate zones is done using an analysis of the distribution of new construction based on data developed by BPA for the years 2002–2008 (Kennedy 2012).

Sector energy use and percent savings are directly estimated from the simulation results for the code-to-code estimates. For the current practice estimates, relative savings are calculated using the current practice savings estimate and the base energy use index (EUI) that was developed separately. There is no OCEC 2019 current-practice estimate.

This process does not account for non-modeled energy use, in particular, energy use resulting from poor operation and scheduling, items that would lead to commissioning and metering savings.

Overall OCEC 2019 savings are presented by several metrics: site Btu, source Btu, carbon dioxide, and energy cost. Key assumptions are shown in Table 10.

**Table 10. Carbon and Cost Factors**

| Quantity | Assumption | Source |
|---|---|---|
| Source Btu – electrical | 10.07 kBtu/kWh | PNNL 90.1-2016 Determination |
| Source Btu – gas | 1.088 kBtu/kBtu | PNNL 90.1-2016 Determination |
| Carbon – Gas | 117 lbs/ mmBtu | Environmental Protection Agency (EPA) |
| Carbon – Electricity NPCC | 0.97 lbs/kWh | NPCC 2031 Marginal Carbon |
| Carbon – Electricity Oregon | 0.97 lbs/kWh | NPCC 2031 Marginal Carbon |
| Energy Cost – Oregon Gas | 0.861 $/therm | US Energy Information Administration (EIA) Natural Gas Monthly (July 2019) |
| Energy Cost – Oregon Electricity | 0.0872 $/kWh | EIA Electric Power Monthly (Jan & Aug 2019) |

# 3. Results

Table 11 presents the energy use indices (EUIs) by prototype and by code edition. The results are the average of the two Oregon climate zones 4C and 5B based on the weighting factors discussed in Section 2.3.7. The values represent regulated and unregulated energy use within the building types assuming properly operating controls and schedules. Gas energy represents all fuel energy sources (e.g., natural gas, propane, and oil).

Table 12 presents the percentage changes between the two codes. Based on the analyzed provisions, the OCEC 2019 reduces total site energy use 9.0%, source energy use 10.8%, electric use 12.3%, and gas use 1.2% from the OEESC 2014. The relatively small decrease in gas use results from the decreases in interior lighting and plug load equipment energy use, which increase heating loads and offset most of the gas efficiency improvements made by the code. Relative savings are lower in Apartment and in the high Energy Use Intensity building types of Hospital, Residential Care, and Restaurant.

These code-to-code savings are larger than the DOE Standard 90.1-2016 Determination (PNNL 2017) which found zone 4C savings of 5.9%, 8.8%, and -0.4% for site energy use, electricity, and gas respectively compared to Standard 90.1-2013. This is to be expected as the OEESC 2014 code is less stringent than 90.1-2013 in a number of areas that contribute significant additional savings including interior and exterior lighting controls, plug load controls, and minimum skylight area requirements.

**Table 11. Prototype Annual Energy Use Indices**

| Building Type | OEESC 2014 | | | | OCEC 2019 | | | |
|---|---|---|---|---|---|---|---|---|
| | Site Energy (kBtu/sf) | Source Energy (kBtu/sf) | Electric (kWh/sf) | Gas (therm/sf) | Site Energy (kBtu/sf) | Source Energy (kBtu/sf) | Electric (kWh/sf) | Gas (therm/sf) |
| Apartment Midrise | 48.9 | 117.3 | 10.1 | 0.144 | 45.7 | 108.2 | 9.2 | 0.143 |
| Apartment Highrise | 43.2 | 103.3 | 8.9 | 0.129 | 39.8 | 94.0 | 8.0 | 0.126 |
| Hospital | 156.9 | 347.2 | 27.8 | 0.621 | 152.9 | 341.0 | 27.5 | 0.591 |
| Lodging - Hotel | 78.8 | 174.6 | 14.0 | 0.310 | 73.5 | 163.5 | 13.2 | 0.286 |
| Lodging - Motel | 55.9 | 117.7 | 9.0 | 0.253 | 51.2 | 107.7 | 8.2 | 0.233 |
| Office - Large | 54.3 | 156.7 | 15.4 | 0.019 | 48.8 | 140.4 | 13.7 | 0.019 |
| Office - Medium | 38.0 | 108.5 | 10.6 | 0.019 | 31.9 | 90.6 | 8.8 | 0.019 |
| Office - Small | 31.1 | 83.7 | 7.8 | 0.044 | 27.1 | 73.1 | 6.9 | 0.037 |
| Residential Care | 64.6 | 127.0 | 8.9 | 0.341 | 63.8 | 126.6 | 9.0 | 0.330 |
| Restaurant - Full Serve | 349.6 | 611.4 | 36.4 | 2.255 | 343.9 | 596.9 | 35.1 | 2.242 |
| Restaurant - Fast Food | 499.3 | 839.1 | 46.6 | 3.405 | 493.2 | 825.0 | 45.4 | 3.383 |
| Retail - Large | 56.1 | 125.3 | 10.1 | 0.216 | 50.6 | 110.1 | 8.7 | 0.210 |
| Retail - Small | 54.7 | 125.9 | 10.4 | 0.191 | 47.8 | 108.0 | 8.8 | 0.177 |
| School - Primary | 50.2 | 118.5 | 10.1 | 0.158 | 44.4 | 99.9 | 8.1 | 0.167 |
| School - Secondary | 35.8 | 88.9 | 7.9 | 0.089 | 33.0 | 78.5 | 6.7 | 0.101 |
| Warehouse | 19.2 | 45.4 | 3.9 | 0.060 | 15.9 | 34.5 | 2.7 | 0.067 |
| **Avg All Models** | **48.9** | **116.9** | **10.0** | **0.147** | **44.5** | **104.3** | **8.8** | **0.145** |

**Table 12. Prototype Energy Use Change (Code-to-Code)**

| Building Type | Energy Savings (%) | | | |
|---|---|---|---|---|
| | Site Energy | Source Energy | Electric | Gas |
| Apartment Midrise | 6.4% | 7.7% | 8.8% | 0.7% |
| Apartment Highrise | 7.8% | 9.0% | 10.1% | 2.3% |
| Hospital | 2.6% | 1.8% | 1.0% | 4.9% |
| Lodging – Hotel | 6.7% | 6.4% | 6.0% | 7.8% |
| Lodging – Motel | 8.3% | 8.6% | 8.8% | 7.7% |
| Office – Large | 10.1% | 10.4% | 10.6% | -1.1% |
| Office – Medium | 16.0% | 16.4% | 16.7% | 1.3% |
| Office – Small | 12.9% | 12.7% | 12.5% | 15.5% |
| Residential Care | 1.2% | 0.3% | -0.9% | 3.2% |
| Restaurant - Full Serve | 1.6% | 2.4% | 3.6% | 0.6% |
| Restaurant - Fast Food | 1.2% | 1.7% | 2.5% | 0.6% |
| Retail – Large | 9.8% | 12.1% | 14.3% | 2.6% |
| Retail – Small | 12.7% | 14.2% | 15.6% | 7.4% |
| School – Primary | 11.5% | 15.8% | 19.4% | -5.7% |
| School – Secondary | 7.7% | 11.7% | 14.8% | -13.8% |
| Warehouse | 17.1% | 24.1% | 30.1% | -11.5% |
| **Avg All Models** | **9.0%** | **10.8%** | **12.3%** | **1.2%** |

Table 13 presents the average annual current-practice energy savings for all evaluated code changes in the 2019 Oregon code. The current practice results reflect adjustments for current practice and are used by NEEA in setting actual code energy savings. Floor area normalized savings acquired each year are 0.99 kWh/ft$^2$-yr of electricity and 0.003 therm/ft$^2$-yr of gas. Forecast statewide annual electricity savings combining the normalized savings with forecast annual floor area additions in the state are 2.05 average megawatts and 5,750 MMBtu of gas and other combustion fuels. Table 14 presents the current-practice percent savings which are similar to the code-to-code savings in Table 12 with the exception that the gas savings are positive rather than negative. This difference highlights how sensitive gas savings are to the balance of measures directly decreasing space heating needs with those with interactions that increase space heating (e.g. lighting). The resulting number is extremely sensitive to small changes. In this case, differences in the applicability of measures in the current practice runs result in smaller interactive effects and results in small net savings rate.

**Table 13. Annual Energy Savings by Building Type (Current Practice)**

| | Floor Area Normalized Savings | | | | | | Forecast Sector Savings | |
|---|---|---|---|---|---|---|---|---|
| **Building Type** | **Site Energy kBtu/sf** | **Source Energy kBtu/sf** | **Electric kWh/sf** | **Gas therms/sf** | **Carbon lbs/sf** | **Energy Cost $/sf** | **Electric aMW** | **Gas MMBtu** |
| Assembly | 3.75 | 10.41 | 1.00 | 0.004 | 1.01 | 0.090 | 0.15 | 478 |
| Hospital | 3.10 | 4.81 | 0.23 | 0.023 | 0.49 | 0.040 | 0.01 | 510 |
| K-12 | 4.12 | 12.35 | 1.24 | -0.001 | 1.19 | 0.107 | 0.13 | -100 |
| Lodging | 3.36 | 8.12 | 0.70 | 0.010 | 0.79 | 0.070 | 0.03 | 303 |
| Multifamily | 3.11 | 8.87 | 0.86 | 0.002 | 0.86 | 0.077 | 0.16 | 260 |
| Office – Large | 3.64 | 10.81 | 1.08 | 0.000 | 1.04 | 0.094 | 0.20 | -75 |
| Office – Medium | 4.35 | 12.76 | 1.26 | 0.000 | 1.23 | 0.111 | 0.22 | 49 |
| Office – Small | 3.76 | 9.85 | 0.91 | 0.007 | 0.96 | 0.085 | 0.04 | 290 |
| Other | 3.75 | 10.41 | 1.00 | 0.004 | 1.01 | 0.090 | 0.58 | 1799 |
| Other Health | 1.38 | 2.35 | 0.13 | 0.009 | 0.24 | 0.020 | 0.02 | 908 |
| Restaurant | 4.07 | 11.57 | 1.12 | 0.002 | 1.12 | 0.100 | 0.02 | 37 |
| Retail Big Box/Anchor | 5.09 | 13.62 | 1.27 | 0.007 | 1.32 | 0.117 | 0.09 | 475 |
| Retail Small/High End | 6.31 | 15.99 | 1.44 | 0.014 | 1.56 | 0.137 | 0.13 | 1142 |
| University | 3.66 | 10.51 | 1.03 | 0.002 | 1.01 | 0.091 | 0.01 | 15 |
| Warehouse | 3.25 | 9.85 | 0.99 | -0.001 | 0.95 | 0.085 | 0.26 | -341 |
| **Total** | **3.71** | **10.35** | **0.99** | **0.003** | **1.00** | **0.089** | **2.05** | **5750** |

**Table 14. Percent Savings – OCEC 2019 (Current Practice)**

| Energy Use | | | | Carbon | Energy Cost |
|---|---|---|---|---|---|
| **Site Energy** | **Source Energy** | **Electric** | **Gas** | **NPCC** | **Oregon Avg** |
| 7.8% | 9.2% | 10.4% | 2.1% | 9.1% | 9.3% |

Figure 1 through Figure 4 present the relative proportions of current practice savings attributable to various code sections. Electric, site Btu, and energy cost savings are dominated by interior and exterior lighting power (allowance and controls) and receptacle controls. Figure 2 only shows the provisions contributing to positive gas savings which are dominated by the envelope savings. The interactive increased gas use resulting from the interior lighting and equipment provisions is not shown.

Table 15 presents the detailed breakout of the average annual current practice savings for the OCEC 2019 by code provision. The negative gas savings associated with interior lighting and receptacles is clear. The air-cooled chiller limit elimination item is an OEESC 2014 requirement that is not in the new code. The DCV kitchen hood item reflects the exception added in the new code that reduces the number of situations required to have DCV kitchen hoods.

**Figure 1. Electric Savings by Section (% of Total)**

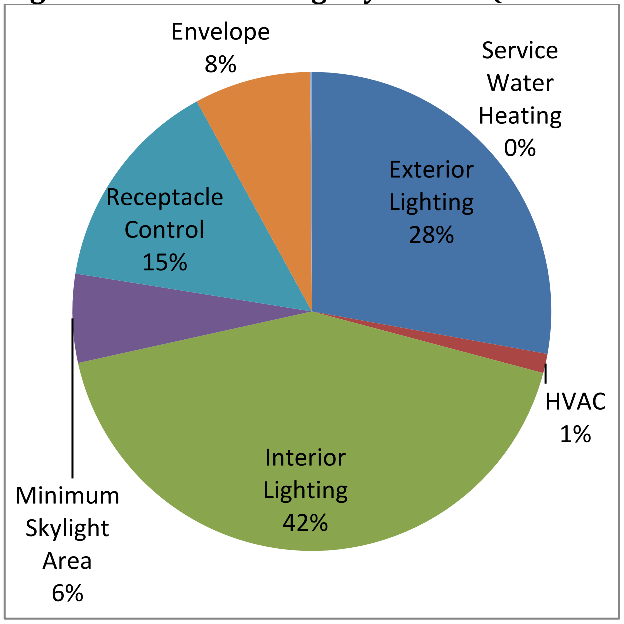


**Figure 2. Gas Savings by Section (% of Total)**

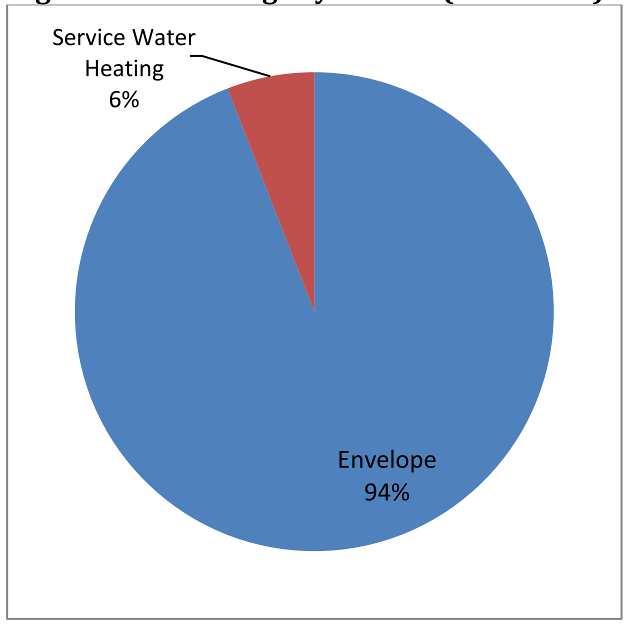


**Figure 3. Site Btu Savings by Section (%)**

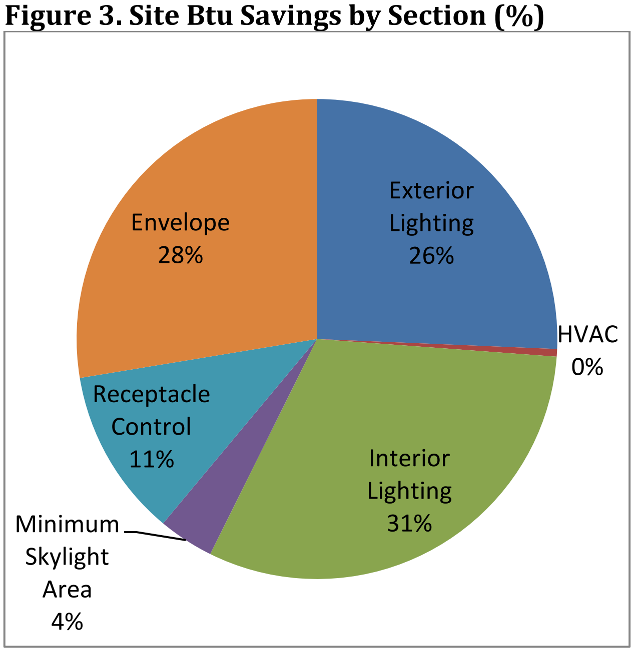


**Figure 4. Energy Cost Savings by Section (%)**

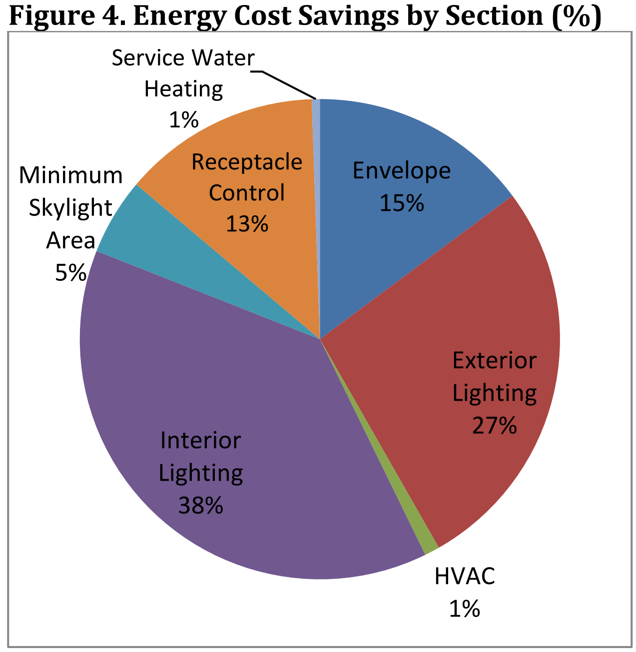

**Table 15. Annual Energy Savings by Measure – Current Practice**

| | Floor Area Normalized Savings | | Forecast Sector Savings | |
|---|---|---|---|---|
| **Code Item** | **Electric kWh/ft²** | **Gas therms/ft²** | **Electric aMW** | **Gas MMBtu** |
| Envelope Changes | 0.079 | 0.0076 | 0.16 | 13703 |
| Minimum Skylight Area | 0.060 | -0.0007 | 0.12 | -1200 |
| Interior Lighting Power | 0.221 | -0.0021 | 0.46 | -3741 |
| Interior Lighting Controls | 0.205 | -0.0009 | 0.42 | -1601 |
| Exterior Lighting Power | 0.152 | 0.0000 | 0.31 | 0 |
| Exterior Lighting Controls | 0.128 | 0.0000 | 0.26 | 0 |
| Receptacles | 0.146 | -0.0008 | 0.30 | -1360 |
| Air Cooled Chiller Limit elimination | -0.011 | 0.0000 | -0.02 | 0 |
| Economizer Control Requirements | 0.007 | 0.0000 | 0.01 | -16 |
| VAV Optimization | 0.006 | -0.0002 | 0.01 | -451 |
| DCV Kitchen Hood Req. Threshold Increase | -0.001 | -0.0001 | 0.00 | -268 |
| New DCV Exception | 0.000 | -0.0001 | 0.00 | -175 |
| High Input Rated Hot Water | 0.000 | 0.0004 | 0.00 | 674 |
| DHW Pipe insulation | 0.001 | 0.0001 | 0.00 | 185 |
| **Total** | **0.994** | **0.0032** | **2.05** | **5750** |

# 4. Conclusions

Adoption of the OCEC 2019 energy code represents a substantial advance in new building energy efficiency. The code-to-code method estimates an 9.0% reduction in site energy while the current practice adjusted method estimates a 7.8% reduction. There are substantial electric savings (12.3% code-to-code, 10.4% current practice adjusted) but very few gas savings (1.2% code-to-code, 2.1% current practice adjusted) because of negative HVAC interaction of the interior lighting and receptacle control provisions. The increased gas savings in the current practice estimates are a direct result of reduced electric savings from interior lighting. The code provision changes generating the bulk of energy savings are those impacting interior and exterior lighting power and controls, automatic receptacle control, and envelope requirements.

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# Appendix A: Measure Evaluation Details

This appendix presents evaluation details of OCEC 2019 code provisions. Inputs for code estimates and current practice estimates are the same unless otherwise noted.

## A.1 Envelope

The impact of all envelope measures is evaluated by applying the codes to the NEEA 2004 NC building data and determining an average UA/ft$^2$ and SHGC by building type to represent the aggregate envelope changes. The Oregon 2014 and 2019 codes are applied to each of the 350 buildings in the data set based on audited component types. For buildings where window-wall ratio (WWR) or skylight-roof ratio (SRR) exceeds code limits, adjustments are made to the window and skylight U and SHGC values to comply with code. The average code thermal conduction and SHGC of each component and code is then determined. These values account for all the code envelope changes and are used in the code-to-code estimates. For the current-practice adjusted-savings estimates, a current practice adjustment is applied to the code values. Past evaluations included a data-based current-practice adjustment to address the below-code-maximum average building heat loss rate in every NW baseline characteristics study. The current data are outdated; for simplicity it was assumed code-compliant buildings will exceed code by an average of 5%, which in turn reduces savings from envelope measures by 5%.

The table below presents the average code heat loss rate and SHGC for the NEEA 2004 NC buildings. The “OR14”, “OR19 4C,” and “OR19 5B” columns are the building heat loss rates per square foot of conditioned floor area and average SHGC under the different codes. A 5% reduction is applied to the current practice savings estimates to capture the fact that early audit data found that the buildings slightly exceeded code on average.

In general, the prototypes have less surface area per unit floor area than those in the NEEA 2004 NC data. This means that using prescriptive u-values for prototype components underestimates envelope heat loss relative to the NEEA 2004 NC data. Therefore, the average code values were adjusted for differences between the prototype geometry and the NEEA 2004 NC data, as discussed in Appendix C1. The averaged and adjusted values, capturing all changes of the envelope code, are then modeled.

**Table 16. Average Code Heat Loss Rate and SHGC**

| | Avg Heat Loss Rate (ua/ft$^2$) | | | Average SHGC | | |
|---|---|---|---|---|---|---|
| **Building Types** | **OR14** | **OR19 4C** | **OR19 5B** | **OR14** | **OR19 4C** | **OR19 5B** |
| Apartment, high-rise | 0.091 | 0.082 | 0.079 | 0.37 | 0.37 | 0.35 |
| Apartment, mid-rise | 0.088 | 0.078 | 0.072 | 0.40 | 0.38 | 0.36 |
| Healthcare—hospital | 0.079 | 0.067 | 0.064 | 0.38 | 0.36 | 0.38 |
| Hotel, large | 0.110 | 0.093 | 0.088 | 0.40 | 0.36 | 0.38 |
| Hotel, small | 0.110 | 0.093 | 0.088 | 0.40 | 0.36 | 0.38 |
| Office, large | 0.086 | 0.077 | 0.075 | 0.28 | 0.32 | 0.34 |
| Office, medium | 0.115 | 0.100 | 0.095 | 0.38 | 0.36 | 0.38 |
| Office, small | 0.167 | 0.141 | 0.132 | 0.40 | 0.36 | 0.38 |
| Residential care | 0.085 | 0.067 | 0.063 | 0.40 | 0.36 | 0.38 |
| Restaurant, full-service | 0.148 | 0.125 | 0.117 | 0.40 | 0.36 | 0.38 |
| Restaurant, quick service | 0.148 | 0.125 | 0.117 | 0.40 | 0.36 | 0.38 |
| Retail, stand-alone | 0.135 | 0.106 | 0.104 | 0.39 | 0.37 | 0.39 |
| Retail, strip mall | 0.199 | 0.144 | 0.136 | 0.38 | 0.35 | 0.37 |
| School, primary | 0.120 | 0.087 | 0.082 | 0.40 | 0.36 | 0.38 |
| School, secondary | 0.099 | 0.076 | 0.071 | 0.39 | 0.36 | 0.38 |
| Warehouse, heated | 0.140 | 0.099 | 0.095 | 0.39 | 0.35 | 0.37 |
| Warehouse, semi-heated | 0.203 | 0.227 | 0.121 | 0.61 | 0.55 | 0.58 |
| Warehouse, unheated | 0.330 | 0.316 | 0.315 | 0.41 | 0.37 | 0.39 |

### A.1.1 Maximum WWR and SRR

The code-maximum window-wall ratio (WWR) changes with the new code and will allow most buildings to have 40% WWR rather than 30%. Code-maximum skylight-roof ratio (SRR) is 3% in both codes except for an OCEC 2019 exception that will allow up to 6% if the skylights have a VT>0.4, have 90% haze value, control all the general lighting in the resulting daylight zone, and result in a top daylight zone encompassing at least 50% of the space. This is an incredibly low bar and pretty much allows any distributed skylight system to qualify if it has diffusers in the skylights. Therefore, a 6% limit was assumed for the new code. Using the NEEA 2004 NC data, buildings with more than the maximum allowed skylight will be assumed to maintain the high SRR and improve U and SHGC to compensate.

### A.1.2 Window and Skylight SHGC

The new code slightly reduces the maximum allowed solar heat gain coefficient of fenestration (SHGC) from 0.4 to 0.38 and 0.36 in zones 4C and 5B respectively. The new code provides new exceptions from SHGC requirements for windows with external shading and for street-level retail. The NEEA 2004 NC data were used to determine the average code SHGC for both codes, and the resulting average SHGC is modeled. Retail, grocery, and restaurant buildings are deemed to qualify with either the street-level retail exception or the projection factor exception. In these cases, the allowed SHGC was set to 0.4, representing no change.

The new code also has a new provision regulating window orientation, which requires east and west window areas to each be ≤ 25% of the total window, or to have the SHGC window area product of east and west windows to each be ≤ 20% of the total. Buildings with less than 20% WWR on both east and west can have an SHGC ≤ 90% code allowance to comply. This provision is applied after any projection factor adjustments in the main SHGC allowance, and also exempts street-level retail.

Evaluating the new provision is difficult. While orientation data exists for windows, there is no orientation data for the walls, so determining when the east and west WWR is ≤ 20% is not possible. This evaluation has assumed that wall area is oriented in proportion to the window area and therefore the WWR of each orientation is the same as that of the building. NEEA 2004 NC buildings were separated into four paths:

- Those with less than 25% of windows on east and west walls respectively,
- Those with less than 20% WWR,
- Grocery/retail/restaurant, and
- Everything else.

Each group was treated according to code requirements and a reduction factor was developed to adjust the overall SHGC allowance. Separate east-west SHGC was not modeled.

The RBSA data sets do not include orientation for high-rise and mid-rise multifamily buildings. The significant possibility for external shading from decks is also not captured. No adjustments were made to the multifamily code requirements as a result of projections or orientation.

Under the new code, skylights are exempt from SHGC requirements if they have a VT>0.4 and a diffuser. These are the same requirements to qualify for the 6% maximum allowance. Therefore, many skylights will be exempt from SHGC requirements in the new code; however, this evaluation assumes an SHGC of 0.4, the same as the OEESC 2014 code.

For current-practice estimates, code SHGC values were adjusted 5% lower.

### A.1.3 Minimum Skylight

The OCEC 2019 introduces requirements for many space types to have skylights with daylight lighting controls for 50% of the space floor area if the spaces are larger than or equal to 2500ft$^2$ and directly under a roof with a ceiling height greater than 14 feet.

Table 17 indicates the zones in which skylights were modeled. For large retail buildings, skylights were also modeled in the sales zones in the base case since skylights have been a fixture of large retail for nearly two decades. The model zones were set up with skylights and controls that provided daylight control to 90% of the zone. For the code-to-code estimates, skylights were modeled in a limited number of zones so that the savings were not overly large for the code provision that required only 50% daylighting. While this solution is not ideal, it fit best with the companion current-practice estimates. The current-practice estimates modeled skylights in all applicable spaces. The savings were normalized by the total daylight area and then adjusted based on the applicability factors in Table 18 and the requirement for 50% of the floor area in said spaces to be in the daylight zones. Data on the current saturation of skylights and floor area meet the space criteria primarily based on the NEEA 2004 NC data.

**Table 17. Minimum Skylight – Zone Selection**

| Building Type | Code-To-Code | Current Practice |
|---|---|---|
| Retail - Large | Sales, Storage | Sales, Storage |
| Retail - Small | 1 of large store | Both large stores |
| School - Primary | Gym | Gym, library, cafeteria |
| School - Secondary | Library, auditorium | Gym, library, auditorium |
| Warehouse | Bulk storage | Bulk & fine storage |
| Warehouse - Semiheated | Bulk storage | Bulk & fine storage |
| Warehouse - Unheated | None | None |

**Table 18. Minimum Skylight Current Practice Applicability Assumptions**

| Building Type | Overall Applicability | Floor Area in Spaces larger than 2,500sf with roof and high ceiling (%) | Current Saturation |
|---|---:|---:|---:|
| Retail - Large | 9.6% | 72.02% | 52.88% |
| Retail - Small | 16.2% | 36.65% | 4.32% |
| School - Primary | 0% | 12.55% | 32.00% |
| School - Secondary | 1.9% | 19.27% | 15.54% |
| Warehouse | 28.3% | 76.24% | 19.60% |

### A.1.4 Envelope Insulation

The OCEC 2019 nonresidential insulation requirements mandate more insulation in all components, opaque and fenestration, except for zone 4C framed walls and zone 4C/5B below-grade walls and joist floors where the values are the same as the current code. Many of the new code requirements constitute significant improvements (e.g., R30ci roof from R20ci, and fully-insulated concrete masonry unit (CMU) walls from allowing only filled cores).

In buildings with a WWR typically less than 30%, the OCEC 2019 represents a significant improvement in required envelope insulation. In large and medium offices where WWR can be quite high, required improvements in insulation will be partially offset by the higher glazing fraction allowance in the new code.

### A.1.5 Infiltration and Vestibules

Both codes require vestibules on most building entrances, although OCEC 2019 includes many exceptions. Exceptions 7 and 8 are confusing and contradictory: exception 7 requires vestibules in buildings over 1,000ft$^2$, while exception 8 exempts doors "that are not the building entrances" in spaces less than 3,000ft$^2$. The 90.1 user guide indicates this latter exception is meant to exempt street-level stores in larger buildings. As such, a store that is a 2,000ft$^2$ building needs a vestibule on the access door, but a 2,000ft$^2$ store in a bigger building does not. The definition of building entrance is not consistent with this interpretation, however, as any door used for entry is an entrance door. For strip malls, the building has no entrance to a larger building, rather each store has its own entrance. The building entrance definition would lead one to consider that each space entrance is a building entrance, but this would be counter to the user guide statement. This work assumes vestibules are not required in the strip mall where spaces are <3,000ft$^2$. The OEESC 2014 is similar, but with fewer and clearer exceptions. The OEESC 2014 exempts entrances for all spaces <3,000ft$^2$. Under these interpretations, no difference exists in the code requirements for a vestibule.

The OCEC 2019 has detailed requirements for the vestibule, such as a minimum distance between the inner and outer doors and implementation of automatic door closers, while the OEESC 2014 does not. This evaluation includes no analysis of this.

## A.2 Mechanical

The mechanical chapter of the code was substantially changed. Rated equipment efficiency remains largely the same, although every requirement in code has changes in some element (requirement, threshold, or exception). ASHRAE 90.1-2016 has more HVAC control requirements and significantly expands the coverage of special cases in the requirement language and exceptions, leaving less room for uncertainty in code requirements.

Many mechanical changes have not been modeled due to the prototypes not being configured to handle the equipment and/or controls, as well as the development time that would be involved to handle the change. In most cases, the changes impact a subset of systems (e.g., VAV systems with fans between 5hp and 7.5hp) so that savings averaged across all commercial buildings would be relatively limited. Even so, taken together, the unevaluated mechanical provisions represent a significant source of uncounted savings that artificially diminish the relative importance attributable to the mechanical chapter.

### A.2.1 HVAC Equipment Performance Requirements

The primary changes in equipment efficiency are:

- Increased packaged terminal heat pump (PTHP) heating coefficient of performance (COP)
- Increased single package vertical air conditioners (SPVAC) and single package vertical heat pumps (SPVHP) energy efficiency ratios (EER) for non-space-constrained units
- Tiny increase in EER for non-weatherized space-constrained SPVAC and SPVHP ≤ 30,000 Btuh
- Small increase in SPVHP heating COP in equipment >135,000 Btuh
- Increased annual fuel utilization efficiency (AFUE) for gas and oil hot water and steam boilers <300,000 Btuh
- Higher performance for axial/propeller fan closed-circuit cooling tower
- Restructured computer room tables
- New efficiency tables covering
    - Variable refrigerant flow (VRF)
    - Commercial refrigerator efficiency
    - Indoor pool dehumidifiers
    - DX-DOAS units with and without heat recovery

Overall, these changes are minor, with the most significant changes for PTHP, SPVAC/SPVHP, and small boiler efficiency. The PTHP and small boiler changes pre-date NEEA standards efforts and are therefore included in the code savings estimates as discussed below. The SPVAC/SPVHP change was not evaluated as the saturation of that equipment type is presumed to be small. Little of this type of equipment existed in the 2005 NEEA 2004 NC buildings.

The added tables for new equipment classes (e.g., VRF, DX-DOAS) were originally introduced to 90.1 not as a means to force change but instead to establish a requirement so equipment ratings will be made available with improved efficiencies for introduction in future code cycles. Therefore, the new tables were not evaluated here as a change in efficiency.

A significant issue for equipment efficiency is that the analysis relies on a distribution of equipment types based on the 2005 NEEA 2004 NC building data. That data included no VRF units, and other system type shifts such as chilled beam had not yet been instituted. As such, the saturation of other equipment types is likely smaller than that found in the 2005 NEEA 2004 NC data.

**Boiler and PTHP Heating Efficiency**

The federal minimum heating efficiency requirements for PTHP equipment increased as of October 8, 2012, and PTHP efficiency increased by approximately 6% on average. ASHRAE

90.1 boiler efficiency for boilers <300,000 Btuh increased with the adoption of ASHRAE 90.1-2013.

Although the OEESC 2014 was intended to implement these higher minimum efficiency requirements, somehow it only captured the PTAC/PTHP cooling requirement and not the PTHP or boiler heating requirements. Whether this was due to an error or to Oregon adopting federal standards before adequate time had elapsed from original publication is unclear.

The OEESC 2014 code savings evaluation assumed the new PTHP and boiler heating efficiency requirements would be adopted, and evaluated these efficiency improvements as part of that change. Since savings have already been accounted for, savings from these measures are not included in current practice savings but are included in the code-to-code stringency measure for the residential care and motel building types.

**Air-Cooled Chiller Capacity Limit**

The OEESC 2014 limits the allowable capacity of air-cooled chillers. Facilities with more than 300 tons of total chiller capacity can have no more than 100 tons of air-cooled chiller capacity. All other chillers must meet the minimum code requirements for water-cooled chillers. The OCEC 2019 removes this limit.

The NEEA 2004 NC data were used to calculate the average compressor cooling efficiency with and without this provision and the results were modeled.

### A.2.2 OEESC 2014 503.2.1.1 Packaged Electric Equipment

This provision, which is eliminated in the new code, establishes a heat capacity threshold (20,000Btuh) above which package AC/electric heat units must be heat pumps. The provision does not impact duct heaters or VAV reheat. With removal of this provision, any package air conditioner will be allowed to have electric resistance heat instead of a heat pump.

In the 2005 NEEA 2004 NC data set, the saturation of single package equipment with electric resistance heat in this size range is very limited. This provision was not evaluated when it was introduced and its removal now is likewise not evaluated.

### A.2.3 Demand Control Ventilation

Both codes have the same threshold of 25 people or more per 1,000ft$^2$ for space to have demand control ventilation (DCV) as well as the general requirement that the system have economizers, a modulating damper, or more than 3,000 cfm of outdoor air. However, the exceptions are quite different.

The OEESC 2014 exempts spaces smaller than 500ft$^2$ served by single-zone systems and those smaller than 150ft$^2$ served by multizone systems. In addition, spaces smaller than

750ft² in which the fan, ventilation damper, or zone damper closes when unoccupied, and systems with heat recovery, are exempt.

The OCEC 2019 exempts spaces in which more than 75% of the design outdoor air flow is required for makeup or exhaust. Exempt systems are those with less than 750cfm of outdoor air, and multizone systems without direct digital control (DDC) of individual zones.

For spaces served by single-zone systems, the OCEC 2019 is less stringent as spaces with 750cfm of outdoor air will range from 500ft² to 2,500ft². The key spaces are classrooms and school media centers, which are often served by single-zone air handlers and will no longer be required to have DCV.

For spaces served by multi-zone systems without zone-level DDC, the OCEC 2019 is again less stringent since all spaces will be exempt, versus the current code which requires DCV in all spaces 150ft² or larger no matter the control arrangement. Luckily the OCEC 2019 requires zone-level DDC in all systems with fan system brake horsepower of 10 hp or more; in talking with designers, most seem to be installing zone DDC. This evaluation assumes that all multi-zone systems have zone-level DDC and that the codes are comparable.

For spaces served by multi-zone systems with zone-level DDC, the OCEC 2019 will extend DCV to spaces less than 150ft². High-occupancy rooms smaller than 150ft² are not common, although small conference rooms could be impacted. This evaluation assumes there are no spaces meeting the occupancy requirements that are less than 150ft² and that the codes are comparable.

The increased energy use from removing the DCV requirement will be evaluated in school classrooms and libraries (aka media centers). This will only be applied to the single-zone system school models. The evaluation assumes that half of the impacted classrooms would not remove DCV.

### A.2.4 Section 6.5.3.2.1 Fan Airflow Control

The code now requires two-speed flow with low-speed operation. This low-speed operation is to be used in ventilation and low cooling modes in all unitary systems >5 tons, and in all CW units >= 0.25hp. System flow is reduced to ≤ 66% of peak flow with power to ≤ 40%. Previous code required this only for unitary systems >9.5 tons to reduce flow to ≤ 66% at ≤ 40% power, and required all non-DX cooling systems serving large rooms with >8000 CFM supply air (~8,000ft²) to have fan turndown to 60% of peak flow.

This is an important expansion of this control, although it impacts only a modest portion of the overall equipment. Savings from this requirement also overlap those from DOE standards for DX minimum part load efficiency. Two-speed fan is one of the primary methods of attaining the required IEER. NEEA has evaluated savings from the DOE standards separately so savings from the two-speed fan requirement in unitary equipment are not evaluated here. Two-speed fan requirements in hydronic equipment are evaluated here.

The OEESC 2014 and OCEC 2019 requirements were applied to equipment data from the NEEA 2004 NC data to determine the fraction of equipment required to have two-speed fan operation under the code. Fan air flow control is modeled in small office, retail, school, and warehouse buildings. Savings were calculated for going from a single-speed fan to a two-speed fan and multiplying savings by the applicability factor.

To properly account for fan power in the evaluation of other measures, a two-speed fan with a modified turndown was modeled. A test found that modeling the two-speed fan with the average fan power and flow turndown from the mix of single- and two-speed equipment resulted in almost the same savings as modeling single-speed and two-speed fans separately and applying the applicability factor. Average turndown was calculated for both before and after the OCEC 2019 provisions and the fan is modeled at the average conditions to ensure fan power is not improperly accounted for when evaluating other measures.

A major caveat to the savings estimate is the clear evidence that many single-zone HVAC units do not have the fan running continuously. The 2014 Commercial Building Stock Assessment (CBSA) found some 75% of units cycling. While the CBSA number is in question, other sources also find a high fraction of units cycling. By code the fans should be operating to deliver code minimum ventilation, so a code-to-code analysis would assume the fan operates while a standard practice to code would have to account for this. Modeling in this evaluation generally assumes continuous fan operation except for the core retail zone, which is assumed to cycle as needed to meet conditioning requirements.

**Table 19. Two-Speed Fan Requirements**

| Building Type | Floor Area Fraction w/ Single-Zone Mechanical Cooling | Two-Speed Fan Required (percent of SZ cooling ) | | | |
|---|---|---|---|---|---|
| | | OEESC 2014 | | OCEC 2019 | |
| | | DX[3] | Big Room / Hydronic | DX | Hydronic |
| Residential/Lodging[1] | 0.734 | 0.051 | 0.000 | 0.144 | 0.005 |
| Office – Large | 0.041 | 0.499 | 0.053 | 0.538 | 0.285 |
| Office – Medium | 0.427 | 0.380 | 0.000 | 0.606 | 0.001 |
| Office – Small | 0.973 | 0.000 | 0.000 | 0.138 | 0.000 |
| Residential Care | 0.868 | 0.032 | 0.000 | 0.044 | 0.000 |
| Restaurant/Bar | 0.937 | 0.477 | 0.000 | 0.714 | 0.000 |
| Retail – Large | 0.759 | 0.691 | 0.000 | 0.745 | 0.000 |
| Retail – Small | 0.940 | 0.222 | 0.000 | 0.511 | 0.001 |
| Education – Primary[2] | 0.426 | 0.134 | 0.044 | 0.236 | 0.400 |
| Education – Secondary[2] | 0.385 | 0.137 | 0.063 | 0.159 | 0.156 |
| Warehouse | 0.449 | 0.074 | 0.000 | 0.103 | 0.000 |
| **Total Com. Sector** | **0.472** | **0.192** | **0.010** | **0.279** | **0.048** |

1 – All equipment requiring two speeds is assumed to be located in the large hotel fraction and is adjusted accordingly.
2 – School OEESC 2014 two-speed requirements are assumed to apply to the large common area systems only. OCEC 2019 changes are applied to the classroom wings of the school.
3 – Informational only. To prevent double counting of savings the OCEC 2019 DX two-speed fan requirements were used for the 2014 and 2019 codes.

### A.2.5 Economizer High Limit

Section 6.5.1.1.3 of the OCEC 2019 introduces requirements for acceptable economizer shutoff control types and required settings. Generally, for single sensor setups, a dry bulb sensor with 75°F high limit is required. Whether this is the changeover temperature or the absolute high limit is in question. Trane Voyager units had high-limit shutoff control independent of the changeover control, which was generally set to a lower temperature. Baseline control is assumed to be dry bulb sensor with a 68°F high limit. This control change is modeled in all prototypes with single-zone systems.

### A.2.6 Section 6.4.3.10 Direct Digital Control Requirements

Adds requirements to detect, raise an alarm, and provide an easy work-around for zones that excessively drive reset logic. This beneficial requirement will ensure buildings operate closer to the performance assumed by current models. Most buildings already do this to some extent, but it will be a change for some. Models generally assume occupation and loads are evenly distributed so the impact of any single zone is not overly significant and the models assume perfect reset. There is no information on the number of buildings that lack this ability and that have problematic critical zones. Therefore, this improvement is not evaluated.

### A.2.7 Section 6.5.3.3 Multiple-Zone VAV System Ventilation Optimization

The International Mechanical Code (IMC) requires multi-zone air systems to follow the Ventilation Rate Procedure to size the air handler outdoor air intake and terminal minimum flow rates so that every zone gets adequate outdoor air. As a design calculation, this procedure often leads to very high outdoor air flow rates. A new energy code provision requires non-fan powered VAV systems to automatically adjust outdoor air flows continuously for changes in the system ventilation efficiency. This generally reduces outdoor air flow significantly from VRP-sized flows.

The saturation of VAV systems with fanless VAV terminals, well-established in the NEEA 2004 NC data, is presented in Table 20. While VAV has a significant saturation, roughly two-thirds of the systems utilize some sort of fan-powered terminal.

**Table 20. VAV Optimization Applicability**

| Building Type | Overall | Fraction Std. | VAV |
|---|---|---|---|
| Health – Outpatient | 0.045 | 0.116 | 0.386 |
| Hospital | 0.211 | 0.435 | 0.485 |
| Lodging – Hotel | 0.00 | 0.000 | 0.009 |
| Lodging – Motel | 0.000 | 0.000 | 0.009 |
| Office – Large | 0.029 | 0.038 | 0.775 |
| Office – Medium | 0.037 | 0.109 | 0.337 |
| Retail – Large | 0.006 | 0.297 | 0.019 |
| Retail – Small | 0.001 | 1.000 | 0.001 |
| School – Primary | 0.234 | 0.802 | 0.292 |
| School - Secondary | 0.060 | 0.335 | 0.178 |
| Warehouse | 0.004 | 0.922 | 0.004 |

Further, some VAV systems may be installed without VRP sizing, which would negate energy savings from the dynamic adjustment. The implementation of this in current new construction appears to be extensive. Two designers each reported they were doing some version of this in both fan less and fan-powered VAV systems. They indicated it was difficult and were sure many were not doing it. Without better data on current practice, all buildings are assumed to be doing VRP sizing and none are assumed to already be doing dynamic VRP.

EnergyPlus has the ability to model this sizing and control with some limitations. For code-to-code estimates, this measure is modeled only in primary schools. For the current practice estimates, savings for this measure for standard VAV systems are modeled in both schools and the large office prototypes. The normalized savings were applied to the fraction of floor area with standard terminal VAV systems.

### A.2.8 Section 6.5.3.5 Fractional Horsepower Fan Motors

OCEC 2019 requires all motors from 1/12hp up to but not including 1hp to be electrically commutated motors (ECM) or 70% efficient unless it is a component of rated equipment, in heating-only situations with cycling fan, or covered by new fractional horsepower efficiency tables. The new fractional horsepower efficiency tables range from 60%–80% depending on the details of the motor. OEESC 2014 Section 503.2.10.4 only regulates motors in series fan-powered terminal units, requiring them to be ECM. This is a significant change that impacts hydronic terminal and exhaust fans. The efficiency tables echo DOE motor efficiency standards, but the provision for motors outside of that standard is not in this standard. The impact of the standards is substantial, but the number of motors falling into the code-only provision is uncertain.

This evaluation has assumed that most small motors fall under the DOE standards which NEEA has evaluated separately. Kitchen and laundry exhaust hoods (in restaurants, schools, hotel, and residential care buildings) and the large hotel fan coil HVAC system are modeled with DOE standard compliant efficiency with the same inputs used for the OEESC 2014 and OCEC 2019 codes. The current BPA prototypes do not have exhaust fans implemented, so they were not modeled.

### A.2.9 Section 6.5.6.1 Exhaust Air Energy Recovery (Not evaluated)

The OCEC 2019 brings major changes to this section of the code. Separate requirements exist for systems operating less than 8,000 hours/yr and for those operating 8,000 hours/yr or more. For the former, energy recovery is not required; for the latter, energy recovery is required based on different supply design flows for various OA fractions. The OEESC 2014 requires energy recovery for systems with supply flow of 5,000cfm or greater with a 70% or greater OA fraction. The new code also introduces an exemption for systems with more than 25% of exhaust air being exhausted from locations more than 20’ away from the other exhaust.

For systems operating less than 8,000 hours/yr, the new code is a rollback. While the number of high OA fraction systems required by OEESC 2014 to have heat recovery that run less than 8,000 hours per year is unclear, some do exist. Hospital systems in this flow range likely run more than 8,000 hours annually, but some systems in outpatient health facilities will have 100% OA systems that will no longer require ERV.

For systems operating 8,000 hours/yr or more, the flow thresholds are considerably reduced so that heat recovery is required in a wide array of systems. In Zone 4C, systems with 5,000 cfm with 40-50% OA and systems with 1,500 cfm with 70-80% OA and 100% OA systems over 120 cfm are required to have heat recovery. Because the change is limited to systems that operate 8,000 hours or more a year, its impact is limited to a few building types: Hospital, and possibly lodging and police/fire. In hospital, most systems operate 8,000+ hours, but many high-OA systems have flows and outdoor air fractions such that they are currently required to have heat recovery. However, smaller systems that previously were not required will now have to have energy recovery. In lodging, central ventilation systems would trigger the threshold if they were configured to run 24/7 but, in many cases, they utilize side wall exhaust, so would be excluded.

The hospital model is set up with four very large systems and is poorly suited to evaluate this measure. With more resources, the model could be reconfigured to break up the large CAV systems serving the medical areas into smaller systems more typical of hospitals. The PNNL models offer a good template for this. The hotel model included substantial uncertainty about the prevalence of central air supply ventilation vs. side wall or bathroom exhaust systems. This measure has not been evaluated in this study. Future model changes will target improving the hospital prototype so that savings might be included in future evaluations.

### A.2.10 Section 6.5.6.2 Kitchen Hood DCV

For kitchens with >5,000 cfm of hood exhaust, OCEC 2019 requires maximum hood flows, limits compensating air, and requires 50% of replacement air to be transfer air or to have demand ventilation systems. The OEESC 2014 does not have maximum hood flow requirements but requires demand ventilation systems for hoods in kitchens with >5,000 cfm. Both codes have an exception for transfer air; however, in the OEESC 2014, this does not apply when the donor zone is required to have DCV or heat recovery. Since many kitchens are associated with spaces required to have DCV, the new code will require DCV hoods less often. The DCV hood is modeled in several prototypes as part of the base OEESC 2014 code. Increased energy use from removing the DCV requirements is modeled in sit-down restaurant buildings for the code-to-code runs.

For the current practice estimates, the DCV elimination is modeled in residential care, sit-down restaurant and secondary school building types. The savings are normalized per cfm of hood flow and applied to the commercial sector based on NEEA 2004 NC estimates of hood flow. Only 50% of sites were assumed to qualify as utilizing transfer air.

The maximum flow rate requirements are not evaluated as data is very limited in terms of how the limits relate to current practice.

## A.3 Service Water Heating

### A3.1 Section 7.5.3—Buildings with High-Capacity Service Water Heating Systems

This new provision requires buildings with 1,000,000 Btuh or more of total gas water heating capacity to have an average thermal efficiency of 90%. Systems excepted from the 90% requirement are those located within individual dwelling units, those with a capacity of 100,000 Btuh or less, and those with 25% of water provided by site solar or heat recovery.

The main threshold will definitely be triggered in hospital and lodging building types; however, the exception for site-solar or site-recovered energy might also be triggered. C403.5.4 requires condenser heat recovery to hot water in facilities based on criteria most hospitals meet. Savings are modeled assuming water heater thermal efficiency changes from a ~80% efficient base to 90%.

For the code-to-code estimates, this was modeled in the hospital and both lodging prototypes. For the current practice estimates, the provision is also modeled in high-rise multifamily and primary school prototypes. The savings are normalized and applied where applicable. The saturation of systems meeting the capacity threshold was determined from the NEEA 2004 NC data. Unfortunately, that data set has very limited water heater efficiency data. This evaluation assumed 20% of existing water heat in these facilities is heated with condensing hot water units. Fifty percent of hospital floor area was assumed to utilize heat recovery.

### A.3.2 Section 7.4.3—Service Hot-Water Piping Insulation

OCEC 2019 requires slightly more insulation in general and requires insulation on the first 8’ of outlets from recirculation systems. Recirculating system piping must have 1” of insulation on pipe with diameters <1.5” and 1.5” of insulation on larger piping, and the first 8’ of piping outlets must insulated. For non-recirculated systems, 1” of insulation is required on the first 8’ of outlet piping, and 1” on the inlet piping between the tank and a heat trap. The OEESC 2014 requires recirculating systems to have 1” of insulation on the loop and non-recirculating systems to have 0.5” of insulation on the first 8’ of outlet piping. It also requires a heat trap.

PNNL evaluated the impact of requiring insulation on the recirculation system outlet piping, which will be evaluated. The increased insulation level will not be evaluated. Many recirculating systems will have the same requirements as before, and many will also have pipe diameters >= 1.5” and thus be required to have more insulation. This will not be accounted for.

The evaluation utilizes model inputs developed for the 90.1-2016 savings determination (PNNL 2017), Appendix B, Section B.1.4.1 Addendum by: Require first 8 feet of SHW piping runout to be insulated. This results in piping savings in high-rise multifamily, hospital, lodging, large and medium office, full-service restaurant, residential care, and schools. For current practice estimates, the model results were adjusted for the fraction of buildings with circulation systems and for the saturation of water and space heating fuels in the building types with circulation systems. These factors were derived from the NEEA 2004 NC data and the OCCE data (discussed in Appendix C).

## A.4 Electrical Power and Lighting Systems

### A.4.1 Section 8.4.2 Automatic Receptacle Control

The new code section on controlled receptacles requires 50% of receptacles in offices, conference rooms, and classrooms to be controlled based on occupancy. This requires an estimate of the applicable floor area and some savings number in terms of average kWh per day, or a kWh profile for each day type. Either the approach used as part of the ASHRAE

90.1 determination, or a savings number derived from the best evaluation report, could be applied to the models.

Very little information is available on metered savings from plug load controls. Acker et al. monitored six office spaces and found savings of 0.6 kWh/yr. Relative savings are not presented on an annualized basis, but appear to be ~18% on weekdays and higher on weekends. Acker et al. also investigated replacing equipment with EnergyStar equipment and found even greater savings. The savings from these two strategies overlap to a degree, and in buildings with EnergyStar equipment, controlled receptacles may save substantially less energy. The methodology of this work raises other concerns (small non-random sample, existing rather than new buildings) in determining annual savings applicable to average new buildings; however, it appears to be the only measured data available.

Plug load controls were evaluated for the 2013 California Building Energy Efficiency Standards, with estimated savings of 0.49 kWh/ft$^2$ in small office and 0.61 kWh/ft$^2$ in large office building types. This evaluation did not report overall plug load consumption or percent savings. Costs were estimated to be \$0.26/ft$^2$ in small office and \$0.19/ft$^2$ in large office buildings.[10] PNNL evaluated nearly the same provision.

PNNL developed equipment loads and schedules that result in savings of ~8% for small and medium office and an absolute savings of ~0.21 kWh/ft$^2$. These values are substantially below the Acker et al and CEC savings estimates. Both PNNL and CEC estimates are based on field-derived equipment counts and energy consumption combined with assumed occupancy and occupant behavior. In its favor, the PNNL evaluation assumes controls only in code-mandated spaces, and codes are generally applied to new buildings which are likely to contain new efficient equipment. In addition, the BPA prototype baseline equipment power density and schedules are borrowed from the PNNL, making implementation easy.

This code savings evaluation will use the PNNL ASHRAE 90.1-2007 equipment power and schedule for the base case and the ASHRAE 90.1-2016 equipment power and schedule of the new code.

### A.4.2 Section 9.2.2.3—Interior Lighting Power Allowances

OCEC 2019 lowered lighting power allowances, with building area allowances averaging ~18% lower and space-by-space allowances averaging 13% lower. The OCEC 2019 space-by-space allowances are more internally consistent than the OEESC 2014 values, which results in significant variation in the changing values within different space types. For example, corridor allowance increases 60% and electrical mechanical decreases 55%. Lighting power allowances were calculated by both paths, building area method and space-

[10] Primary source: http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_Residential-Plug-load-Controls.pdf

by-space method. And after review, the space-by-space allowances were chosen for all building types.

**Building-Area Allowance**
Building area allowances are estimated with a method similar to that used in previous Northwest energy code evaluations. The NEEA 2005 New Construction Characterization (NEEA 2004 NC) data were used to calculate average LPD allowances by building area type for the Northwest. These calculations primarily used building area allowances, but some space-by-space allowances were used to fill in missing building area types (e.g., laboratory).

The NEEA 2004 NC data needs some caveats in that it represents building area allowances lumped together by primary building type. As such, it does not represent pure building types such as those represented in the models; retail has restaurants and warehouse can have significant office, as examples. The prototype models and floor area forecasts used in this work represent pure use areas, with the office portion of an office/warehouse considered office and the warehouse as warehouse. Additionally, the NEEA 2004 NC building areas were not defined to be lighting code building areas; while they are similar, there are notable distinctions.

**Space-by-Space Allowance**
In the interest of simplifying the data requirements of the compliance effort, two alternative space-by-space approaches were explored for this and the WSEC 2015 analysis. First was a process similar to that used in the 90.1 determinations, in which the prototype models were assigned space-by-space LPD allowances based on their constituent space types. In cases where the prototype space is really an aggregate of different space types, a weighted value was determined with space type weighting used by PNNL for similar work. This produced base and proposed code LPD allowances for each prototype building.

The second approach was to use the IES/ASHRAE space type weights that are used to determine the 90.1 building area values from the individual space type models. Base and proposed code space-by-space allowances are combined with the IES/ASHRAE weights to calculate equivalent building area values, which are assigned to the prototypes.

Both methods lack a direct way to make ceiling height adjustments per the OEESC 2014. The LPD change as a result of ceiling height adjustments was derived from the NEEA 2004 NC data space type data and is applied to the space-by-space results. Ceiling height adjustments increase the average OEESC 2014 space-by-space allowance by 3.3%. The increase is less than 1% in most building types but is 3% in large retail, 2.1% in secondary schools, and 12.9% in warehouse. The OCEC 2019 does not have a ceiling height allowance.

Both methods also lack a direct way to calculate the OCEC 2019 decorative light allowance. This covers pretty fixtures, wall sconces, and other accent light applications. Again, utilizing the NEEA 2004 NC data to determine the LPD of decorative fixtures in buildings built before this credit existed (adjusted to assume LED light sources) indicated an increase in average allowance of 1.6%. However, if designers utilized this to its fullest, the credit allows an increase of up to 97%. One of the limits to utilization is that decorative fixtures must be separately controlled; however, as lights become individually controllable, this will no longer be a limit and utilization of this exception may increase.

Table 21 shows code allowance values for three calculation methods before any current practice adjustments. The space-by-space allowances are similar to one another, and both methods show lower LPD allowances for both codes than the NEEA 2004 NC building area approach. The difference between the two paths is hard to explain. The primary difference is the 2019 building area value, which is noticeably lower than that of the other methods. Buildings under the new code will be more likely to utilize the space-by-space path given the relative stringency of the building area allowances.

The IES and prototype/PNNL weighted allowances yield suitable agreement except in apartment, hospital, and office. In apartments, the PNNL model has only a small office and lots of corridor (whose allowance goes up 150%) while the IES model has those spaces plus lobby, stairway, storage, and electrical/mechanical, whose allowances decrease. In office, the prototype/PNNL numbers are customized by the office type (small, medium, large) and the IES values are not.

Since the building area values are calculated using NEEA 2004 NC building area weights that are likely less pure than the building types being modeled, the evaluation team has chosen to follow the space-by-space values that are based on the IES weighting scheme.

For the current practice estimates, a current practice adjustment is made to the table values. The current practice adjustment in NEEA evaluations has traditionally used the field data determination of the ratio of real building lighting power to the code allowance to scale both code allowances, as extensively documented in previous reports. Starting with the 2015 evaluations, the adjustment was changed to a deemed across-the-board 10% because the underlying field data are now outdated. A deemed value current practice adjustment better reflects that lack of current data than does a convoluted process applied to 15-year-old data.

In this cycle of the Oregon energy code, the OEESC 2014 and OCEC 2019 code lighting allowances are clearly behind standard practice. The OCCE study found LPD levels exceeding the OEESC 2014 and the OCEC 2019 code allowances. Changes in lighting power are likely the result of a myriad of factors (codes, programs, free drivers). Buildings will definitely achieve the new code levels; in fact, it appears they meet the anticipated next code change (ASHRAE Standard 90.1-2019) as well. Next code cycle, the code will catch up to current practice and the savings estimates will finally have captured the full LED-induced drop. The code is following technology in these cases, so the savings are not directly from code; however, they do constitute regional load reduction.

**Table 21. Code Interior Lighting Power Allowance – No current practice adjustment (W/ft²)**

| | Building Area Allowance - NEEA 2004 NC Weighted | | | Space-by-Space Allowance - IES weighting | | | Space-by-Space Allowance - Prototype/PNNL weighting | | |
|---|---|---|---|---|---|---|---|---|---|
| **Building Type** | **OEESC 2014** | **OCEC 2019** | **Ratio** | **OEESC 2014** | **OCEC 2019** | **Ratio** | **OEESC 2014** | **OCEC 2019** | **Ratio** |
| Apartment, mid-rise, common area only | 0.58 | 0.68 | 1.17 | 0.577 | 0.571 | 0.99 | 0.467 | 0.688 | 1.47 |
| Apartment, high rise, common area only | 0.58 | 0.68 | 1.17 | 0.577 | 0.571 | 0.99 | 0.534 | 0.72 | 1.35 |
| Healthcare—hospital | 1.087 | 1.059 | 0.97 | 1.046 | 1.115 | 1.066 | 0.825 | 0.909 | 1.10 |
| Hotel, large | 0.969 | 0.694 | 0.72 | 0.771 | 0.826 | 1.071 | 0.761 | 0.841 | 1.11 |
| Hotel, small | 0.969 | 0.694 | 0.72 | 0.747 | 0.818 | 1.095 | 0.719 | 0.796 | 1.11 |
| Office, large | 0.911 | 0.791 | 0.87 | 0.877 | 0.797 | 0.909 | 0.914 | 0.812 | 0.89 |
| Office, medium | 0.911 | 0.799 | 0.88 | 0.863 | 0.81 | 0.939 | 0.856 | 0.809 | 0.95 |
| Office, small | 0.901 | 0.779 | 0.86 | 0.864 | 0.816 | 0.944 | 0.784 | 0.775 | 0.99 |
| Residential care | 0.999 | 0.612 | 0.61 | 0.739 | 0.896 | 1.212 | 0.839 | 0.888 | 1.06 |
| Restaurant, full-service | 0.897 | 0.787 | 0.88 | 0.887 | 0.801 | 0.903 | 0.88 | 0.784 | 0.89 |
| Restaurant, quick service | 0.897 | 0.787 | 0.88 | 0.892 | 0.836 | 0.937 | 0.908 | 0.834 | 0.92 |
| Retail, stand-alone | 1.259 | 1.01 | 0.80 | 1.408 | 1.159 | 0.823 | 1.408 | 1.186 | 0.84 |
| Retail, strip mall | 1.205 | 0.981 | 0.81 | 1.389 | 1.263 | 0.909 | 1.381 | 1.25 | 0.91 |
| Retail, supermarket | 1.311 | 1.052 | 0.80 | 1.355 | 1.114 | 0.822 | 1.415 | 1.156 | 0.82 |
| School, primary | 1.007 | 0.806 | 0.80 | 0.966 | 0.815 | 0.844 | 1.02 | 0.835 | 0.82 |
| School, secondary | 1.01 | 0.808 | 0.80 | 0.978 | 0.811 | 0.829 | 0.982 | 0.798 | 0.81 |
| Warehouse | 0.699 | 0.519 | 0.74 | 0.746 | 0.465 | 0.623 | 0.782 | 0.469 | 0.60 |
| **Sector Floor Area Weighted Average** | **0.93** | **0.75** | **0.80** | **0.92** | **0.80** | **0.87** | **0.93** | **0.80** | **0.85** |

**Dwelling Unit Lighting**
Dwelling unit lighting power is not regulated by the OEESC 2014 and is unlikely to be regulated by the OCEC 2019 depending upon interpretation. However, both codes have a requirement that a percentage of installed lamps or fixtures meet minimum efficacy requirements. The OEESC 2014 requires 50% of the fixtures to be fitted with high efficacy lamps. The OCEC 2019 requires 75% of the fixtures to be fitted with lamps exceeding 55 lumens per watt, to be in fixtures rated over 45 lumens per watt.

In an oversight, the OCEC 2019 (ASHRAE 90.1-2016) does not exempt dwelling unit lighting from lighting power requirements. This in itself is not a problem, but the code also provides no lighting power allowances for dwelling units, making implementation difficult. This is reportedly an unintended consequence of shifting language in ASHRAE 90.1-2016. This evaluation has assumed the code will be interpreted in such a way that dwelling unit lighting will be exempt from power requirements and only the efficacy requirement is applied.

The 2016 NEEA Multifamily Code savings evaluation estimated the change in unit LPD of 0.705 W/ft$^2$ and 0.578 W/ft$^2$ in response to the 50% and 75% thresholds respectively assuming standard incandescent efficacy for the remaining lamps.

However, this provision overlaps with DOE standards, which require most standard socket lamps to meet minimum efficacy requirements that force better than standard incandescent efficacy in general purpose lamps. NEEA evaluated residential lighting (NEEA 2020) and found 65% of lamp sales to be LED or CFL, 72% of general purpose lamp sales and 58% of specialty lamp sales. The remaining general purpose lamps were primarily halogen while the remaining special purpose lamps were generally incandescent. The same study estimated that general purpose lamps sales were 52% of the total. Since LED and CFL lamp lifes are longer than incandescent and to a lessor degree than halogen lamps this sales data underestimates the installation saturation. Several incandescent lamps will need to be purchased for a single socket vs a single LED.

The fate of DOE standards is uncertain but the market transformation towards LED lighting would seem to be unstoppable and be utilized in a large fraction of applications.

Another consideration is that code regulates the initially installed lamp. Nothing in code ensures that subsequent lamps meet the efficacy requirements. For both reasons this evaluation has assumed no savings for dwelling unit lighting.

**Display Lighting**
Both codes have an additional retail display light allowance based on retail area type. The allowance can only be applied to separately-controlled display light and not to the general lighting. The OEESC 2014 display allowances are higher per square foot, but the OSEC 2019 allows an additional 1,000W allowance per permit. On a building basis the new 1,000W

allowance would have little impact, but in a strip mall with separate permits for each tenant, the difference would more than overshadow the improvements in the lower per-square-foot values. For the lowest retail allowance category, permits for spaces with more than 6,667ft$^2$ of display area will have lower allowances in the new code while smaller spaces will have higher allowances. At the highest retail allowance, the crossover is 1,600ft$^2$ of display area.

The PNNL 90.1-2016 determination (PNNL 2017) analysis assumed installed retail display lighting in 25% of the floor area of half of the strip mall prototype. This worked out to a base extra allowance of 0.347W/ft$^2$ for the building. No retail display was assumed in standalone retail, and grocery was not evaluated. The NEEA 2004 NC data found 0.08 W/ft$^2$ of display lighting installed in small retail, 0.07 W/ft$^2$ in large retail, and 0.04W/ft$^2$ in grocery. This was primarily provided by incandescent technology. When the NEEA 2004 NC and PNNL values are weighted by sector floor area, the total wattage is very similar.

Using the PNNL analysis framework to evaluate the OEESC 2014 to OSEC 2019 change estimates, the new code increases the display allowance by 250%. This is definitely a correct representation of strip mall spaces; however, display light that occurs in large retail might reflect a different degree of change.

This analysis used the PNNL approach, but decreased the spaces in strip mall and added calculations for standalone retail and grocery to better align with the frequency of display lighting in the NEEA 2004 NC data.

**Table 22. Display Light Calculations (W/ft²)**

| PNNL Analysis Technique | | | OEESC 2014 | | | OSEC 2019 | | |
|---|---|---|---|---|---|---|---|---|
| **Strip Mall Zone** | **Area** | **Area with display light** | **Display Allowance** | **Display Adder** | **Display LPD** | **Display Allowance** | **Display Adder** | **Display LPD** |
| Large store 1 | 3749 | 0.25 | 1.4 | 0 | 0.35 | 1.05 | 1000 | 0.53 |
| Small store 1 | 1874 | 0.25 | 1.4 | 0 | 0.35 | 1.05 | 1000 | 0.80 |
| Small store 2 | 1874 | 0.25 | 0.6 | 0 | 0.15 | 0.45 | 1000 | 0.65 |
| Small store 3 | 1874 | 0.25 | 0.6 | 0 | 0.15 | 0.45 | 1000 | 0.65 |
| Small store 4 | 1874 | 0.25 | 0.6 | 0 | 0.15 | 0.45 | 1000 | 0.65 |
| **Strip Mall Total** | **22490** | | | | **0.125** | | | **0.316** |
| **MDK Analysis Technique** | | | | | | | | |
| **Strip Mall** | | | **OEESC 2014** | | | **OSEC 2019** | | |
| **Zone** | **Area** | **Area with display light** | **Display Allowance** | **Display Adder** | **Display LPD** | **Display Allowance** | **Display Adder** | **Display LPD** |
| Large store 1 | 3749 | 0.25 | 1.4 | 0 | 0.35 | 1.05 | 1000 | 0.53 |
| Small store 2 | 1874 | 0.25 | 0.6 | 0 | 0.15 | 0.45 | 1000 | 0.65 |
| Small store 3 | 1874 | 0.25 | 0.6 | 0 | 0.15 | 0.45 | 1000 | 0.65 |
| **Total** | **22490** | | | | **0.083** | | | **0.196** |
| **Stand Alone Retail** | | | | | | | | |
| Core Retail | 17227 | .15 | .6 | 0 | 0.09 | 0.45 | 1000 | 0.13 |
| **Total** | **22500** | **.15** | **.6** | **0** | **0.069** | | | **0.096** |
| **Grocery** | | | | | | | | |
| Core Retail | 32686 | .10 | .6 | 0 | 0.06 | 0.45 | 1000 | 0.08 |
| **Total** | **45006** | | | | **0.044** | | | **0.055** |

### A.4.3 Section 9.4.1.1 Interior Lighting Controls

The new code introduces several changes to lighting control requirements. Most involve subtle changes that result from changing from one code base, IECC/Oregon, to another, ASHRAE 90.1-2016. This change results in certain levels of complexity in teasing out differences. The significant changes are:

- New requirement for 50%-Off OS control in corridor, lobby, stairwells, storage >1000ft², and warehouse
- New requirement for OS or captive key control of the sleeping unit lights and switched plugs
- New requirement for automatic daylight controls in side daylight secondary zones
- Eliminates the OEESC 2014 exception which exempted all control requirements in spaces with LPD <0.5W/ft²

#### A.4.3.1 Interior Light Schedule Development

For this evaluation, lighting schedules were developed to reflect the controls of the OEESC 2014 and OCEC 2019 codes. The PNNL 90.1-2007 determination model schedules were used as a starting point. Several changes were made to the base schedules to capture adjustments for CBSA operating hours that were made as part of the BPA prototype development. The adjustments to the base schedules included:

- Large hotel corridor schedule set to always on rather than varying down to 10% at night
- Standalone retail hours extended ~3 hours earlier in the day per the BPA project and CBSA
- Strip mall retail maintained BPA schedules, which are shorter and simpler than PNNL schedules. Shorter is supported by CBSA data on small retail. In addition, adopting PNNL schedules adds complexity by establishing three different operating profiles in various spaces that would require changing all schedules.
- Midrise apartment residence schedule fractions, which range from 0.02 to 0.32 in the PNNL schedule, are quite low. The DOE reference building schedules are quite high. The two schedules were averaged to get schedule fractions from 0.0435 to 0.66.
- Schools. The BPA work established school operating schedules relying on CBSA hours or operation and the NEEP monitoring data. Both of these sources lead to much shorter operating hours than the DOE/PNNL schedules. For this code work, the PNNL schedules were the starting point. All lighting schedules except the secondary school gym, and corridors and lobby in both schools, were reduced from 14 hours per weekday to 11 hours, assuming the unoccupied period begins at 5pm rather than 9pm as assumed in the DOE/PNNL models. Corridor and lobby space occupied periods were reduced from 14 hours per day to 12 hours. The gym was maintained at 14 hours per day. The summer schedules were reduced from 12 hours per day semi-occupied to 8 hours semi-occupied.
- Hospital schedule occupied hours were increased in corridor and lobby spaces. Separate schedules were developed for patient areas from other critical care areas with patient areas having a reduced fraction of lighting on and other critical care areas having a higher fraction.

Further changes were made to reflect OEESC 2014 and OCEC 2019 control provisions by applying savings factors to the ASHRAE 90.1-2007 schedule values. Factors were applied to occupied and/or unoccupied hours. For consistency with national determinations, savings factors utilized by PNNL were used unless specific concerns led to use of a different factor. PNNL documentation indicates that the occupancy sensor control factors impact occupied and unoccupied hours, but based on the PNNL published models, this was inconsistently applied (e.g., school classroom and enclosed office factors are applied only to occupied hours, but large hotel storage is applied to occupied and unoccupied hours). This evaluation has tried to be consistent with the PNNL models. The final lighting schedules were used for both the code-to-code and current practice estimates.

#### A.4.3.2 Code Control Requirements

*Manual Light Reduction*

The OEESC 2014 requires manual light reduction controls in spaces with LPD ≥ 0.6 W/ft$^2$ with no occupancy sensor control, with exceptions for warehouse, storage, corridor, lobby, stairway, and restroom lighting. The OCEC 2019 requires manual light reduction controls in the same space types but does not exempt spaces with low LPD or with OS control. Savings from this measure come from occupants voluntarily turning off some of the lights. PNNL did not evaluate this measure since it was a manual control. Significant overlap exists between this measure and the automatic harvest provisions for daylighting in perimeter daylight zones, which have the maximum potential to reduce lighting from multi-level control. Because of the overlap, multi-level savings here are considered to be zero. A discussion of the savings without competition from automatic daylight harvest is included below.

This control allows occupants of most buildings to choose from three levels of illumination. Savings predictions in the literature for this measure are highly variable. A study monitoring bi-level lighting estimated savings as a fraction of lighting energy use to be 8% in schools and 17.9% in offices (ADM 2002). Savings were found in daylit and non-daylit spaces. Several important factors are not addressed in the study. First, the spaces were not new and do not represent current lighting systems or levels. Only spaces with lighting power over 1 watt per square foot were included. Some of the spaces may have had more light in one of the partial switch states than current codes allow.

The study also assumed that the baseline condition was all lighting on. While this might seem reasonable, the study found a significant number of occupied hours when all lighting was switched off. If one assumes that the baseline condition is a weighted average of the off and on conditions, the savings estimate in offices drops to 2.4% and is negative in classrooms. The authors of the study did not agree with this interpretation of the data and considered increased usage in classrooms a suspect conclusion.

Five percent reduction in lighting energy was chosen in the previous regional code evaluation to represent bi-level savings for whole buildings. With the interaction with perimeter daylighting, overlap in savings for this measure is likely pronounced.

*Occupant Sensor Control – 100% Off*

The control is required in the same spaces in both codes, except the OEESC 2014 requires occupancy sensor (OS) control in enclosed offices between 250ft$^2$ and 300ft$^2$ and in storage areas less than 50ft$^2$. No data exists on the distribution of spaces falling into these space types, although it has been deemed a limited amount.

OS control provisions of the OEESC were not explicitly addressed in all space types in previous evaluations, which limited the scope to enclosed offices and classrooms. However, the floor area model used in the previous evaluation overstated floor area in classrooms and enclosed offices relative to the current assumptions. When combined with the different

LPD assumptions used by evaluations in different code cycles, it was decided that calculating savings for the differences in evaluations and applicability would be a non-trivial endeavor with insignificant impacts on overall results. For this evaluation, OS control is assumed in the base OEESC 2014 code and no savings are attributed to it.

*Occupant Sensor Control – 50% Off*

The OCEC 2019 requires 50% off OS control in corridor, lobby, stairwells, storage >1000ft$^2$, and warehouse. OEESC 2014 has no such requirements. The OCEC 2019 does have an exception for spaces with LPD <0.8W/ft$^2$ that have HID lighting and have 30% off within 30 minutes. This exception is assumed to be only applicable in warehouse spaces due to lighting technology limits; unfortunately, the current technology saturation is unknown. This analysis assumes all warehouse lighting will be LED.

*Manual or 50% On*

The OCEC 2019 requires lighting have manual-on or auto 50%-on in most spaces except for corridor/lobby/restroom spaces, healthcare, and storage rooms <50ft$^2$. OEESC 2014 requires manual-on if the spaces are controlled by OS and also include daylight zones, but not if they are scheduled switching or do not have daylight zones.

The requirement for manual or auto 50%-on almost everywhere is a significant advantage to the ASHRAE 90.1 code. PNNL only evaluated savings in daylight zones, but having manual-on or auto 50%-on rather than 100% sweep-on clearly will save energy in non-daylit spaces. Scheduled-on is uncommon, but where it occurs, manual- or 50%-on would be preferable. In the case of OS-controlled spaces, manual- or 50%-on would also appear advantageous, especially in daylight zones that are too small for daylight controls.

PNNL evaluated this control in perimeter-enclosed offices, which would generally be too small for daylight control. Savings likely exist in other spaces as well, but this evaluation follows PNNL procedure and does not evaluate savings outside of perimeter enclosed offices. With modern lighting power densities, the ASHRAE 90.1 primary daylight zone wattage threshold would typically be a space between 200-300 ft$^2$, so automatic OS control is required in more or less all enclosed offices, and all but the biggest are exempted from daylight control.

*OEESC 2014 General Exceptions*

The OEESC has a few important general control exceptions. Manual controls are exempt in warehouse, parking garage, "single-tenant retail spaces," and spaces with LPD <0.5 W/ft$^2$. In these spaces, no manual switching is required, though presumably in most cases some sort of switching occurs. More importantly, other controls are not required, since only spaces required to have manual control are required to have lighting reduction, automatic-off, or daylighting controls.

For warehouse space types, it was assumed that the building lighting was switched off at night. For parking garage, no control action was assumed with lighting running 24/7. The way to interpret the applicability of the contiguous single-tenant retail spaces is unclear. The Oregon Building Code Division stated it only applies to retail businesses that are a single room and have no office or storage rooms. However, the language uses the term "space," which would apply to any retail space. Since most retail spaces will have lighting controlled to a set schedule anyway, and the applicability of this language is uncertain, it is assumed that lighting is off at night and that no other control is implemented.

The 0.5W/ft$^2$ exemption was pretty reasonable in 2008 when the guts of the OEESC were conceived, but now (and for some time) 0.5W/ft$^2$ is achievable in many space types. In previous code cycles, all spaces were assumed to exceed this threshold and savings were claimed for various applicable controls. To assume it applied now would require a negative savings term to adjust for the previous savings claims. Therefore, the base case for this analysis assumes all spaces with low LPD will be required to install applicable automatic controls.

Another OEESC 2014 exception limits automatic-off controls to buildings >2,000ft$^2$. In the NEEA 2004 NC data, only 5% of the small office space type would trigger this exception. Whether this threshold is applied to the permit area rather than to a building is open for interpretation. Strip mall buildings are always larger that 2,000ft$^2$ but the individual tenant spaces are often less than that. Assuming the building interpretation in impacted, the floor area is very small, and given some calculation difficulties, this exception is not accounted for.

**Table 23. Interior Lighting Control Savings Factors**

| Control Requirements | Code | PNNL Savings | Savings Fraction Assumed in Previous OEESC Evaluations | Adjustment Applied to 90.1-2007 Schedule |
|---|---|---|---|---|
| Classroom OS (includes lab classrooms) | OR14, OR19 | 32% (occupied hours) | 10% (all hours)- CEC work found savings of 32% but this assumed savings over no automated control rather than spaces with sweep controls. OS assumed to save 10% beyond sweep control | 20% (occupied hours) |
| Enclosed office OS | OR14, OR19 | 22% (occupied hours) | 20% | 22% (occupied hours) |
| Restroom OS | OR14, OR19 | 34% (occupied hours) | Not evaluated | 34% (occupied hours) |
| Storage <1000ft$^2$ OS | OR14, OR19 | 48% (all hours) | Not evaluated | 48% (all hours) |
| Dressing Room OS | OR14, OR19 | 10% (occupied hours) | Not evaluated | 10% (occupied hours) |
| Conference/Meeting Room | OR14, OR19 | Not evaluated | Not evaluated | 22% (occupied hours) |
| Corridor OS (50%) | OR19 | 35% (occupied hours) | NA | 35% (occupied hours) |
| Lobby OS (50%) | OR19 | 5% (occupied hours) | NA | 5% (occupied hours) |
| Stairwell OS (50%) | OR19 | 45% (occupied hours) | NA | 45% (occupied hours) |
| Storage >1000ft$^2$ OS (50%) | OR19 | 24% (occupied hours) | NA | 24% (occupied hours) |
| Warehouse OS (50%) | OR19 | 10% (occupied hours) | NA | 10% (occupied hours) |
| Automatic Controls in buildings 0-2000ft$^2$ | OR14 | 10% (all hours) | None | Not evaluated |
| Manual light reduction control | OR14, OR19 | Not evaluated, manual controls "are not counted for savings in PI" | Assumed to save 0% due to overlap with daylight harvest | 0% (occupied hours) |
| Manual On or 50% Automatic On | OR14, OR19 | Evaluated only in perimeter enclosed offices. Whole building schedule reduced 2.9%, 1.7%, and 1.3% in small , medium and large office respectively | OEESC 2014 required this in daylit zones with OS controls. Not previously evaluated. | Whole building schedule reduced 2.9%, 1.7%, and 1.3% in small, medium and large office respectively. |
| Egress Lighting | OR14, OR19 | The preliminary 90.1-2016 evaluation does a detailed analysis to ensure no more than 0.02W/ft$^2$ is on at night. | OEESC 2010 evaluation assumed savings were estimated at 4% of total lighting energy. | Reduce unoccupied lighting fraction by 20% |

Note: Many of these factors differ from the WSEC 2015 analysis, as it was discovered that the interpretation of the PNNL implementation of the OS savings factors differed from what is implemented in the published models. The factors here have been modified to reflect the conditions of published models following the 2014 model enhancement.

*Hotel/Motel Unit controls*
The OEESC 2014 requires hotel/motel sleeping units to have a master switch at the door and requires bathrooms to have OS control. The OCEC 2019 requires OS control for the bathroom lights and either OS or captive key control of the remaining lights and switched plugs. PNNL evaluated OS control of bathroom lights for the ASHRAE 90.1-2010 and bathroom OS control with captive key/OS control for the rest of unit for ASHRAE 90.1-2013. PNNL curves were taken from the ASHRAE 50% Advanced Energy Design Guide savings determination work. This evaluation uses the PNNL curves.

Note these curves discount the value of master switches and claim significant savings. The PNNL difference between the unit OS and the bathroom OS-only schedules is approximately 26%. For context, the CEC chose savings of approximately 16% for unit OS, which it states is conservative. PNNL also modeled at 17% reduction in plug loads for the switched receptacles.

**Daylighting Controls**
The OCEC 2019 requires automatic daylight controls for which the primary side daylight zone has >=150W, the primary and secondary side daylight zone has >=300W, and where top daylight zones are =>150W. Lighting is required to have two intermediate steps and off. The OEESC 2014 requires separate controls and manual switches in all daylight zones and automatic controls in primary side daylight zones >350ft$^2$ and top daylight zones >350ft$^2$. Lighting is required to have one intermediate step and off. The OEESC 2014 only requires daylight controls in the primary zone, and even there it does not require daylight control where OS control is implemented or where the LPD is <0.5W. Since the OEESC requires classrooms and conference rooms to have OS control, they do not need automatic daylight control.

Daylighting savings were previously calculated based on engineering calculations. With the new models, daylighting is handled explicitly and inputs for both the OEESC 2014 and OCEC 2019 are listed below.

The OCEC 2019 primary side daylight zone size threshold is more stringent than the OEESC for all spaces with an LPD greater than 0.43W/ft$^2$, which is to say for almost all spaces. The OCEC 2019 requires one additional intermediate step in stepped dimming situations. The requirements for daylighting in the secondary zone, the removal of the OS control exception, and the requirement that rooms over 2,500ft$^2$ have skylights (Secton A.1.3) and controls are new.

Neither code specifies minimum power for continuous dimming. LED lighting is purportedly much better in this regard, but power at dimmed conditions is never published. A 2015 NEMA presentation indicates that at 20% light, LED luminaire efficacy is equal to rated efficacy. Between 20% and 100% light, LED luminaires have higher efficacy than full power, and below 20% light the efficacy falls below full power conditions to about 10% power at 5% light, which easily meets code. Continuous dimming will be assumed in both codes to be 15% power, 5% light with the ability to switch off in side daylight spaces. The required illuminance is set to 550 lux in retail space, 500 lux in classroom, 375 in office, 300 in assembly areas and fine warehouse storage, and 200 in bulk warehouse storage.

**Table 24. Top Daylighting Assumptions**

| Building Type | Control Type[1] | | Illuminance[2] (lux) | Spaces required to have skylights | | |
|---|---|---|---|---|---|---|
| | OEESC 2014 | OCEC 2019 | | OEESC 2014 | OCEC 2019[3] Code-To-Code | OCEC 2019[3] Current Practice |
| School, primary | Stepped | Stepped | 500 | None | Gym | Gym, library, cafeteria |
| School, secondary | Stepped | Stepped | 500 | None | Library, auditorium | Gym, library, auditorium |
| Retail, stand-alone | Step 1 | Step 2 | 550 | Sales | Sales, back | Sales, back |
| Retail, strip-mall | None | Step 2 | 550 | None | One large store | Both large stores |
| Warehouse – storage | Step 1 | Step 2 | 300 fine storage/200 bulk storage | None | Bulk Storage | Bulk and fine storage |

1 – Daylight controls are assumed to switch to off. Continuous dimming is assumed to dim to 15% power and then off. Step 1 dimming assumes one step (50%) followed by off. Step 2 dimming assumes two steps (66%, 33%) followed by off.
2 - Control illuminance set points are derived from the PNNL 90.1 evaluations.
3 – Assuming space ceiling height >15 feet. Sites can exclude side daylight zones from the zone before applying the size threshold so that spaces larger than the threshold will have potential top daylight zones below the threshold.

**Table 25. Zones Modeled with Top Daylighting**

| Building type | Code-to-code | Current practice |
|---|---|---|
| Retail – Large | Sales, Storage | Sales, Storage |
| Retail – Small | 1 of large stores | Both large stores |
| School – Primary | Gym | Gym, library, cafeteria |
| School – Secondary | Library, auditorium | Gym, library, auditorium |
| Warehouse | Bulk storage | Bulk & fine storage |
| Warehouse Semiheated | Bulk storage | Bulk & fine storage |
| Warehouse Unheated | None | None |

Because of the ceiling height exception and OCEC 2019 requiring only 50% of the space to be in a daylight zone, daylighting is not required in many areas. For the code-to-code estimates, daylighting was modeled in a selection of spaces whose relative area roughly captures the amount of floor area that would be required to have top daylighting. For the current practice estimates, applicability is determined from the NEEA 2004 NC data (See

Table 18). Savings per square foot are determined by simulation and combined with the applicability factor.

**Table 26. Side Daylighting Assumptions**

| | Control Type[1] | | Fraction of Lighting Controlled[4] | | Spaces Requiring Daylight Control |
|---|---|---|---|---|---|
| **Building Type** | **OEESC 2014** | **OCEC 2019** | **Primary zone** | **Secondary zone[5]** | |
| Hospital | Continuous to Off | Continuous to Off | 0.56 | 0.21 | Lobby, various offices |
| Hotel, small | Continuous to Off | Continuous to Off | 0.29 | 0.29 | Lounge |
| Hotel, small | Continuous to Off | Continuous to Off | 0.26 | 0.26 | Front office |
| Hotel, small | Continuous to Off | Continuous to Off | 0.28 | 0.28 | Meeting room |
| Hotel, large | Continuous to Off | Continuous to Off | 0.07 | 0.07 | Lobby |
| Hotel, large | Continuous to Off | Continuous to Off | 0.39 | 0.20 | Café |
| Office, small | Continuous to Off | Continuous to Off | 0.24 | 0.03 | All |
| Office, medium | Continuous to Off | Continuous to Off | 0.38 | 0.14 | All |
| Office, large | Continuous to Off | Continuous to Off | 0.39 | 0.14 | All |
| Restaurant, fast food | Continuous to Off | Continuous to Off | 0.25 | 0.25 | Dining |
| School, primary | Continuous to Off | Continuous to Off | 0.28 | 0.28 | Cafeteria, Classrooms,[3] Lobby, Office, Library |
| School, secondary | Continuous to Off | Continuous to Off | 0.28 | 0.28 | Cafeteria, Classrooms,[3] Lobby, Office, Library |
| Warehouse | Continuous to Off | Continuous to Off | 0.29 | 0.10 | Office |

1 – Continuous dimming is assumed to dim to 15% power/2% light and then off. Step 1 dimming assumes one step (50%) followed by off. Step 2 dimming assumes two steps (66%, 33%) followed by off.
2 – Control illuminance set points are derived from the PNNL 90.1 evaluations.
3 – OEESC 2014 exempts spaces with OS control. Classrooms and conference rooms are zones which will not need daylight control for OEESC 2014 code runs.
4 – Fraction of lighting controlled is largely borrowed from PNNL 90.1-2013 evaluation. Schools are the exception; PNNL assumed 76% of corner classroom lighting and 56% of lighting in other classrooms is in daylight zones. This stems from having high glazing levels and ceiling height compared to NW field data and assuming corner classrooms have windows on two sides where most designs do not have extensive windows on the second side.
5 – OCEC 2019 only. For OEESC 2014 daylight control is not required in zones with OS control.

### A.4.4 C405.2.7 Exterior Lighting Power and Control

*Lighting Power*

Exterior lighting power in the BPA prototypes is set to match CBSA levels. The CBSA new vintage mostly predates the ASHRAE 90.1-2010 allowances found in WSEC 2012 and OEESC 2014. PNNL calculated a 10%–40% reduction in exterior lighting power based on the introduction of the new lighting allowances in ASHRAE 90.1-2007. The WSEC 2015 evaluation set baseline exterior wattage to 75% of CBSA wattages to account for new lighting sources and code allowances. This was adequate for the WSEC 2015 evaluation, which did not involve a change in exterior lighting power.

The OSEC 2019 changes exterior lighting wattages. The OEESC 2014 to OSEC 2019 increment is the same as the ASHRAE 90.1-2013 to ASHRAE 90.1-2016 increment. The PNNL 90.1-2016 determination (PNNL 2017) of exterior lighting power is calculated by combining code maximum allowed power with parking area, lit façade, and doorway assumptions based on NC3 data (Richman 2008) and designer interviews. The resulting values differ substantially from those calculated at 75% of the CBSA data. On a simple average basis, 90.1 exterior lighting power is lower than 75% of CBSA, but in large hotel, large office, full-service restaurant, and warehouse, the ASHRAE 90.1-2013 values are higher than the total installed wattage found by CBSA in buildings built between 2003 and 2012, a period in which lighting technology was on average less efficient.

The OCCE data represents more current construction and in comparison to the assumed ASHRAE 90.1-2013 determination wattage, found far less wattage in multifamily, retail, and schools and more wattage in office. OCCE sample sizes are small, and there is reason to suspect that some school lighting such as sports fields has not been counted due to the extremely low wattage.

For simplicity, the ASHRAE 90.1 determination values were used for the OEESC 2014 and OCEC 2019 lighting power. Using the ASHRAE values is justified by the poor quality of available audit data. NEEA 2004 NC data are outdated and the OCCE sample sizes are small. For the current practice estimates, lighting power was reduced by 10% to account for the difference between code allowance and actual installed wattage.

If the OCCE data turns out to be accurate, actual energy savings will be smaller because in two cases the total OCCE wattage is larger than the ASHRAE 90.1 determination delta wattage between ASHRAE 90.1-2013 and ASHRAE 90.1-2016. The PNNL assumptions are outdated as well. Exterior lighting appears to be increasing and some of the parking assumptions may not account for trends toward allowing less parking as cars are de-emphasized, particularly in high-rise residential.

*Parking Garage Lighting Power*

Parking garage lighting is included by energy codes in the interior lighting power budget. The evaluation models do not include an explicit garage area and the PNNL 90.1 determination models (Thorton et al. 2011, PNNL 2017)assume all parking is surface parking. Since allowances for parking garages and surface parking generally change together, this may be a reasonable assumption in the 90.1 work. However, with the OSEC 2019, parking garage wattages change less than those for surface parking and the two areas are subject to different control requirement changes.

For this evaluation, we have created a separate garage and surface parking lighting objects. NEEA 2004 NC data were used to determine the amount of parking provided in garages. The PNNL 90.1 determination parking lot areas were assumed to describe the total facility parking. Parking lot area was estimated as the difference between the PNNL parking area and the assumed garage area.

Table 27 presents the code budgets for exterior lighting used in the code-to-code estimates. The current practice estimates used values 10% lower. Table 28 presents parking garage lighting power assumptions. The code values are used directly for the code-to-code runs; for the current practice runs, the code power was adjusted to be no higher than the garage wattage found in the NEEA 2004 NC data. This significantly reduces OEESC 2014 code lighting power and in some cases reduces the OEC 2019 code power where the NEEA 2004 NC LPD exceeded both codes.

*Exterior Control*
The OEESC 2014 requires photocell or astronomic time clock control for lighting designated dawn-to-dusk. Lighting not designated dawn-to-dusk must have a photocell and time clock or an astronomic time clock. In addition, uncovered parking expected to operate more than 2000 hours a year must have motion sensor controls to reduce lighting by 33%.

The OSEC 2019 requires a photocell and time clock, or an astronomic time clock. It requires façade and landscape lighting to turn off automatically between 12am-6am or between business closing and opening, whichever is shorter. Some buildings open and/or close at times that lead to reduced savings from the 12am to 6am assumption; others are closed many more hours and, although not required to, turn lighting off for all closed hours. Other lights shall have controls to reduce lighting by at least 50% between 12am and 6am, or from one hour after close to one hour prior to open, whichever is less, or it shall have OS sensors that turn down the lighting 50% after 15 minutes of inactivity. Parking lot luminaires mounted <= 24 feet with greater than 78W are required to have OS control to reduce wattage by 50%. Covered vehicle exit and entrance areas are excepted from this requirement, as is other egress lighting.

Handling the baseline OEESC 2014 control creates issues. It requires a photocell and time clock for lighting not designated dawn-to-dusk. The OCEC 2019 changes require that lighting be separated into two groups (façade and landscape); there is no dawn-to-dusk category, and certain hours are specified for lighting to be off. The issue is how much lighting to assume is controlled by the time clock in the OEESC 2014, and what operation to assume. The ASHRAE 90.1 evaluation assumed no lighting was controlled by the time clock and that all exterior lighting was on all night, even though a time clock was required by the OEESC 2014. Exterior lighting constitutes a significant energy use, so simply assuming the time clock is not utilized in the base case produces a large amount of savings. This analysis assumed that 25% of buildings use the time clocks to turn off exterior lighting from 9pm to 6am, or one hour before and after closing, whichever is shorter. While this is not substantiated, it does create a way to reduce savings for the above considerations.

For OSEEC 2014, this analysis assumed 25% of non-24/7 buildings turn off entrance and façade lighting from 9pm until 6am or one hour before and after building close, whichever is shorter. Facilities with 24/7 operation (apartment, hospital, hotel, and residential care types) are assumed to not to reduce lighting at night since the buildings have round-the-clock operation.

The OEESC 2014 code requires parking lot lighting expected to be on more than 2000 hours to have OS 33% off control, which equates to 6 hours a day. This analysis assumed that only 24-hour facilities are required to meet this requirement and that lighting power will be reduced 26% from 9pm to 6am (2 hours of operation at full power). For non-24/7 facilities, this analysis assumed that only time clock control is required, and that it is utilized in enough facilities to reduce lighting 25% from 9pm to 6am or one hour before and after building close, whichever is shorter. Parking garage lights are assumed to be on 24/7.

For OSEC 2019, this analysis assumed 25% of non-24/7 buildings turn off façade and entrance lighting from 9pm to 6am or one hour before and after building close, whichever is shorter. The remaining 75% of façade lighting is assumed to comply with code and to turn off from 12am to 6am. The remaining 75% of building entrance lighting is assumed to be 50% off from 12am to 6am. Facilities with 24/7 operation (apartment, hospital, hotel, and residential care types) are assumed to not reduce lighting at night since the buildings have round-the-clock operation.

For OCEC 2019 parking lot lighting, this analysis assumed that 25% of non-24/7 building lighting is turned off from 9pm to 6am. For the remaining lighting (75% for non-24/7 and 100% for 24/7), this analysis assumed, where poles are likely to be over 24 feet in height (retail and warehouse), that lighting is reduced to 50% from 12pm to 6am; in facilities likely to have shorter poles with 50% OS control, lighting is assumed to be 39% (2 hours of full-on operation) off from 9pm to 6am.

OCEC 2014 requires parking garage luminaires to have occupant sensing controls to turn lighting down 30% when unoccupied. Garages with open sides are also required to have daylight control of the perimeter lighting to reduce wattage by at least 50%. This analysis assumes that 30% of garage lighting will be off as a result of this control combination.

**Table 27. Exterior Lighting Power Assumptions**

| Building Type | OEESC 2014 (W) Building façade | OEESC 2014 (W) Entries | OEESC 2014 (W) Parking Lot | OCEC 2019 (W) BuifaçadeFacade | OCEC 2019 (W) Entries | OCEC 2019 (W) Parking Lot | Parking Lot Pole |
|---|---|---|---|---|---|---|---|
| Apartment, high-rise | 222 | 0 | 1143 | 222 | 0 | 715 | ≤ 24’ |
| Apartment, mid-rise | 2493 | 0 | 4114 | 2493 | 0 | 2506 | ≤ 24’ |
| Healthcare—hospital | 2932 | 1669 | 845 | 2932 | 1499 | 515 | ≤ 24’ |
| Hotel, large | 4997 | 487 | 9588 | 4997 | 444 | 5831 | ≤ 24’ |
| Hotel, small | 573 | 247 | | 4497 | 400 | 5248 | ≤ 24’ |
| Office, large | 516 | 222 | 2867 | 516 | 203 | 1721 | ≤ 24’ |
| Office, medium | 11681 | 933 | 9594 | 11681 | 871 | 5908 | ≤ 24’ |
| Office, small | 467 | 410 | 4159 | 467 | 338 | 2600 | ≤ 24’ |
| Residential care | 46 | 134 | 642 | 46 | 104 | 401 | ≤ 24’ |
| Restaurant, full-service | 243 | 0 | 2245 | 243 | 0 | 1403 | ≤ 24’ |
| Restaurant, quick service | 111 | 50 | 881 | 111 | 38 | 547 | >24’ |
| Retail, stand-alone | 139 | 129 | 1939 | 139 | 111 | 1203 | >24’ |
| Retail, strip mall | 284 | 1375 | 2520 | 284 | 1174 | 1576 | ≤ 24’ |
| Retail, supermarket | 376 | 2957 | 3024 | 376 | 2248 | 1891 | >24’ |
| School, primary | 136 | 2116 | 781 | 136 | 1481 | 518 | ≤ 24’ |
| School, secondary | 398 | 3426 | 3823 | 398 | 2696 | 2391 | ≤ 24’ |
| Warehouse | 103 | 4135 | 1441 | 103 | 3560 | 903 | >24’ |

**Table 28. Parking Garage Lighting Power Assumptions**

| | Code-to-code | | Current Practice | |
|---|---|---|---|---|
| | **OEESC 2014** | **OCEC 2019** | **OEESC 2014** | **OCEC 2019** |
| Apartment, high-rise | 3572 | 2143 | 3572 | 2143 |
| Apartment, mid-rise | 8942 | 5365 | 8942 | 5365 |
| Healthcare—hospital | 0 | 0 | 0 | 0 |
| Hotel, large | 17522 | 10513 | 14018 | 10513 |
| Hotel, small | 1291 | 775 | 1291 | 775 |
| Office, large | 457 | 274 | 457 | 274 |
| Office, medium | 60778 | 36467 | 20421 | 20421 |
| Office, small | 7267 | 4360 | 4709 | 4360 |
| Residential care | 0 | 0 | 0 | 0 |
| Restaurant, full-service | 877 | 526 | 614 | 526 |
| Restaurant, quick service | 0 | 0 | 0 | 0 |
| Retail, stand-alone | 0 | 0 | 0 | 0 |
| Retail, strip mall | 0 | 0 | 0 | 0 |
| Retail, supermarket | 92 | 55 | 92 | 55 |
| School, primary | 55 | 33 | 37 | 33 |
| School, secondary | 158 | 95 | 105 | 95 |
| Warehouse | 9 | 5 | 9 | 5 |

### A.5 Completion Requirements

The 2014 OEESC requires that the means for test and balance be installed, but addresses nothing about actually doing test and balance. It also requires HVAC system documentation including drawings, submittals, O&M manuals, and narrative description. There are no requirements for commissioning.

The OCEC 2019 code has these same requirements and introduces explicit test and balance, HVAC commissioning, and lighting controls functional testing requirements to the Oregon code.

Test and balance is required in all buildings, to be completed in a manner that minimizes throttling losses. Buildings over 5,000ft$^2$ must have a requirement in the construction documents for a balance report to be provided to the owner.

The HVAC commissioning requirements in OCEC 2019 provide no specifics on what should be tested, other than reference to an Appendix E which in turn references an ASHRAE guideline. It requires buildings to have control elements "calibrated, adjusted, and in proper working condition." It requires the designer to provide detailed commissioning instructions for buildings over 50,000ft$^2$. Given the lack of detail, absence of preliminary or final commissioning reporting requirements, and no specified list of items to be tested in the code, levels of compliance with these limited requirements is difficult to predict. Code officials will have no "checklist" to verify compliance, and the impact will largely be up to interpretation by the local code official. While this may lead to real commissioning, it will largely depend on active enforcement of what testing means.

Section 9.4.3 requires that lighting controls be functionally tested by an individual not involved in their design or construction. A list of specific checks for OS, time switch, and daylight controls is provided, and code requires documentation certifying "meet or exceed" performance criteria.

Evaluations of commissioning requirements in other Northwest state codes have included savings. Details of the savings claimed from code-driven commissioning are discussed in Kennedy (2014), Appendix A. The basic method involved establishing a literature base savings rate for third-party commissioning and then assuming that code-driven savings capture a portion of that. The assumed savings from third-party commissioning are 22.4% of HVAC gas use, 15.7% of HVAC electric use, and 3.1% of interior lighting electric use; these savings are based on evaluations of largely owner-chosen third-party commissioning. Code-driven commissioning saved an assumed 10% of the above numbers in the early Washington code up to 25% for the more refined requirements in the current Washington code.

Due to NEEA's desire for a conservative savings assessment, coupled with concern that much of the savings from commissioning are already counted by assuming proper operation of various code requirements, commissioning is not evaluated.

### A.6 Metering

OCEC 2019 Sections 8.4.3 and 10.4.5 require all buildings over 25,000ft$^2$ to meter all fuels hourly and to implement electrical submetering.

OCEC 2019 requires metering equipment to record hourly data and generate reports on a minimum of 36 months of data. Submetering equipment requires automatic connection to a digital control system, if installed, with graphical display. In situations with no digital control system installed, reports should be made available. Data displayed or reported shall include the most recent 36 months. Almost all buildings over 50,000 ft$^2$ have some sort of data collection and display systems installed. This code provision requires installation of energy meters and connection to the energy management system, typically requiring five or six data points: pulse output from gas and electric utility meters (and sub-metering for total), HVAC, interior lighting, exterior lighting, and receptacles. Buildings with HVAC components distributed in multiple locations may require additional sub-meters and associated wiring.

Metering saves energy by bringing awareness to and facilitating understanding of energy use patterns. Meter installation significantly decreases the effort involved in diagnosing high energy use or energy use changes. Metering does not save energy directly; instead, it helps initiate and target energy saving activities that might otherwise not be undertaken for lack of information.

Energy savings from metering are highly uncertain. The US Department of Energy (2011) published information for federal facilities managers trying to implement federal regulations requiring cost-effective metering. Savings are estimated to be 0%–2% for the "Hawthorne Effect" (which describes behavior change when subjects know they are being observed), 5%–15% for building tune-up, and 15%–45% for continuous commissioning. The US DOE publication recommended that federal facilities use at least 2% savings for evaluating the cost-effectiveness of installing metering. The US-DOE has since updated the publication to "Release 3" (USDOE 2015). The previous savings estimates have been replaced by a listing of three studies that show savings of 10%-20% when accompanied by intervention. The updated publication does not discuss doing a cost benefit calculation and mostly presumes that buildings are doing advanced metering. It makes no recommendation on minimum savings assumptions.

The WSEC 2012 analysis assumed savings of 2% of whole building energy use. The US DOE guidance was updated in 2014

Given concerns over the uncertainty of savings, and the concern that at least some of the savings overlap savings related to the correct functioning of other code provisions, the conservative assumption of no savings has been used in the OCEC 2019 evaluation.

**Table 29. End-Use Submetering Energy Savings Ranges – USDOE**

| Action | Observed Savings |
|---|---|
| Installation of meters | 0% to 2% (the "Hawthorne effect") |
| Bill allocation only | 2.5% to 5% (improved awareness) |
| Building tune-up | 5% to 15% (improved awareness and identification of simple O&M improvements) |
| Continuous commissioning | 15% to 45% (improved awareness, ID of simple O&M improvements, project accomplishment, and continuing management attention) |

# Appendix B: Oregon Commercial Energy Code 2019 Changes

Table 30 below provides a list of all changes in the Oregon energy code prescriptive provisions between the OEESC 2014 and OCEC 2019 codes. Green indicates increased efficiency with two tones, with very light green indicating items likely to have modest savings and the darker shade indicating larger savings. Peach shading indicates decreased efficiency with the light shade indicating slightly increased energy use and the darker shade indicating items with a larger increase in energy use. These determinations are based on subjective judgement of each item's impact on a situation and the frequency of the situation within the building stock.

**Table 30. Detailed Oregon Energy Code Changes from OEESC 2014 to OCEC 2019**

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| **90.1-2016 Chapter 4 Administration and Enforcement** | | | |
| 4.2.1.1 New Buildings – Modeling paths | 90.1-2016 includes two simulation paths, while the OEESC 2014 has the Section 506 whole-building approach. | No comparison has been made. | Not evaluated |
| **90.1-2016 Chapter 5 Building Envelope** | | | |
| 5.1.2 Space-condition categories – semi-heated - threshold | 90.1-2016 allows less heating capacity and limited cooling in spaces considered semi-heated. The allowed heat for Zones 4 and 5 is 8Btuh/ft$^2$ and 12btuh/ft$^2$ respectively, with up to 3.4 Btuh/ft$^2$ cooling. The OEESC 2014 allows 10btuh/ft$^2$ and 15btuh/ft$^2$ respectively, with no mention of cooling. | 90.1-2016 will allow fewer buildings to qualify for semi-heated. Buildings will either have to limit the heating capacity further, or insulate the building, to qualify. | Model based on NC2005 data |
| 5.1.2 Space-condition categories – semi-heated - treatment | 90.1 has reduced insulation requirements for all envelope components in semi-heated, increasing allowed conductance from 50% to 100%. The OEESC reduces only wall insulation by allowing buildings to drop the rigid insulation portion of the prescriptive R-value path. For mass walls, typically of semi-heated buildings this eliminates all insulation. | Both codes eliminate insulation on mass walls and significantly reduce wall insulation for other walls. 90.1 goes further in reducing the roof, floor, and window requirements, and also in eliminating continuous air barrier requirements. | Model based on NC2005 data |
| 5.1.3 Envelope alterations | Very similar requirements, except 90.1 requires 25% of all windows in the building to be replaced before the U-value needs to comply, whereas the OEESC requires this if 25% of all the windows in any one wall are replaced. | 90.1-2016 will apply this requirement to slightly fewer situations where only one side of a building is being changed. | Not evaluated |
| 5.1.3 Envelope alterations | 90.1 makes no provision for upgrading the envelope when HVAC alterations change the space conditioning category to conditioned from semi-heated or unconditioned, or to semi-heated from unconditioned. OEESC 101.4.3 requires buildings changing space conditioning categories to bring the envelope into compliance with the new category. | This is a significant oversight in 90.1, particularly in warehouse buildings. Unconditioned warehouse can move to semi-heated or fully conditioned, and semi-heated warehouse can move to fully conditioned without upgrading the envelope insulation. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 5.4.3 Air leakage | Both codes require compliance via materials, assemblies, or testing with slightly different language about the definition of each of those. | Open cell spray foam will no longer be automatically accepted. Non-fully-grouted CMU walls "painted to fill pores" will be automatically accepted. | Not evaluated |
| 5.4.3.4 Vestibules | Requires vestibules on most building entrances. 90.1-2016 has lots of detailed exceptions. It also set out some requirements for the vestibule to have a minimum distance between the inner and outer doors and to have automatic door closers. The OEESC is similar, but with fewer yet much broader exceptions, and with far fewer specifics on the vestibule itself. | 90.1 exempts buildings <1000ft$^2$, and doors from spaces that are <3000ft$^2$, as long as they are separate from the building entrance. How to interpret this later statement is very unclear. The OEESC 2014 exempts doors from all spaces <3000ft$^2$. As such, small strip mall-like buildings with entrances into spaces in the 1000ft$^2$ to 3000ft$^2$ range will now need vestibules. | Not evaluated |
| 5.5.3.2 Above-grade wall insulation | 90.1 defines the above-grade/below-grade division to be exactly at grade level, and requires insulation of a wall with both above- and below-grade to be insulated on the same side for both sections with below-grade insulated to its requirement and above-grade insulated to its requirement. OEESC defines walls with >15% AG area to be above-grade and those with <=15% to be below-grade. The whole wall is then insulated to the AG or BG spec based on that determination. | Different yet similar. Since below-grade wall insulation levels are reduced, the current OEESC is slightly more stringent since more walls will be considered AG than under 90.1. | Not evaluated |
| Table 5.5-4/5.5-5 | 90.1 nonresidential insulation requirements require more insulation in all components, opaque and fenestration, except for framed and below-grade walls and joist floors where the values are the same as the current code. Many of the improvements are by very significant margins (R30ci roof from R20ci and fully-insulated CMU walls from allowing only filled cores). In Zone 5, 90.1 values require more insulation in all but below-grade walls and joist floors. Group R requirement differences are similar. | In buildings that typically have a WWR less than 30%, 90.1 represents a significant improvement in required envelope insulation. In large and medium office buildings where WWR can be quite high, required improvements in insulation will be offset by the higher glazing fraction allowance in 90.1. | Model combined with maximum glazing limits based on impacts to NC 2005 buildings. |
| 5.5.4.1 Fenestration traits | 90.1 has 10% lower SHGC (0.36 vs. 0.40) and also requires VT to be 10% higher than SHGC. | Higher VT and lower SHGC will decrease energy use to a small degree. Not sure of impact as VT appears to typically be much higher than SHGC so this provision may not have significant impact on installed windows. | Model |
| 5.5.4.2.1/5.5.4.2.2 Fenestration/ skylight area | 90.1-2016 sets the maximum allowed WWR at 40% and maximum SRR at 6%, OEESC maximums are 30% and 3% respectively. | Significant difference. | Model combined with u-value requirements based on impacts to NC2005 buildings. |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 5.5.4.2.3 Minimum skylight fenestration area | 90.1-2016 requires a large number of space types that are >=2500ft$^2$ directly under a roof to have skylights with daylight controls. | New requirement. | Model |
| 5.5.4.5 Fenestration orientation | Requires buildings to have no more than 25% of the total window area on the east and on the west face of the building, or to have east and west SHGCxA values less than or equal to 20% of the SHGC budget. Exceptions exist if the WWR on those faces is >20% and the SHGC is 10% lower than code requirements, and also for street-level retail. | Very little basis for understanding the baseline considerations. Large office tends to have equal glazing levels by orientation, except for the lower floors, unless it is backed up to other properties. Calculate adjusted average code SHGC from NEEA 2004 NC data by assuming equal glazing in baseline and apply 90% of maximum SHGC to half of the buildings with <=20% WWR. Where WWR is >20%, apply formula assuming equal glazing. Add parameters to create SHGCew and SHGCns. | Not Evaluated (intended to) |
| 5.8 Product information and installation requirements | 90.1 has specific installation requirements such as insulation location, protection, and extent. OEESC currently contains very little of this language. | These are all good requirements that provide code officials with things to look for to identify proper installation and lead to improved, longer-life insulation. Identifying the impact of these requirements is impossible. | Not evaluated |
| 5.8.1.6 Recessed equipment | 90.1 requires all recessed equipment to be installed in such a way that insulation levels are not impacted, or so that the area weighted insulation conductance passes code. It mentions that air leakage through and around equipment shall be limited to comply with 5.4.3, but neither this section nor 5.4.3 offer any details. OEESC 502.4.7 Recessed Lighting requires ASTM 283-compliant fixtures and that they be sealed with a gasket or caulk. OEESC makes no mention of other recessed equipment or insulation levels. | 90.1 limits insulation impacts of all recessed equipment while the OEESC only limits and specifies install details for recessed lighting. The difference here is primarily whether 90.1 language requiring a continuous air barrier—but not even mentioning recessed fixtures in that discussion—will lead to proper selection and installation of recessed lighting fixtures. The current OEESC is very clear, but makes no mention of insulation impacts. The amount of commercial floor area with recessed lighting and equipment in exterior surfaces is unclear. | Not evaluated |
| 5.9 Inspection and verification | 90.1 provides an inspection checklist not currently in the OEESC. | Checklist will help code officials to get up to speed quickly on the new code, particularly on the air barrier details for which they should be checking. | Not evaluated |

| **Heating, Ventilating, and Air Conditioning** | | | |
|---|---|---|---|
| 6.1.1.3 Alterations to HVAC in existing buildings | Both codes require anything that changes to comply with code, except economizer capacity does not need to increase in most cases. | | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.3 Simplified approach option for HVAC systems | Expedited compliance for simple systems is available in both codes. Most but not all requirements are in sync with the non-simple path requirements. Optimum start is required only by the 90.1 simple path in equipment >10000CFM, whereas the main 90.1 path and the OEESC have no such limit. | | Not evaluated |
| 6.4.1.1 Minimum equipment efficiency | 90.1 extends maximum 0.75% jacket loss requirement to electric furnaces >225000Btuh. | This provision is not in the OEESC, but is not needed since the current 503.2.1.1 requires packaged electric equipment to be heat pumps, which will have jacket losses included in the performance rating. | Not evaluated |
| OEESC 503.2.1.1 "Package electric equipment" | 90.1 does not have a parallel to this OEESC section, which requires electric resistance in "unit and packaged electric equipment" >20000Btuh to have a heat pump as the primary source. This provision did not impact duct heaters or VAV reheat. | This could be a significant rollback in the code. With its removal, any package rooftop unit or water-cooled package will be allowed to have electric resistance heat instead of a heat pump. In the 2005 NEEA 2004 NC buildings, the saturation of single-package equipment with electric resistance heat in this size range is very limited, so this provision was not evaluated when it was introduced. It will therefore not be evaluated on its elimination. | Not evaluated |
| 6.4.2.2 Pump head | 90.1 requires pressure drop to be calculated for each device and pipe segment in the critical circuit. | This is likely the way most hydronic systems are handled. | Not evaluated |
| 6.4.3.3 Off-hour controls | 90.1 exempts units with heating and cooling capacity <15000Btuh from having a programmable thermostat, and it allows dwelling units to have weekday/weekend programing rather than 7-day. The OEESC exempts equipment with heating and cooling <=6800 Btuh from required programmable thermostats. | A fairly significant rollback, especially in the context of Group R occupancies where heating capacity is very likely to fall below the 90.1 limit. Individual baseboard heaters might also sometimes fall below the OEESC limit. This is difficult to quantify. | Not evaluated |
| 6.4.3.3.4 Zone isolation | 90.1 requires systems serving zones intended to be occupied non-simultaneously to be divided into isolation zones with dampers, valves, and controls. The OEESC 2014 requires systems serving multiple occupancies or floors to be divided into isolation areas unless the system has <240000 Btuh cooling or <300000 Btuh heating. | The 90.1 language is much better in terms of getting at the main issue, which is having areas with different uses in the same occupancy. It also does not exempt some sizeable systems. The OEESC would require different systems or isolation zones in different occupancies. The impact depends on interpretation of the word "occupancies," but it likely does not cover a situation in which a hospital has certain spaces that are 24/7 and others that are only 12 hours. The OEESC likely considers these the same occupancy. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.4.3.3.5 Automatic Control of HVAC in hotel/motel guest rooms | 90.1 requires motels/hotels with more than 50 rooms to have automatic controls that set up /back temperatures 4°F and turn off ventilation and exhaust fans when room is unoccupied for 30 minutes, and when room is unrented or unoccupied for 16 hours, shall automatically set heating/cooling set points to 60°F /85°F. Systems with a design heating capacity and design cooling capacity less than 15000Btuh are exempt. | While the OEESC has no parallel to this requirement, 90.1 shoots itself in the foot with the exception, which covers 90% of all motel/hotel systems. Review the hydronic fraction in NEEA 2004 NC. | Not evaluated |
| 6.4.3.4.3 Damper leakage | 90.1 increases allowed damper leakage from 4cfm/ft$^2$ to 10 cfm/ft$^2$. | Impacts will include a small but definite increase in infiltration and increased outdoor air being introduced into the space during warm-up when dampers are supposed to be closed. | Not evaluated |
| 6.4.3.4.4.5 Enclosed parking garage ventilation | 90.1 introduces exception to air quality modulation for garages with less than 1hp of fan power per 1500ft$^2$. | 1500ft$^2$/1hp is a generous threshold and likely results in the opportunity for many garages to avoid automatic controls. | Not evaluated |
| 6.4.3.5 Heat pump auxiliary heat control | 90.1 introduces exception for equipment regulated by NAECA. | Huge exception. This is typically controlled by the thermostat, and the HSPF calculation assumes perfect control, so this exemption is confusing. | Not evaluated |
| 6.4.3.8 Ventilation controls for high-occupancy areas | 90.1 has an exemption for systems with design OA <750; OEESC exempts rooms <500ft$^2$ with single-zone systems and rooms <150ft$^2$ served by multiple zone systems. | The 90.1 exception will exclude spaces up to 2500ft$^2$ that are served by single-zone systems. This will primarily impact school classrooms and media centers. | Model in single-zone school classrooms and media center |
| 6.4.3.9 Heated or cooled vestibules | 90.1 introduces requirements that vestibule heaters have automatic controls to turn them off when OAT is >45F and to be capable of and configured to have set points of 60°F/85°F. | | Not evaluated |
| 6.4.3.10 Direct digital control (DDC) requirements | 90.1 introduces requirements to have DDC in medium/large buildings with multizone systems with >=10bhp and in heating or cooling plants and their coils if capacity is >=300000Btuh. | Not sure this is much of a change from standard practice but it enables far superior system control. Could evaluate some specific controls. | Not evaluated |
| 6.4.3.12 Economizer fault detection and diagnostics | 90.1 introduces economizer FDD requirements for all systems with economizers. | Theoretically this should lead to be better economizer performance in the future, but studies that establish the degree of performance improvement are lacking. | Not evaluated |
| 6.4.4.1.4 Sensible heating panel insulation | 90.1 introduces requirements for the backside of sensible heating panels to be insulated to R3.5. | Not a common system type. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.4.4.1.4 Radiant floor heating | 90.1 introduces requirements for the backside of radiant floor heating to be insulated to R3.5. | Not a common system type in commercial. | Not evaluated |
| 6.4.4.2.1 Duct sealing | 90.1 specifies that only the duct tape used for sealing needs to be UL 1811 or B compliant. OEESC is silent on this matter. | | Not evaluated |
| 6.4.4.2.2 Duct leakage tests | 90.1 requires high-pressure ducts to be tested to 4 cfm/100ft$^2$ at 1 in of water. OEESC requires 6 cfm/100ft$^2$ at 1 in of water. | 90.1 is more stringent. Saturation of high-pressure systems is not well-known and the impact of leakage from ducts in unconditioned and indirectly-conditioned space is hard to quantify. | Not evaluated |
| 6.4.5 Walk-in coolers and walk-in freezers | 90.1 introduces walk-in refrigeration insulation, anti-sweat heater power, anti-sweat heater and defrost control, lighting efficacy, and condenser fan motor requirements. | Significant change that overlaps national standard. According to PNNL, the requirements are in line with standard practice as reported by Navigant in 2009. PNNL evaluated condenser fan and lighting only, and states the insulation, anti-sweat heater power and control are standard practice. | Not evaluated |
| 6.4.6 Refrigerated display case | 90.1 requires time switch or motion sensor lighting control, temperature-based defrost control with temperature and time limit bounds, humidity-based anti-sweat heater controls, and compliance with case efficiency tables, which are based on DOE standards. | Significant change. PNNL does not discuss or evaluate this change. This may be due to the absence of a PNNL grocery model. Savings overlap savings from DOE standards. The DOE Reference model would need extensive work-up to get proper deltas for this. | Not evaluated |

<table>
<tr><th>Section</th><th>Description</th><th>Comment</th><th>Evaluation Method</th></tr>
<tr><td>6.5.1 Economizers</td><td>90.1 <u>expands</u> the following exceptions:<ul><li>Places no limit on fan-cooling units <54000Btuh without economizer, while OEESC limits this to 240000Btuh or 10%</li><li>Systems serving building computer rooms in building with total computer room load <3,000,000Btuh, where building is not served by centralized chilled water plant</li><li>Computer rooms with cooling load <600000Btuh, where buildings served by centralized chilled water plant. The OEESC requires water side economizer in all new situations.</li><li>Dedicated systems for computer rooms classified as “essential facility,” Tier IV design, or spaces where financial clearing and settlement occur</li></ul>90.1 <u>adds</u> the following exceptions:<ul><li>1,400,000Btuh of chilled water cooling where no fans are used or where induced flow is used (chilled beams)</li><li>Systems that require non-particulate air treatment per 62.1, Section 6.2.1.</li><li>Systems with certain humidification requirements (hospital, process)</li><li>Residential spaces with <270,000 Btuh</li><li>Systems running less than 20 hours per week</li><li>Where outdoor air will affect supermarket open refrigerated casework</li><li>Where cooling equipment is 64% better in Zone 4C or 59% better in Zone 5B</li></ul>90.1 <u>eliminates</u> the following exceptions:<ul><li>For systems where internal/external heat recovery is used (aka WSHP and probably VRF). These are mostly smaller terminals that likely fall into 90.1’s unlimited <54000 Btuh exception, so removing this does not change much.</li></ul></td><td>90.1 introduces a large number of additional economizer exceptions, most importantly all small equipment and many more computer room exceptions. Buildings with less than 870kW of computer room equipment load are exempt. This covers the vast majority of server rooms outside of buildings with major data centers.</td><td>Not evaluated</td></tr>
<tr><td>6.5.1.1.3 High-limit shutoff</td><td>90.1 introduces requirements for acceptable economizer shutoff control type and required settings.</td><td>Important table, although equipment manufacturers may not interpret it the way code writers do. Trane Voyager units had a high limit shutoff control independent of the changeover control which was generally set to a lower temperature.</td><td>Combined simulation and engineering model</td></tr>
</table>

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.5.1.2.1 Fluid economizers design capacity | 90.1 greatly reduces the fluid economizer requirements for computer rooms to 100% at DB of 30°F with WB of 25°F. | 90.1 is really responsive to the computer room contingent that doesn't want economizers. None of the current models include a proper set of equipment rooms with fluid coolers and water-side economizer to model this easily. | Not evaluated |
| 6.5.1.2.2 Fluid economizer maximum hydronic pressure drop | 90.1 introduces a limit to the allowed hydronic pressure drop for fluid economizers. | Good requirement, but it should include an airside pressure drop requirement as well to hit condenser loop systems that add an extra coil to deliver water-side economizer. | Not evaluated |
| 6.5.1.3 Integrated economizer control | 90.1 requires DX units over 65,000Btu to be two-stage if controlled by space temperature and three or four stages if by discharge temperature. | A huge improvement in a very narrow slice of the equipment market. Almost all equipment over 90000 and half the equipment at 7.5 tons is already two-stage. | Not evaluated |
| 6.5.2.1 Simultaneous heating and cooling – zone controls | 90.1 directly outlaws reheating, recooling, and simultaneous heating and cooling systems. It then prescribes min air of 20% if DDC and 30% otherwise. It also limits reheat to 20°F above the space temperature. OEESC 2014 does not definitively outlaw reheating, recooling, and simultaneous heating and cooling, but prescribes air systems will be VAV and have min air of 20%. | 90.1 is much clearer but OEESC delivers the goods too and effectively forces DDC by requiring the 20% min air. Since 90.1 requires DDC when the fan system bhp is >10hp, and the number of systems smaller than this is limited, the impact here is likely negligible. | Not evaluated |
| OEESC 503.4.6 Limited use of air cooled chillers | OEESC limited air cooling chillers to 100 tons in plants with more than 300 total tons. 90.1 does not have this limit. | This is a rollback where applicable. Based on the NC 2005 data, a very small number of projects were impacted by this OEESC provision, as most either had smaller plants or were already water-cooled. | Model as reduction in average EER based on NEEA 2004 NC data |
| 6.5.2.3 Dehumidification | 90.1 has a specific section addressing dehumidification. The section requires a minimum air flow turndown of 50% or requires a significant portion of the reheating energy be from site-recovered heat before reheating occurs. OEESC completely exempts these systems from turndown requirements. | Technically a big change although the amount of dehumidification in the NW is limited and most people likely comply with these provisions anyway. Healthcare would be one application, but most of the impacted systems would already be exempt from turndown due to pressure difference and ventilation requirements. | Not evaluated |
| 6.5.2.4 Humidification | 90.1 requires jacket preheat to shut off when humidification is not needed and also requires some insulation in the humidification systems. | | Not evaluated |
| 6.5.2.5 Preheat coils | 90.1 requires preheat coils to be off when cooling is occurring. | | Not evaluated |
| 6.5.2.6 Ventilation air heating control | 90.1 limits supply air temperature of DOAS-like systems to 60°F when building loads or OAT indicate that the majority of zones require cooling. | | Not evaluated |
| 6.5.3.1.3 Fan efficiency | 90.1 introduces a requirement for fans and fan walls over 5hp to comply with a fan efficiency grade of 67. | This requirement was allegedly chosen to establish the metric without pushing efficiency too much, so savings are likely limited. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| Table 6.5.3.1-2 Fan power limitation pressure drop adjustment | 90.1 adds negative adjustments to reduce allowable fan power for systems without heating, without cooling, and with electric resistance heat. | Number of systems over 5hp without both heating and cooling is limited. The electric heat credit would be significant and will be going forward, but in comparison, the OEESC would require large electric resistance package equipment to be a heat pump. So this 90.1 provision just reduces the impact of the code rollback as a result of eliminating that heat pump provision. | Not evaluated |
| 6.5.3.2.1 Supply fan airflow control | 90.1 requires all DX cooling equipment >=65000Btuh and all chilled water/evaporative cooling equipment with fans >=0.25hp to have two-speed fans with ventilation and low cooling at no more than 66% speed (<40% power). OEESC requires DX >=110000Btuh to turn down to 66% speed and requires single-zone fan systems over 8000 CFM to have a turndown to 60%. | 90.1 reduces the threshold for requiring two-speed operation in a small slice of DX equipment and introduces the control to most hydronic single-zone systems. | Model |
| 6.5.3.2.3 VAV set-point reset | 90.1 requires VAV systems with system fan power exceeding 5hp to have static pressure reset. | Good requirement saving fan power. Hard to model. | Not evaluated |
| 6.5.3.2.4 Return and relief fan control | 90.1 requires relief fans over 0.5HP on systems with economizers to have variable speed drives or four or more speeds. | This is standard practice on larger systems; small systems typically use a relief damper without a fan. So impact is on medium-sized systems where it may also be standard practice at this point. Primary benefit is better pressurization control, but if done with a variable-speed drive, then savings would accrue. Prototype models do not have return fans; PNNL did not evaluate for that reason. | Not evaluated |
| 6.5.3.3 Multiple-zone VAV system ventilation optimization | 90.1 introduces requirement for VAV systems to automatically reduce outdoor air in response to changes in system ventilation efficiency. Exempts dual-duct dua-fan VAV and VAV with fan-powered terminals. | Great provision, but savings are limited by the requirement to not have fan-powered terminals, which is a minority situation in the NW. | Model |
| 6.5.3.4 Parallel-flow fan-powered VAV air terminal control | 90.1 requires parallel fan-powered terminals to turn off, except when heating required, and to turn on as the first stage of heating. | Purportedly parallel terminal fans are/were often set up to operate during ventilation-only hours and even low cooling in some cases. No basis for determining relevance. | Not evaluated |
| 6.5.3.5 Supply air temperature reset controls | 90.1 requires a 25% temperature reset. The OEESC 2014 requires a 35% reset. | 90.1 decreases the reset requirement. This increases cooling by decreasing economizer hours, and increases reheat energy but also decreases air flow and fan power for zones requiring cooling. | Not evaluated |
| 6.5.3.5 Fractional horsepower fan motors | 90.1 requires all motors from 1/12hp up to but not including 1hp to be ECM or 70% efficient unless it is in rated equipment, in heating-only situations with cycling fan, or are covered by new fractional hp efficiency tables. The OEESC 503.2.10.4 requires series fan-powered terminal fans to be ECM. | Significant change which is echoing national motor efficiency standards. May be difficult to evaluate. | Model in kitchen hood exhaust fans |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.5.3.7 Ventilation design | Limits the design ventilation to 135% of the calculated amount unless there is exhaust air heat recovery. | Good design guidance but not likely to have significant impact, especially since the designer gets to specify the design occupancy and number of people. | Not evaluated |
| 6.5.4.1 Boiler turndown | 90.1 introduces modulating boiler requirements. | | Not evaluated |
| 6.5.4.2 Hydronic variable flow systems | 90.1 increases the pump size threshold for VFD from >5hp to >=7.5hp for chilled water pumps and >=10hp for heating pumps. 90.1 requires modulation based on desired flow or differential pressure. If differential pressure controlled systems are used and there is DDC, the pressure set point must be reset downward until one valve is completely open. The OEESC requires modulation be done as "a function of load or other approved means" and does not require pressure reset. | Dropping the VFD requirement is a significant energy use increase to a small slice of total installed pump power. The control requirements decrease energy use and potentially impact a larger slice of pump power. | Not evaluated |
| 6.5.4.4 Chilled and hot water temperature reset controls | 90.1 requires temperature reset to be based on valve positions where DDC is used. | Savings here if DDC. Savings shared with requirement for DDC. | Not evaluated |
| 6.5.4.6 Pipe sizing | 90.1 establishes minimum chilled and condenser water pipe sizing requirements for the critical loops. | | Not evaluated |
| 6.5.4.7 Chilled-water coil selection | Sets cooling coil sizing limits requiring at least a 15°F delta between leaving and energy water temperature and a minimum leaving water temperature of at least 57°F. | Intended to reduce water flow and save pump energy. Can model where hydronic coils are modeled (hospital, school) by changing coil design temperature difference. | Not evaluated |
| 6.5.5.2 Heat rejection equipment – fan speed control | 90.1 lowers threshold for modulating fan control from >=7.5hp to >= 5hp and requires 50% turndown with 30% power vs. 33% turndown with no power spec. It requires multi-cell equipment to operate as many fans as possible at reduced speed rather than one or a few at full speed. | Significant change in smaller water cooling systems, but the population of small water cooling systems is limited. | Not evaluated |
| 6.5.5.3 Limitation on centrifugal fan open-circuit cooling towers | Requires towers with over 1100 gpm to comply with axial fan tower efficiency requirements. | In NW this is pretty exclusively applicable to hospital, lab, and a few offices. | Not evaluated |
| 6.5.5.4 Tower flow turndowns | Requires parallel operation of cells IF tower is configured with multiple or variable speed condenser water pumps. | Not sure this really does anything. Needs to require towers to have this pump set up | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.5.6.1 Exhaust air energy recovery | 90.1 makes major changes to this section. It introduces a new exemption for systems with <75% of exhaust air being exhausted within 20'. It also separates the requirements into systems operating <8000 hours/yr and those >= 8000 hours/yr. For the former, energy recovery is not required; for the latter energy recovery is required based on cfm for various OA fractions. The OEESC requires energy recovery if the system is >= 5000cfm with 70% or greater OA fraction. | For <8000-hour systems, 90.1 is a major rollback. Its applicability is uncertain since the number of high OA systems in this flow range is limited. Outpatient facilities likely have 100% OA systems that will no longer need ERV. For >=8000-hour systems, the flow thresholds are considerably reduced. In Zone 4C, 5000 cfm with 40-50% OA, 1500 cfm with 70-80% OA, and 100% OA systems over 120 cfm are required to have heat recovery. This provision will likely impact some healthcare systems, but most of those systems operate with higher flows that previously would have been required to have energy recovery, so the net effect is very likely a push. Residential buildings mostly utilize transfer air from corridor to unit and side wall exhaust from the units, so they would be exempt based on the 75% rule. Applicability to lodging is unknown; PNNL evaluated in residential but not in lodging. | Not evaluated |
| 6.5.7.2 Kitchen exhaust systems | For kitchens with >5000 CFM of hood exhaust, 90.1 requires maximum hood flows, limits compensating air, and requires 50% of replacement air to be transfer air or to have demand ventilation systems. The OEESC 2014 does not have maximum hood flows but requires demand ventilation systems for hoods in kitchens with >5000. There is an ambiguous exception when the hood is exhausting air that would otherwise be exhausted. Zones must have DCV or heat recovery. | Many facilities will be able to qualify for the 90.1 transfer air path at design OA. The OEESC would have resulted in reduced fan power in these cases since most kitchens are associated with spaces required to have DCV. As such, 90.1 is probably a rollback. The maximum flow rates might be important but little data is available on that point. | Evaluate in restaurant model |
| 6.5.8.1 Heating unenclosed spaces | 90.1 requires radiant heat but does not specify control. OEESC requires radiant heat with OS or timer switch control. | 90.1 is definitely the weaker code in this respect. | Not evaluated |
| 6.5.9 Hot-gas bypass limitation | 90.1 removes exception of packaged systems <=90000Btuh and lowers the % of total capacity allowed to have bypass to 15% from 50% for systems <=240000Btuh and to 10% from 25% for larger systems. | | Not evaluated |
| 6.5.10 Door switches | 90.1 requires door switches to disable heating and cooling or change set points to 55°F/90°F if the doors have been open for five minutes. It exempts loading docks and building entries with automatic closing devices. | A spring is an automatic closing device and most all commercial entries therefore qualify as having an automatic closing mechanism. PNNL models this is residential and lodging with a highly speculative set of assumptions and spreading out the impact that would be concentrated in a few units to all units. Could follow their path. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 6.5.11 Refrigeration systems | 90.1 introduces requirements for refrigeration condenser and compressor systems including design condition limits, requires all condenser fans to have variable speed capabilities to reset the condensing temperature based on OAT or OAWB, and adds floating suction pressure logic. | Good design and operation practices. PNNL determined this was a major measure in 90.1-2013, but does not quantify it and doesn't say why, perhaps because it assumed that it applied to grocery only, which PNNL does not model. The DOE Reference model would need extensive work-up to get proper deltas for this. | Not evaluated |
| 6.6.1 Computer room systems | 90.1 an alternate path for computer rooms that need to achieve a PUE0 and PUE1 for Zone 4C of <=1.38 and for Zone 5B of <=1.33. | Given all the economizer exceptions for computer rooms in the main path, people would be unlikely to use this. Perhaps it is even easier for computer rooms as the generous economizer exceptions elsewhere in code indicate an inclination to not require economizers in computer rooms. | Not evaluated |
| 6.7.2.3 System balancing | 90.1 requires test and balance of all air and hydronic systems to minimize throttling losses; air systems >1hp must have speed adjusted and pumps >10hp must have impellers adjusted to achieve design flows. OEESC requires that the means of testing and balance be provided, but does not require test and balancing be completed. | 90.1 requiring flow adjustments is a pretty significant deal. It is not a change from current practice in large projects, but for air systems in the 1-5hp range, it likely is. | Not evaluated |
| 6.7.2.4 System commissioning | 90.1 introduces a very short section requiring HVAC control systems to be tested, and for projects over 50000ft$^2$ excepting warehouses and semi-heated spaces, detailed commissioning instructions shall be included in the construction documents. OEESC has no parallel requirement. | It's unclear whether the 90.1 language triggers anything; it really gets down to what the code officials require. The language does not require reports and mentions no specifics other than "tested to ensure control elements are calibrated, adjusted, and in proper working condition." There is no formal testing process especially in projects >= 50000ft$^2$. In general, the installer can just say they tested the equipment. In larger projects the tests have to be written down, but there are no specifics regarding what that means. While it is possible this results in real commissioning, it is highly dependent on active enforcement of testing. | Not evaluated, per NEEA |

| Section | Description | Comment | Evaluation Method |
| --- | --- | --- | --- |
| Table 6.8.1 Equipment efficiency | Improves PTHP heating efficiency, SPVAC efficiency, SPVHP cooling efficiency, SPVHP heating efficiency for cap >10tons, adds reduced efficiency for non-weatherized space-constrained SPVAC & SPVHP units, lowers values for room air conditioners with louvered sides, improves values for gas hot water and steam boilers <300000 btuh, higher performance for axial/propeller-fan closed-circuit cooling tower, completely restructures computer room tables, adds tables for VRF, commercial refrigerator efficiency, indoor pool dehumidifiers, DX-DOAS units with and without heat recovery. | For tables present in OEESC, efficiency changes are limited. Improvements to PTHP heating efficiency, boilers <300000btuh, at one type of cooling tower. New tables are mostly purported to not significantly push performance. Display case efficiency would be difficult to model with the current resources. | No evaluation this cycle. PTHP and boilers evaluated last cycle. Commercial refrigerator efficiency change is part of standards change. |
| 6.4.4.1.2 Duct and Plenum insulation Table 6.8.2 minimum duct insulation R-Value | 90.1 specifies slightly more duct insulation for Zone 5B ducts outdoors and for all ducts in unconditioned spaces. 90.1 requires supply ducts in indirectly-conditioned spaces to have R1.9, whereas OEESC considers these spaces conditioned and requires no insulation. 90.1 reduces insulation (to R3.5) for runouts less than 10ft in length to terminals; this would only impact ducts outdoors or in unconditioned spaces. | Most ducts are located in indirectly-conditioned spaces, and the 90.1 duct insulation requirements will result in delivering more conditioning to where it is needed rather than above ceiling plenums and shafts. | Not evaluated |

| **Chapter 7. Service Water Heating** | | | |
| --- | --- | --- | --- |
| 7.4.2 Equipment efficiency, Table 7.8 performance requirements of water-heating equipment | 90.1 changes the water heater efficiency table to note that equipment is regulated by US DOE, and the value is not echoed in the table. Other non-DOE-regulated equipment has the same efficiency requirements as OEESC. | This is a great change that perhaps will limit time spent verifying compliance with obscure unpublished water heater efficiency ratings when it is all regulated by US DOE. | Not evaluated |
| 7.4.3 Service hot-water piping insulation | 90.1 requires slightly more insulation in general and requires insulation on the first 8’ of outlets from recirculation systems. Recirculating system piping must have 1” of insulation on pipe with diameters <1.5” and 1.5” of insulation on larger piping, and the first 8’ of piping outlets must insulated. For non-recirculated systems, 1” of insulation is required on the first 8’ of outlet piping, and 1” on the inlet piping between the tank and a heat trap. The OEESC requires 1” on recirculating systems and 0.5” on the first 8’ of outlet piping. It also requires a heat trap. | Many recirculating systems will have the same requirements; many will also have pipe diameters >= 1.5” and be required to have more insulation. PNNL evaluated the impact of requiring insulation on the recirculation system outlet piping, and that also is evaluated in this analysis. The increased insulation level is not evaluated. | Modeled |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 7.4.4. Service water-heating system controls | 90.1 adds requirements for tempering valves in public facility restrooms and circulation pump controls that limit circulation pump operation to the heating cycle. It eliminates the OEESC requirement for "demand sensing controls" that turn off the system when there is no demand while operational. | The IECC/OEESC demand sensing requirement is very controversial as to its viability and safety, and this IECC/OEESC provision is likely not enforced. | Not evaluated |
| OEESC 504.7.4 Heat recovery | 90.1 eliminates the OEESC requirement for heated indoor pools, spas, and hot tubs with surface area over 200ft$^2$ to have dehumidification with integral reheat and condenser heat recovery for water heating or exhaust air heat recovery. | Pretty significant measure in a limited number of cases. | Not evaluated |
| 7.5.3 Buildings with high-capacity service water-heating systems | 90.1 requires new buildings with >= 1000000 Btuh of water heating to have 90% Et gas heat or 25% of heat requirement made up by site-solar or site-recovered energy. Excludes tanks <=100000Btuh and tanks in dwelling units, | Pretty significant measure in lodging and hospital and any multifamily buildings with central service hot water systems. | Evaluate in engineering calculation |

| Chapter 8. Power | | | |
|---|---|---|---|
| 8.4.1 Voltage drop | 90.1 introduces wire sizing constraint by limiting the combined voltage drop across feeder conductors and branch circuits to 5% or less. | No idea whether this will change designs. | Not evaluated |
| 8.4.2 Automatic receptacle control | 90.1 requires 50% of receptacles in private offices, conference rooms, print/copy rooms, break rooms, classrooms, and individual workstations to have either a time clock control or OS control. Also, 25% of the branch circuits for modular furniture need to have the control. | Potentially a big savings, but if the control is a centralized time clock, the chance of a single problem area leading to the whole system getting disabled seems high. | Evaluated based on PNNL 90.1 determination schedules |
| 8.4.3 Electrical energy monitoring | 90.1 introduces requirement for submetering building energy use in buildings >= 25000ft$^2$ with tenant spaces >= 10000ft$^2$. Metering needs to cover total, HVAC, interior lighting, exterior lighting, and receptacles circuits. | Metering to facilitate troubleshooting in problem buildings and to track changes in energy use both have potential to result in significant savings in some fraction of buildings. Savings were claimed in WSEC 2012 analysis for metering that was less thorough on the electric side, but also required gas loads to be sub-metered. The basis for the savings value has been deemed poor-quality and is not used here. | Not evaluated |
| 8.4.4 Low-voltage dry-type distribution transformers | 90.1 increases efficiency requirements for three-phase dry-type low-voltage transformers but drops OEESC requirements that cover medium-voltage dry-type and low- and medium-voltage wet-type transformers. | Looking at standards may offer clues as to why 3/4 of the transformer types are no longer regulated. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| **Chapter 9. Lighting** | | | |
| 9.1.2 Lighting alterations | Very similar requirements, except 90.1 requires LPD compliance when more than 20% of the lighting load is changed and the OEESC requires it in spaces where 10% or more of the fixtures change to comply. For lamp/ballast changes, 90.1 sets a 20% threshold while OEESC is 50%. | Pretty similar, but lamp and ballast changes that impact between 20% and 50% of the lighting will have new treatment. | Not evaluated |
| 9.1.4 Interior and exterior luminaire wattage | 90.1 determines wattage as:<br>• Line voltage luminaire - the maximum luminaire rating<br>• Ballasted/driver luminaire – input wattage of MAXIMUM lamp/auxiliary combo<br>• Line voltage Track– fixture wattage of 30 W/LF, or current limiter<br>• Low-voltage Track – wattage of transformer<br>OEESC determines wattage as:<br>• Line voltage luminaire - the maximum luminaire rating<br>• Ballasted/driver luminaire – wattage of the lighting equipment<br>• Line voltage Track– fixture wattage of 50 W/LF, or current limiter<br>• Low-voltage Track – wattage of transformer | A bit of a compliance question, but using the maximum lamp criteria in fluorescent fixtures will generally result in a higher proposed wattage than using the installed lamp, so less light will be allowed. Similarly, the lumen package for an LED fixture also has a range than can be significant. Compliance documents rarely use the maximum lamp criteria, even though several NW codes have had that criteria in the past. | Not evaluated |
| 9.5 Building area method | 90.1 allows trade-offs between separate building areas while the OEESC does not. The 90.1 allowances are 10%-40% lower than OEESC, with most categories in the 15%-20% range. | Trading off between building areas keeps the method similar to the space-by-space path and likely doesn't impact overall lighting too much. The lower allowances are a big change and keep this path in line with the new space-by-space allowances. | Not evaluated |
| 9.6 Space-by-space method | 90.1 allowances, including retail display lighting, are from 33% higher (corridors) to 40% lower than OEESC with most categories in the 5%-20% lower range. 90.1 also allows increased lighting power when the rooms have a higher room cavity ratio than used to calculate the budget, an extra allowance when non-required lighting controls are installed, and up to 0.75W/ft$^2$ of lighting "for the purpose of decorative appearance or for lighting art or exhibits." This last group must be separately controlled from the general lighting. The OEESC allows higher budgets for higher ceilings. | The decorative appearance allowance includes wall sconces, and very likely cove light and art is hung on most walls. They do have to be separately controlled, but wall sconces are often combined with overhead lights to properly light a space. This likely heavily compromises the 90.1 code. | Model change in LPA |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 9.4.1.1 Interior lighting controls – manual | 90.1 requires these almost everywhere except for parking areas, bathrooms, and stairs. OEESC requires these except for parking areas, warehouses, lighting for single contiguous single-tenant retail spaces, and spaces with <0.5 W/ft$^2$. | The OEESC exemption for local switching is somewhat baffling, especially since spaces not required to have manual controls are not required to have any other control. Presumably this was meant to keep from requiring a switch for every 2000ft$^2$ in a warehouse; however, not requiring any switching means no controls. It's unclear how to interpret the applicability of the contiguous single-tenant retail spaces.Oregon Building Codes division thinks it only applies to retail businesses that are a single room, so those having no office or storage rooms are exempt. Since the language says space, it seems like it would apply to any retail space.<br>The 0.5W/ft$^2$ exemption was pretty reasonable in 2008 when most of the OEESC was conceived, but now (and for some time) 0.5W/ft$^2$ is achievable in many space types. | Not evaluated |
| 9.4.1.1d Interior lighting controls – light reduction (aka bi-level switching) | 90.1 requires light reduction in most space types except warehouse and storage and corridor/lobby/stair/restroom-type areas. OEESC requires light reduction in the same zones (all but warehouse and corridor/lobby/stair/restroom-type areas) but excludes areas with <0.6W/ft$^2$ and spaces with OS control. | With the exclusion of spaces with LPD <0.6W/ft$^2$, the OEESC is likely excluding many areas given the achievable LPD with LED lighting. The OS exemption also greatly reduces the applicability. | Evaluate using engineering model to estimate schedules for simulations |
| 9.4.1.1h Interior lighting controls – OS full off | 90.1 requires OS control on classrooms, lecture halls, conference and meeting rooms, lunch/break rooms, office spaces <=250ft$^2$, restrooms, dressing and locker rooms, and storage rooms between 50ft$^2$ and 1000ft$^2$. OEESC requires OS control on classrooms, lecture halls, conference and meeting rooms, lunch/break rooms, office spaces <=300ft$^2$, restrooms, dressing and locker rooms, and storage and supply rooms. A critical issue, however, is that this only applies to spaces with LPD >=0.5W/ft$^2$. The OEESC requires OS controls in daylight zones to be manual-on but otherwise they can be full-on. | The control is required in the same spaces as in 90.1, except the OEESC requires it in OS in enclosed offices between 250ft$^2$ and 300ft$^2$ and in storage areas between 0ft$^2$ and 50ft$^2$. Also, the OEESC provision is only required where manual control is required, and spaces <0.5W/ft$^2$ are exempted from that. So some restrooms, offices, and break rooms will be exempt. The 90.1 manual-on/auto-on to 50% requirement saves energy in non-daylight zones, but in daylight zones the requirement for manual-on only by the OEESC has the advantage. | Not evaluated |
| 9.4.1.1g Interior lighting controls – OS partial off | 90.1 requires 50% off OS control in corridor, lobby, stairwells, storage >1000ft$^2$, and warehouse. It includes a narrow exception for spaces with LPD <0.8W/ft$^2$ that have HID lighting and have 30% off within 30 minutes. OEESC has no such requirement. | 90.1 exception is likely only applicable in warehouse buildings due to lighting technology limitations.  Since LED saturation is large and increasing it is assumed exception is not important. | Evaluate |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 9.4.1.1i Interior lighting controls – automatic off | Both codes require automatic off in pretty much all areas of buildings, except OEESC exempts buildings less than 2000ft². It can be OS or scheduled in zones not required to have OS. **The OEESC requirements only apply to spaces with LPD >=0.5W/ft².** | | Evaluate |
| 9.4.1.1b/c Interior lighting controls – manual on | 90.1 requires manual-on/auto 50%-on in spaces except for the corridor/lobby/restroom spaces, healthcare, and storage rooms <50ft². OEESC requires manual-on if the spaces are controlled by OS and include daylight zones, but not if they are scheduled switching or do not have daylight zones. The OEESC requirements only apply to spaces with LPD >=0.5W/ft². | The requirement for manual-/partial-on almost everywhere is a significant advantage to the 90.1 code. PNNL only evaluated savings in daylight zones, but having manual-on rather than sweep-on and 50% auto rather than 100% clearly will save energy in non-daylit spaces. | Not evaluated |
| 9.4.1.1e,f Interior lighting controls – daylight | 90.1 requires automatic daylight controls where the primary side daylight zone has >=150W, the primary and secondary side daylight zone has >=300W, and where top daylight zones are =>150W. The OEESC requires separate controls and manual switches in all daylight zones and automatic controls in daylight zones >350ft². The OEESC does not require daylight control where OS control is implemented or where the LPD is <0.5W. 90.1 requires two intermediate steps and off while the OEESC requires one intermediate step and off. | With modern lighting power densities, the 90.1 primary zone wattage limit would typically be a space between 200-300 ft², so automatic control is required in more or less the same areas. The big difference is the OEESC OS control exception which would result in requiring at least classrooms and conference rooms to have OS control rather than automatic daylight control. | Evaluate using PNNL assumptions. Assume classrooms do not have in OEESC due to OS exception. |
| 9.4.1.2 Parking garage lighting control | 90.1 requires parking garages to have automatic shutoff, activity sensors that reduce lighting power by 30% when inactive for 20 minutes (zones up to 3600ft²), requires building entrance and exit lighting to be dimmed 50% at night, and requires automatic daylight control to reduce power by 50% where the net wall opening is 40%. OEESC has no requirements. | | Evaluate |
| 9.4.1.3 Special Applications – Separately Controlled | 90.1 introduces requirements that display and accent, display case, non-visual lighting (plant growth, food warming), and lighting for sale to be controlled separately from the general lighting. | A good provision that is mostly standard practice with the exception of display and accent lighting. | Not evaluated |
| 9.4.1.3 Special applications – guest rooms | 90.1 requires each guest room space to have automatic-off controls based on OS or captive key. Bathrooms are required to have separate occupant sensor. OEESC requires master switch by door that shuts off all lighting and switched receptacles except the bathroom. The bathroom must have OS control. | OS control likely trumps a master switch. | Evaluate |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| 9.4.1.3 Special applications – task lighting | 90.1 introduces requirement that task lighting (under shelf/under counter) be controlled by a switch on the luminaire on the wall in proximity to the light. | | Not evaluated |
| 9.4.1.4 Exterior lighting control | 90.1 requires all exterior lighting to have photocell control, requires façade and landscape lighting to turn off from midnight to 6am (or at close/open), and requires non-façade/landscape lighting to have OS control or scheduled control (midnight to 6am or one hour after close to one hour before open) to 50% off. OEESC allows lighting to be declared “dawn to dusk” and only have photocell control. Other lighting must also have time switch control. | 90.1 is considerably better | Evaluate |
| 9.4.1.4 Exterior lighting parking area | 90.1 requires parking lots to have OS control to 50% or less power if luminaire wattage is >78W and mounting height is <=24ft. Other fixtures would need to either have OS control or scheduled 12am–6 am (or one hour after/before closing/opening) to 50% power. OEESC requires parking lot lighting that will operate over 2000 hours/year to have motion sensors to reduce lighting power by one third. | 90.1 is more aggressive for >78W <=24ft height fixtures, but likely less aggressive in other fixtures for which OEESC gets 33% reduction for more hours. | Evaluate using engineering model to estimate schedules for simulations |
| 9.4.2 Exterior building lighting power | 90.1 allowances are from 0%-50% lower than the OEESC 2014 , with most being 20%-30% lower. | | Evaluate |
| 9.4.3 Functional testing | 90.1 requires that lighting controls be functionally tested by an individual not involved in the design or construction. A list of specific checks for OS, time switch and daylight controls is provided and code requires documentation certifying “meet or exceed” performance criteria. OEESC has no requirements. | This section is more detailed than the mechanical chapter testing requirements. | Not evaluated |
| 9.4.4 Dwelling units | 90.1 requires 75% of fixtures to have lamps with at least 55lm/W or luminaires with at least 45lm/W. OEESC requires 50% of the lamps to be high efficacy ( >= 40 lm/W if <=15 W, >= 50 lm/W if 15–40W, and >= 60 lm/W if >40 W). | High efficacy lamps in dwelling units will typically be 10W-30W, and in this size range, 90.1 has a higher requirement. The percentage change is significant though federal lamp standards potentially require all lamps to be high efficacy. | Evaluate |
| 9.4.4.1.1. Scheduled shutoff - egress lighting | 90.1 exempts automatic shutoff where it endangers safety or security of the room or occupants, and also up to $0.02 W/ft^2$. Both of these could be used for egress. OEESC 505.2.1.1 requires egress lighting to have listed emergency relay plus OS on all egress lighting that is not in building exits, as defined in Section 1002 of the Building Code. | Not clear what happens in Oregon, as proponents can claim the shutoff endangers safety. | Not evaluated |

| Section | Description | Comment | Evaluation Method |
|---|---|---|---|
| **Chapter 10. Other** | | | |
| 10.4.1 Electric motors | 90.1 introduces motor efficiency requirements to a wide range of general-purpose design A, B, C, H, and N motors between 1hp and 200hp to comply (oddly one of the tables goes to 500hp, but the text is explicit about 200hp). It also requires small polyphaser, capacitor-start capacitor-run, and capacitor-start induction–run motors between 0.25hp and 3hp to comply. | These are mostly standards-driven. PNNL evaluated 2010 changes, but not 2013 changes. | Not evaluated |
| 10.4.2 Service water pressure-booster systems | 90.1 requires pressure sensors to vary pump speed or turn it on/off, requires that no device reduces pressure to all the water coming out of the system except for safety devices, and requires pumps to be off when there is no service water flow. OEESC has no requirements. | Uncertain baseline. | Not evaluated |
| 10.4.3 Elevators | 90.1 requires cab lighting to be >= 35 lm/W, vent fan (in uncooled cabs) <=0.33 W/cfm, and OS control to off after 15 minutes on lighting and vent fans. | Uncertain baseline. Could model fans change per PNNL 90.1-2013 determination. | Not evaluated |
| 10.4.4 Escalators | 90.1 requires escalators to slow down when not in use. | Small number of installations. | Not evaluated |
| 10.4.5 Energy monitoring | 90.1 introduces requirement for non-residential buildings over 25000ft$^2$ and residential buildings with >= 10000ft$^2$ of common areas to monitor hourly energy use for each non-electric energy source (natural gas, fuel oil, propane, steam, chiller water, hot water) and to have a system capable of maintaining and summarizing 36 months of data. | Part of the 90.1 metering requirements. | Not evaluated |

# Appendix C: Base Model Adjustments

A great deal of development was required to prepare the base models and the modeling framework for evaluating new building energy codes. This work was done as part of the WSEC 2015 evaluation, but is repeated here. The base models were developed to model existing "real" buildings and did not have many of the controls required of new buildings. Work included:

- A large number of new parameters were required to model control strategies.
- To facilitate system modeling, every prototype template got a major rewrite of its system assignment portion, so there was only a single occurrence of each system specification. This was required to keep input manageable.
- Added skylights and daylighting to most single-story prototypes with the ability to specify whether skylights exist and the skylight-to-roof ratio for the daylit zones.
- Added ability to specify the window-to-wall ratio and to have the geometry adjust.
- Added ability to add conference rooms and specify the percent conference room in the medium and large offices to explore issues related to VRP sizing.
- Implemented a new infiltration treatment based on NIST research.
- Developed new inputs for outdoor air requirements.

This appendix addresses several aspects of the prototypes that were changed to better represent new construction. This is not a complete listing. In particular, Appendix A addresses several additional base model changes in discussing specific code provisions.

## C.1 Prototype WWR

Building gross wall, roof and floor areas are determined by the prototype geometry. However, the prototype geometry has significantly less surface area (roof and wall) per unit floor area than the NEEA 2004 NC data set. The regional average wall area per square foot of floor area is ~30% higher than represented by the prototypes. The regional average roof area is ~10% higher than the prototypes. Since code limits glazing as a percentage of wall area, window area is also 30% higher. In the last evaluation, prototype heat loss rates were adjusted so that the model heat loss rate per unit floor area agreed with the average code heat loss rate calculated from the NEEA 2004 NC data. This corrects for the difference in conduction but does not adjust for the large difference in solar.

The NEEA 2004 NC data—the basis for change—has not been updated in 12 years and represents 2002–2004 construction practices. Regional average surface area per unit floor area is likely larger than that captured by the prototype geometry, but this is uncertain given that building geometry is shifting over time.

Three cases were explored: no adjustment, adjustment for conduction differences, and adjustment for conduction and solar differences. The results are presented below:

**Table 31. Total Building Energy Use for Alternative Envelope Treatments (kBtu/ft²)**

| Building & Input Type Case | WWR | Prototype ua/ft² | Site kBtu/ft² | HVAC kBtu/ft² |
|---|---|---|---|---|
| **Stand Alone Retail** | | | | |
| Compliant prototype envelope | 8.1% | 0.147 | 47.0 | 22.7 |
| Conduction correction | 8.1% | 0.111 | 44.9 | 20.5 |
| Conduction and solar correction | 5.7% | 0.111 | 45.1 | 20.5 |
| **Small Office** | | | | |
| Compliant envelope | 18.4% | 0.086 | 33.1 | 12.8 |
| Conduction correction | 18.4% | 0.106 | 34.0 | 13.6 |
| Conduction and solar correction | 26.5% | 0.106 | 34.0 | 13.7 |
| **Large Office** | | | | |
| Compliant envelope | 41.1% | 0.042 | 34.5 | 8.4 |
| Conduction correction | 41.1% | 0.070 | 35.5 | 9.5 |
| Conduction and solar correction | 60.3% | 0.070 | 35.4 | 9.3 |

Using the models as constructed would reduce the importance of envelope loads. Correcting U-values and window area so that heat loss rate and window area per unit floor area matches NEEA 2004 NC will better represent the envelope load. Rather than more exterior surface, the building will have surfaces with higher heat loss areas and solar gain. This study chose to use the models with conduction and solar adjustments.

*School Window Area*

The NEEA 2004 NC data found the average WWR in schools was 12.3%. WWR in schools is almost certainly higher now than during the 2002–2004 period as a result of the emphasis on daylighting as a productivity enhancer. A spot check of two new schools found substantial window area, in the 25%–35% range, with high ceilings and window head heights. Another data point is the ASHRAE 90.1 evaluation prototypes, which assume a WWR of ~35% for schools. The evaluation team has decided to double the window area for schools. After the adjustment of conduction and window area for the geometry differences, the modeled WWR is 33%.

*Thermal Bridging*

The BPA prototypes implemented framing correction factors based on detailed studies by Morrison-Hershfield. For codes work, these thermal bridging factors were not implemented.

## C.2 Entry Door and Vestibule Infiltration

The Params framework has an entry door/vestibule template based on the same source work as the PNNL entry door/vestibule inputs. The template produced huge entry zone infiltration many times higher than PNNL estimates, and was not utilized in the BPA models. For this work, several modifications were made to the Params template to bring it closer to the PNNL work, including: setting door size to a single entry door rather than the total door area; using the PNNL peak people entering, rather than the summed zone occupancy for the number of door openings; and adjusting the calculation of the air flow coefficient to use interpolation/extrapolation at the lower and upper ends rather than relying on a curve fit. The template now produces values similar to PNNL, although some differences exist.

Deviations from the PNNL method include:

- Using straight line interpolation for hourly door openings below 30 results in flow coefficients very close to the values presented in the original work (RP-763). The PNNL values are as much as 100% higher for low numbers of door openings. PNNL likely used a curve fit or estimated the values from figures that lack precision rather than visiting the original data tables.
- Using a larger door size (30ft$^2$ vs. 21ft$^2$) in stand-alone retail, since in many cases the doors are a double slider rather than single-swing. This increases the infiltration in stand-alone retail by 43%.
- Spreading peak office entry over two hours rather than assuming everyone arrives at the same hour.

The assumptions used and resulting flows are presented in the next table. Entry door infiltration is treated as additive with the envelope leakage, which is based on envelope leakage with the doors closed.

**Table 32. Entry Door Infiltration—Comparison of NEEA Models with PNNL**

| | | | | | NEEA (cfm) | | | | PNNL (cfm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration with Vestibule | | Infiltration without Vestibule | | Infiltration with Vestibule | | Infiltration without Vestibule | |
| | Door Area (ft²) | Building height (ft) | Door-opening frequency | | | | | | | | | |
| Facility | | | Peak | Off-Peak | Peak | Off-peak | Peak | Off-peak | Peak | Off-peak | Peak | Off-peak |
| Large office | 21 | 156 | 970 | 92 | 9666 | 1367 | 13683 | 2085 | | | | |
| Medium office | 21 | 39 | 105 | 10 | 1441 | 130 | 2189 | 213 | 1438 | 188 | 2210 | 318 |
| Small office | 21 | 10 | 9 | 1 | 114 | 13 | 187 | 21 | 162 | 21 | 275 | 40 |
| Warehouse | 21 | 28 | 23 | 2 | 296 | 26 | 485 | 42 | 374 | 49 | 612 | 88 |
| Quick service restaurant | 21 | 10 | 90 | 9 | 1212 | 114 | 1851 | 187 | 1237 | 162 | 1913 | 275 |
| Sit-down restaurant | 21 | 10 | 57 | 6 | 763 | 76 | 1189 | 125 | 826 | 108 | 1302 | 187 |
| Strip mall, large | 21 | 17 | 34 | 3 | 441 | 38 | 713 | 63 | 511 | 67 | 824 | 118 |
| Strip mall, small | 21 | 17 | 16 | 2 | 204 | 26 | 335 | 42 | 285 | 37 | 471 | 68 |
| Stand-alone retail | 30 | 20 | 153 | 15 | 2904 | 274 | 4363 | 450 | 1986 | 260 | 3006 | 432 |
| Primary school | 21 | 13 | 580 | 58 | 5877 | 779 | 8460 | 1212 | 6423 | 840 | 9205 | 1323 |
| Secondary school | 21 | 26 | 1041 | 104 | 9443 | 1414 | 13341 | 2149 | 10837 | 1417 | 15161 | 2179 |
| Small hotel | 21 | 38 | 90 | 9 | 1238 | 117 | 1890 | 191 | 1254 | 164 | 1940 | 279 |
| Large hotel | 21 | 71 | 254 | 25 | 3312 | 338 | 4909 | 553 | | | | |
| Hospital | 40 | 78 | | | 0 | 0 | 0 | 0 | | | | |
| Outpatient healthcare | 21 | 30 | 123 | 12 | 1668 | 155 | 2521 | 254 | 1646 | 215 | 2513 | 361 |
| High-rise apartment | 21 | 100 | 115 | 13 | 1642 | 169 | 2486 | 277 | | | | |
| Mid-rise apartment | 21 | 40 | 46 | 5 | 623 | 65 | 983 | 106 | 694 | 91 | 1103 | 159 |
| Grocery | 30 | 20 | 153 | 15 | 2904 | 274 | 4363 | 450 | | | | |

## C.3 Envelope Infiltration

Infiltration levels in commercial buildings are highly uncertain. A simplified design flow rate method is used by both the DOE Reference buildings and the PNNL ASHRAE 90.1 modeling. The model takes a design flow rate, a scheduled multiplier, and four coefficients that determine wind and stack effect modifiers. The design flow rate and the coefficients are equal partners in the resulting infiltration. Unfortunately, coefficient inputs are not established based on much more than history, with projects assuming the original defaults used by older energy simulation programs (DOE2 or BLAST) or assuming constant infiltration (E+ default).

The DOE reference buildings and the BPA prototypes assume a constant flow of outdoor air with a design air leakage rate of 0.0595cfm per ft$^2$ of exterior surface (0.4 cfm/ft$^2$ above grade wall area at 75 Pa adjusted to 5 Pa). There is no variation due to wind speed or interior to exterior temperature difference. This is modified by an infiltration schedule that reduces the leakage 75% during HVAC equipment operation.

PNNL goes through a complicated analysis of the test leakage rate at 75 Pa to calculate a design flow. This design flow is developed based on the total above-ground surface area of the building, but for some reason is only applied to the walls. PNNL models also have additional entry zone infiltration, and there may be some justification for this. Even so, single-story buildings are predicted to have very low infiltration as a result of leaving out leakage through the roof. PNNL utilizes the DOE2 default coefficients which make infiltration 100% dependent upon wind speed. The calculated infiltration in each hour is the design rate times 0.224 times the wind speed, which is calculated at the building's location and average height (substantially less than at the weather tower at 30' located at an open airport, except for the large office).

While general agreement exists that pressurization due to operation of mechanical ventilation fans reduces infiltration, the average degree to which this is true is debatable. The DOE reference and PNNL 90.1 prototypes assume a 75% reduction in infiltration when the fans are on in most building types. For retail and restaurant they assume a 50% reduction in infiltration. The difference presumably accounts for entry door openings unaccounted for with a separate entry model in the high traffic building types.

Neither the reference building nor PNNL approach reflects the underlying physics. One method is constant flow with no change based on wind or stack; the other is 100% wind speed-dependent and assumes zero leakage through the ceiling. Building science indicates stack effect is the primary mover for most buildings, particularly smaller buildings that dominated the prototype suite, and stack is not part of the driving term of either method. While the reason for PNNL excluding ceiling leakage area (excluded fraction = gross roof area/(gross wall area + gross roof area) is not known, in the single-story prototypes it constitutes a huge reduction in leakage area, and is no doubt one reason PNNL infiltration is so low.

NIST recently developed a correlation between detailed multi-zone air flow model results, building traits, and the coefficients to use in the simplified infiltration model. One feature of the NIST model is that it explicitly accounts for some building pressurization in the model whereas the PNNL model uses a common modeling guess that infiltration during HVAC operation is reduced 75%. Based upon the required ventilation air and building shape, the NIST fan-on infiltration reduction varies. The reduction in small office is 35%–45%, in medium office is 60%–75%, and in stand-alone retail is 55%–60%. These results, based on detailed modeling with CONTAM, show considerably smaller reductions due to HVAC operation than assumed by the PNNL modeling, which is based on the very common modeling assumption.

Another feature of the NIST coefficients is that infiltration is dependent upon wind and temperature, whereas the PNNL coefficients are dependent only on wind. As a result, in the Seattle climate, infiltration in the NIST building varies winter to summer by a factor of 2. The PNNL building has one month, September, which is half of the peak, April, but all other months are within 8% or less of the mean. In the small office prototype, this leads to a much larger heating energy impact from the NIST method vs. PNNL's method.

The next table shows a comparison of average annual air changes per hour of the various approaches. The whole building results include the envelope infiltration and added infiltration in the entrance zone from door operation. The entry zone leakage is for an entry without a vestibule. The Building without Entry Zone results exclude the entry zone and yield a good comparison of the envelope models. The assumed whole building tested leakage rate is 1.0 cfm/ft$^2$.

**Table 33. Envelope Infiltration—Comparison of NIST Models with PNNL**

| **Case** | | **Small Office** | **Medium Office** | **Stand-Alone Retail** |
|---|---|---|---|---|
| Whole Building | BPA Assumption | 0.14 | 0.08 | 0.23 |
| | PNNL | 0.08 | 0.07 | 0.13 |
| | NIST | 0.40 | 0.07 | 0.26 |
| | PNNL adjusted | 0.15 | 0.07 | 0.24 |
| *Building without Entry Zone* | BPA Assumption | 0.13 | 0.07 | 0.23 |
| | PNNL | 0.04 | 0.03 | 0.02 |
| | NIST | 0.34 | 0.03 | 0.09 |
| | PNNL adjusted | 0.11 | 0.03 | 0.07 |

Small office whole-building infiltration varies by a factor of 5 between the NIST results and the PNNL method. For perspective, if the small office with a tested leakage of 1.0 cfm/ft$^2$ were treated as a single-family residence, the expected annual average infiltration would be approximately 0.35 air changes per hour. Pressurization from mechanical ventilation would be expected to reduce this and infiltration from door operation would increase it (significantly in retail and food service establishments). The medium office results are very similar between the models, presumably because of the reduced importance of the roof leakage. Stand-alone retail experiences an intermediate impact.

The PNNL adjusted case assumes leakage through the walls and ceilings rather than just the walls, and the vestibule model is modified as discussed in the vestibule section. The difference between the PNNL results and PNNL adjusted results is primarily driven by including roof leakage area; this helps to explain some of the differences between PNNL and the other methods in the small office and stand-alone retail models, which are single-story and have ceiling areas that make up a large portion of the exterior above-grade surface area.

The NIST prediction is at the upper end of realistic values for the small office, but produces more mid-range values for the other building types. This work chose to use the NIST model for the following reasons:

- Based on detail room-by-room air flow models
- Accounts for leakage of walls and roof rather than just walls
- Accounts for stack effect with higher leakage in winter
- Higher infiltration rates seem closer to truth than very low rates in small offices
- As discussed in the UA section, real-world wall and ceiling area is likely underestimated by the prototypes. Underrepresenting the wall and ceiling area per unit floor area will result in decreased infiltration. Choosing a method that produces a higher infiltration level will partially offset that.

The baseline leakage rates also generate considerable uncertainty. The primary air leakage data set has buildings from the whole country and is dominated by east coast buildings, particularly buildings in Florida. The data set also includes very few new buildings, although the data that is present shows no diminishment of leakage in new buildings. Second, the performance of the material and sealing paths in older codes and the requirement for an air barrier are highly uncertain.

A data set of 47 new building air leakage tests (Emmerich et al. 2005) were used in the ASHRAE 90.1-2010 evaluation. The data set characterizes leakage data on the basis of CFM per square foot of building surface area. These data show a mean leakage of 1.8 cfm/ft$^2$ at 75 Pa, although three extreme outliers in the data are responsible for moving the average from 1.0 cfm/ft$^2$ to 1.8 cfm/ft$^2$. The median is also 1.0 cfm/ft$^2$. The 2005 NIST paper (Emmerich and Persily, 2005) determined a mean of 1.54 cfm/ft$^2$ (ft$^2$ does not include floor), with higher levels in warehouse and lower in office for all climates. The paper also shows a strong correlation between air tightness and heating degree days, with much lower leakage rates in colder climates. The data shows an average of 0.99 cfm/ft$^2$ for climates with >2,000 heating degree days, with the caveat that they have little data for the western US.

PNNL chose to use the mean value of the aforementioned data set (1.8 CFM/ft$^2$) as the baseline. PNNL assumed that the code air barrier and envelope sealing requirements in the code would reduce the infiltration 45% to 1.0 CFM/ft$^2$, and that a testing requirement would be needed to reduce leakage further.

The current analysis assumes a baseline leakage of 1.0 CFM/ft$^2$ of exterior surface. Air barrier, sealing, and material language will be assumed to achieve a 45% reduction, and codes with testing requirements will be assumed to achieve the leakage consistent with the maximum allowed test result. This is “conservative” in that the lower baseline assumption means the sealing language will be assumed to reduce infiltration by 0.45 CFM/ft$^2$ compared with the 0.8CFM/ft$^2$ increment used in the ASHRAE 90.1 evaluation. In terms of a real baseline, this value may yet prove to be high.

For the WSEC 2012 code with testing requirements, the design leakage rate is assumed to be 0.0595cfm per ft$^2$ of exterior surface (0.4 cfm/ft$^2$ above-grade wall and roof area at 75 Pa adjusted to 4 Pa). For the OEESC 2014 and OCEC 2019, which only require an air barrier, the design leakage rate is assumed to be 0.0818 cfm per ft$^2$ of exterior surface (0.55 cfm/ft$^2$ above-grade wall and roof area at 75 Pa adjusted to 4 Pa).

## C.4 Mechanical

### C.4.1 Mechanical Ventilation

The BPA prototype mechanical ventilation levels in the base models do not reflect IMC code ventilation rates, and where exhaust hoods are present, the modeling of the hood is incorrect as it underestimates the fan power. Demand control ventilation is also not implemented in the templates.

Mechanical ventilation has a large impact on energy use and savings. During WSEC 2015 deliberations, Ecotope claimed that buildings are over-ventilated. Ecotope based its claim on spot field measurements of outdoor air from rooftop units with an assumption of occupancy type and density. The actual required ventilation rates were never calculated, fans operating continuously during ventilation were assumed (although many weren’t), and the measurement system used was deemed likely flawed for the application by the manufacturer of the flow testing device. A study in California found real-world ventilation in 40 buildings to be all over the map. On average, it found ventilation rates in approximately half the buildings to be less than the ASHRAE 62.1 requirements at default occupancy. This under-ventilation resulted from a myriad of causes, ranging from fans not operating during ventilation to inadequate damper settings. Unfortunately, the study did not report the average ventilation rate related to average ASHRAE 62.1 requirements.

Given the lack of data, ventilation has been assumed to comply with the IMC minimum requirements at IMC default occupancies for the space types. IMC minimum occupancy rates and required outdoor air volumes were calculated for each prototype based on the actual mix of spaces for which the model is explicit (e.g., schools) and upon a weighted average of assumed spaces where the prototype is not specific (e.g., office).

To allow EnergyPlus to size ventilation and properly handle DCV and multi-zone variable rate procedure calculations, the peak occupancy rates and per-person and area rates were input into the EnergyPlus models. Since the peak occupancy rates were often considerably higher rates assumed by the BPA/DOE reference models, for thermal gain purposes the occupancy schedules were scaled so that non-design schedules produced the same net occupancy as the model default occupancy rate and schedule.

### C.4.2 Demand Control Exhaust Hoods

The kitchen hood modeling was corrected in all prototypes with hoods. An explicit transfer air and dummy exhaust air flows parameters were added to the framework and all flows were specified.

**Table 34. Exhaust Hood Assumptions**

| Prototype | Hood Exhaust (cfm) | Kitchen MUA (cfm) | Transfer Zone | | |
|---|---|---|---|---|---|
| | | | Transfer Zone | Supply OA (cfm) | Transfer Air (cfm) |
| Restaurant, full service | 5400 | 3208 | Dining | 2192 | 2192 |
| Restaurant, quick service | 3300 | 2434 | Dining | 866 | 866 |
| Hotel, large | 4000 | 2000 | Dining | 2000 | 2000 |
| School, primary, kitchen | 4500 | 1500 | Cafeteria | 3154 | 3000 |
| School, primary, bathroom | 600 | 0 | Gym | 1153 | 600 |
| School, secondary, kitchen | 5400 | 1400 | Cafeteria | 6247 | 4000 |
| School, secondary, bathroom | 1200 | 0 | Gym | 10412 | 1200 |
| Hospital | 7200 | 3200 | Dining | 5286 | 4000 |
| Retail, supermarket-deli | 3000 | 290 | Sales | 3003 | 2710 |
| Retail, supermarket-bakery | 750 | 270 | Produce | 919 | 480 |
| Residential care | 3000 | 2400 | Dining | 1115 | 600 |

### C.4.3 Fan Power

Fan traits, efficiency and total static, are meant to capture the range of actual fan conditions and equipment sizes found in a given situation rather than the specific size of equipment that happens to get sized for the specific model zone. Model zoning and zone sizes are in no way typical of what is often installed. Small office systems are often a single air handler and rarely more than four; however, the small office prototype has five zones. Consequently, the equipment that gets sized by the model is smaller than the average installed unit. Assigning values meant to be sector averages eliminates this issue.

Fan power assignment was handled differently based on system type. The static pressure is consistent among prototypes. Hospital is an exception for which model static fan and fan motor efficiencies were not changed.

Non-hospital VAV systems were assigned fan efficiency and total static pressure consistent with code maximum fan power allowances for those systems, assuming no credits for filtration, heat recovery, or fully ducted return and no debits for lacking a cooling coil.

Single-zone systems were assigned based on the equipment typically installed in the spaces. Internal and external static pressure are highly variable and not well-characterized. In general, the larger the equipment, the higher the internal and external static pressure.

Detailed test data for single-zone air handlers including total static pressure were collected during development of the most recent California Database of Energy Efficiency Resources (DEER). For tests of 5–20-ton equipment, the average total static at the rated testing point was 1.7 inches. For equipment over 20 tons the average total static was 2.8 inches. Both of these are from Air-Conditioning, Heating, and Refrigeration Institute (AHRI) testing data. Presumably these tests reflect the lowest external static pressures allowed by AHRI for rating tests, which in general are very low, starting at 0.25 inches for 5-ton equipment. To make pressure drops more representative of typical installations, additional external static pressure was added to the above numbers. Small equipment (1–7 tons) was assumed to have an additional half inch, medium equipment (7–12 ton range) was assumed to have an extra inch, and large equipment was assumed to have an additional 1.5 inches. This resulted in total pressure drops of 2.2, 2.7, and 2.9 respectively. These values were assigned by the modeling team based on the prototype and the area type served.

# Appendix D: 2019 Oregon New Commercial Construction Code Evaluation

The 2019 Oregon Commercial Code Evaluation (OCCE) study provides data on current new construction practices that support many suspected building trends. Several baseline characteristics were examined from this data set; however, modification to the building prototypes was limited. OCCE data are limited to the office, retail, education, and mid-/high-rise residential building types, leaving no coverage for five modeled building types. In addition, each OCCE-sampled building type is represented by more than one prototype. Each prototype represents differing size and height categories or use types. This level of data was not available from the OCCE report. OCCE office characteristics would need to be used for small, medium, and large office prototypes which is not ideal. Several baseline characteristics were examined for potential modification from this data set, including:

Envelope
- WWR

HVAC
- Space heating fuel saturations
- Baseline space heating system types
- Service water heating fuel type
- Service water heating system type

Lighting
- Interior lighting power
- Exterior lighting power

Each data is discussed below, with a few recommended changes.

*Glazing area*
The baseline prototype window-to-wall ratios (WWR) are based on the NEEA 2004 NC geometry. The OCCE compares WWR between the OCCE data and the NEEA 2004 NC data. Several differences are apparent, but due to differences between studies, the small OCCE sample size, and the lack of detail within the OCCE building types, the differences are not actionable.

Standard deviations are not presented in the OCCE study, but a reasonable guess is that the differences between the studies fall within the standard deviation of the OCCE study and are likely due to differences in the selected style of buildings rather than to a definitive change in the overall building type. For example, the retail WWR difference is likely a function of type of retail, with small strip mall looking dominant in OCCE data whereas NEEA 2004 NC data contained large standalone retail establishments in addition to small strip mall. The difference in office is as likely to be the result of the OCCE-sampled buildings being primarily small and medium compared to the NEEA 2004 NC full size range as it is to any actual change. Only one OCCE office building was over 72,000ft$^2$. The education trend may be real, given the new emphasis on daylighting in schools.

**Table 35. OCCE Window % of Gross Wall Area**

| | Multifamily | Office | Retail | School |
|---|---|---|---|---|
| 2002-2004 New Commercial Baseline[1] | 24.5 | 28.9 | 13.5 | 13.9 |
| OCCE Study[1] | 27.1 | 23.5 | 22.5 | 18.6 |
| Modeled[2] | 15.0/25.0 | 14.8/24.2/43.4 | 14.3/6.3 | 13.4/11.0 |

1 – Data from OCCE report Table 12
2 – This is the target "sector WWR." The actual modeled WWR differs based on adjustments made to better capture overall NEEA 2004 NC geometry, which differs substantially from the PNNL prototypes.

*Space Heat Fuel and System Type*

The most important aspect for the OCEC data is the potential to update the baseline fuel saturations. In the code savings work there are three "fuel types"—electric resistance, electric heat pump, and combustion. Due to small sample sizes, the OCCE data do not represent building types representing 55% of floor area. Thus, the data could not be used to update the baseline fuel saturations across the board.

The OCCE data verify the obvious trend towards variable refrigerant flow (VRF) system types. VRF and chilled beam systems were not installed with any frequency during the NEEA 2004 NC sampling window.

The office building category, for which OCCE notes this trend as being most prevalent, is statistically weak with only seven buildings surveyed and those poorly distributed in terms of size. Only one building was larger than 72,000ft$^2$ and none was smaller than 15,000ft$^2$; as such, the office data represents only the medium office prototype aside from a single building representing the large prototype. This poor representation of the office category is partially reflected in the standard deviations in Table B9 of the OCCE report. The NEEA 2004 NC data found single-zone systems to be more prevalent than VAV in medium office, which casts further doubt on the nature of the transition.

The OCCE office data and the medium office data of NEEA 2004 NC show very similar fuel saturations. The shift in heating fuels and HVAC types discussed in the OCCE report is based on the assumption that the OCCE offices represent all offices where as the data largely represents medium office.

Heat pumps in schools and possibly retail appear to have decreased from past studies, but have greatly increased in multifamily. The multifamily fuel and system saturations used in the most recent code studies are from the 2014 RBSA, which had little data on Oregon high-rise residential as most of the sites were from Seattle. Cooling constitutes a significant issue in multifamily, relatively more important in Oregon whereas the Seattle buildings in RBSA had very little unit cooling. This difference may largely explain the very high saturation of heat pumps in multifamily as the hurdle to adding heat pumps is small once package cooling is installed.

The fuel saturation assumptions currently used in the code energy savings framework and the OCCE data are summarized below. Given the large difference in multifamily, the logical conclusion that Oregon has more heat pumps than represented in RBSA, and that OCCE has an adequate sample size (13) in multifamily, a change in the fuel saturation assumption seems warranted.

We chose to use the OCCE fuel saturation for both multifamily prototypes. The modeled system types remain largely unchanged except for multifamily, where the heating will be provided by PTHP. The OCCE office data shows a large presence of VRF, but the sample mostly represents medium office. Looking just at medium office there is very little change in the heat pump fraction. The NEEA 2004 NC data found significant numbers of water source and air source heat pumps. Since there are concerns about OCCE sample and since savings predictions are made through engineering adjustments for the non-modeled fuel types, no change is made.

**Table 36. Current Fuel Saturation Factors based on NEEA 2004 NC/RBSA**

| Building Type | Electric | Heat Pump | Gas |
|---|---|---|---|
| Apartment, high-rise | 0.90 | 0.02 | 0.09 |
| Apartment, mid-rise | 0.52 | 0.35 | 0.13 |
| Grocery | 0.01 | 0.00 | 0.98 |
| Hospital | 0.09 | 0.00 | 0.90 |
| Hotel, large | 0.30 | 0.28 | 0.41 |
| Hotel, small | 0.30 | 0.28 | 0.41 |
| Office, large | 0.60 | 0.02 | 0.18 |
| Office, medium | 0.30 | 0.40 | 0.30 |
| Office, small | 0.03 | 0.22 | 0.76 |
| Residential Care | 0.01 | 0.37 | 0.62 |
| Restaurant, full-service | - | 0.07 | 0.93 |
| Restaurant, quick service | - | 0.07 | 0.93 |
| Retail, stand-alone | 0.05 | 0.01 | 0.91 |
| Retail, strip mall | 0.03 | 0.16 | 0.81 |
| School, primary | 0.02 | 0.13 | 0.80 |
| School, secondary | 0.00 | 0.14 | 0.78 |
| Warehouse | 0.05 | 0.03 | 0.90 |
| Warehouse, semi-heated | 0.05 | 0.03 | 0.90 |
| Warehouse, unheated | 0.05 | 0.03 | 0.90 |

**Table 37. OCCE Heating Fuel by Building Type (% Floor Area)**

| Heating Fuel | Multifamily | Office | Retail | School |
|---|---|---|---|---|
| Heat Pump | 63.4 ± 8.3 | 40.6 ± 30.3 | 5.8 ± 11.0 | 5.4 ± 2.7 |
| Electricity | 26.5 ± 9.0 | 3.7 ± 3.0 | 2.5 ± 3.0 | 6.9 ± 1.5 |
| Natural Gas/Propane | 10.1 ± 1.6 | 55.7 ± 29.5 | 91.7 ± 13.7 | 87.7 ± ~4.8 |

*Water Heat Fuel and System Type*

The OCCE water heat fuel saturation data show a pronounced shift to gas water heat in multifamily, a lesser shift in office and retail, and school data similar to the NEEA 2004 NC data. The shift in multifamily is dramatic. The RBSA data are mostly from buildings that predate the OCCE study buildings by approximately eight years and are also dominated by buildings from Washington State. The OCCE sites may represent a particular segment of the multifamily sector more disposed to gas water heat. Luckily, few code changes impact water heat, so the choice here will not impact absolute savings. It will, however, impact overall electric EUI and therefore impact any measure of relative electric savings.

The evaluation team proposes to shift multifamily and large office electric saturations to reflect OCCE data.

**Table 38. Current Water Heat Fuel Saturation Factors (NEEA 2004 NC/RBSA)**

| | Electric | Non-Electric | Gas | Other |
|---|---|---|---|---|
| Apartment, high-rise | 0.82 | 0.18 | 0.18 | - |
| Apartment, mid-rise | 0.52 | 0.48 | 0.48 | - |
| Grocery | 0.25 | 0.75 | 0.67 | 0.08 |
| Hospital | - | 1.00 | 0.98 | 0.02 |
| Hotel, large | - | 1.00 | 1.00 | - |
| Hotel, small | - | 1.00 | 1.00 | - |
| Office, large | 0.48 | 0.52 | 0.36 | 0.16 |
| Office, medium | 0.37 | 0.63 | 0.63 | - |
| Office, small | 1.00 | - | - | - |
| Residential care | - | 1.00 | 1.00 | - |
| Restaurant, full-service | - | 1.00 | 1.00 | - |
| Restaurant, quick service | - | 1.00 | 1.00 | - |
| Retail, stand-alone | 0.57 | 0.43 | 0.42 | 0.01 |
| Retail, strip mall | 0.38 | 0.62 | 0.62 | - |
| School, primary | 0.05 | 0.95 | 0.91 | 0.04 |
| School, secondary | 0.07 | 0.93 | 0.93 | - |
| Warehouse | 0.76 | 0.24 | 0.24 | - |

**Table 39. Water Heat Fuel Saturation (OCCE Table B26) - % Installed Capacity**

| Water Heating Fuel | Multifamily | Office | Retail | School |
|---|---|---|---|---|
| Natural Gas | 87.3 ± 17.0 | 87.9 ± 18.3 | 63.8 ± 45.3 | 97.4 ± 1.4 |
| Electricity | 12.7 ± 17.0 | 12.1 ± 18.3 | 36.2 ± 45.3 | 2.6 ± 1.4 |

### Interior Lighting Power

The lighting power allowance in the last cycle was determined using the building area method based on the building area types found in the NEEA 2004 NC data. In the most recent WSEC 2015 analysis, this method of allowance determination was abandoned and building lighting power allowance (LPA) was determined using space-by-space allowances combined with the ASHRAE/IES space weights used in determining the building area allowances. This change was made due to issues with the space-by-space allowances, which were obviously very different from building area allowances, and also due to a desire to get away from using real building data with a mix of use types to inform a model of a pure building types. This new approach to lighting, which is proposed for use in this evaluation, is not informed by real building data so there is little reason to use the OCCE data.

However, the OCCE interior lighting is reported to be 16% to 40% below the code allowance. Code-to-code changes when the baseline lighting level is 40% below code will not represent the energy code savings accurately. The LPD reduction has occurred, although it was driven by technology rather than by code. Some of this is likely the result of OCCE using a unique determination of the building area allowance, particularly in education and retail. The OCCE code allowance is determined assuming the whole building is a single building area. All other codes break a building into occupancy areas; for example, gym and auditorium would typically be required to be broken out as separate building areas from education, and each tenant in a strip mall would be a separate building area, so a restaurant would get a different allowance from the retail space next door. Another issue is that it appears no re-categorization occurred for buildings found in the retail segment that didn’t contain a majority of retail floor area, which poses problems when trying to apply the results to models of pure building types. Even if one were to return to the previous “current practice” approach to lighting, the OCCE data still does not provide useable data because there is no building area summary from which to calculate lighting power allowance.

Another factor is the studied buildings are built under two different energy codes where the building allowances as applied by the audit team do not change, but several building area types and many space-by-space types do change, which may have impacted the actual buildings in the sample.

The ASHRAE/IES space weighted LPA was chosen for this study.

**Exterior Lighting Power**

The OEESC 2014 utilizes the ASHRAE 90.1-2010/2013 exterior lighting power allowances. Adopting 90.1-2016 will reduce exterior lighting power allowances in almost all outdoor areas and in parking garages.

The BPA prototypes modeled exterior lighting power based on CBSA data. The WSEC 2015 evaluation reduced the CBSA wattages by 25% for the base case WSEC 2012 lighting to account for new lighting sources and code allowances that are part of WSEC 2012. This was adequate for the WSEC 2015 evaluation which did not involve a change in exterior lighting power, but is not adequate for the current evaluation in which allowances change.

The OSEC 2019 changes exterior lighting wattages. The OEESC 2014 to OSEC 2019 increment is the same as the ASHRAE 90.1-2013 to ASHRAE 90.1-2016 increment. The PNNL 90.1-2016 determination (PNNL 2017) of exterior lighting power is calculated by combining code maximum allowed power with parking area, lit façade, and doorway assumptions based on NC3 data (Richman 2008) and designer interviews. The resulting values differ substantially from those calculated at 75% of the CBSA data. On a simple average basis, 90.1 exterior lighting power is lower than 75% of CBSA, but in large hotel, large office, full-service restaurant, and warehouse, the ASHRAE 90.1-2013 values are higher than the total installed wattage found by CBSA in buildings built between 2003 and 2012, a period in which lighting technology was on average less efficient..

OCCE data represents much more current construction and in comparison to the assumed ASHRAE 90.1-2013 determination wattage, OCCE found far less wattage in multifamily, retail and schools and more wattage in office. The school lighting in particular is extremely low in comparison to previous field work. Prevalence of the various exterior lighting categories is not broken out, making application of code changes difficult. The OCCE authors indicated that parking garage lighting is included with interior LPD, but could not provide an estimate of how much garage area was present.

For simplicity, the study proposes using ASHRAE 90.1 determination assumptions for various outdoor area types as the basis for calculating baseline and new code lighting power. This is partly justified by the poor audit data quality, the outdated NEEA 2004 NC data, and the small OCCE sample sizes. However, the assumed parking lot areas, which were based on parking needs, are modified to split parking between parking lots and garages based on garage saturation in the NEEA 2004 NC data.

**Table 40. Exterior Lighting Power Density (W/CFA)**

<table>
<tr><th>Building Type</th><th>75% of CBSA</th><th>90.1-2013</th><th>PNNL 2013 w/garage</th><th>OR2014 w/garage</th><th>OR2019 w/garage</th><th>OCCE LPD</th></tr>
<tr><td>Apartment, high-rise</td><td>0.08</td><td>0.07</td><td>0.10</td><td>0.15</td><td>0.09</td><td rowspan="2">0.04</td></tr>
<tr><td>Apartment, mid-rise</td><td>0.12</td><td>0.13</td><td>0.12</td><td>0.18</td><td>0.12</td></tr>
<tr><td>Healthcare—hospital</td><td>0.18</td><td>0.19</td><td>0.07</td><td>0.19</td><td>0.14</td><td></td></tr>
<tr><td>Hotel, large</td><td>0.12</td><td>0.06</td><td>0.07</td><td>0.08</td><td>0.06</td><td></td></tr>
<tr><td>Hotel, small</td><td>0.09</td><td>0.13</td><td>0.05</td><td>0.13</td><td>0.10</td><td></td></tr>
<tr><td>Office, large</td><td>0.09</td><td>0.10</td><td>0.03</td><td>0.10</td><td>0.07</td><td></td></tr>
<tr><td>Office, medium</td><td>0.09</td><td>0.11</td><td>0.06</td><td>0.09</td><td>0.08</td><td rowspan="3">0.2</td></tr>
<tr><td>Office, small</td><td>0.15</td><td>0.15</td><td>0.09</td><td>0.19</td><td>0.15</td></tr>
<tr><td>Outpatient healthcare</td><td>0.20</td><td>0.17</td><td>0.04</td><td>0.17</td><td>0.11</td></tr>
<tr><td>Residential care</td><td>0.07</td><td>0.07</td><td>0.02</td><td>0.08</td><td>0.06</td><td></td></tr>
<tr><td>Restaurant, full-service</td><td>0.35</td><td>0.98</td><td>0.12</td><td>0.98</td><td>0.65</td><td></td></tr>
<tr><td>Restaurant, quick service</td><td>0.35</td><td>0.21</td><td>0.03</td><td>0.21</td><td>0.14</td><td></td></tr>
<tr><td>Retail, stand-alone</td><td>0.24</td><td>0.19</td><td>0.07</td><td>0.19</td><td>0.14</td><td rowspan="2">0.22</td></tr>
<tr><td>Retail, strip mall</td><td>0.49</td><td>0.32</td><td>0.17</td><td>0.32</td><td>0.23</td></tr>
<tr><td>Retail, supermarket</td><td>0.11</td><td>0.05</td><td>0.03</td><td>0.05</td><td>0.03</td><td rowspan="2">0.02</td></tr>
<tr><td>School, primary</td><td>0.11</td><td>0.04</td><td>0.02</td><td>0.04</td><td>0.03</td></tr>
<tr><td>Warehouse</td><td>0.08</td><td>0.12</td><td>0.09</td><td>0.12</td><td>0.10</td><td></td></tr>
</table>

# Appendix E: End-use Energy Use Indices

**Table 41. Code-to-Code End Use EUI and Savings by Code**

| Apartment Mid-rise | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 9.0 | 8.5 | 6% |
| Cooling | 0.5 | 0.5 | 5% |
| Interior lights | 3.7 | 3.2 | 12% |
| Exterior lights | 6.0 | 4.0 | 34% |
| Interior equipment | 14.7 | 14.6 | 1% |
| Ventilation | 0.7 | 0.7 | 1% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 14.4 | 14.4 | 0% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 49.0 | 45.8 | 6% |
| Electricity (kWh/sf) | 10.1 | 9.2 | 9% |
| Gas (therms/sf) | 0.145 | 0.144 | 1% |

| Apartment High-rise | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 8.4 | 8.0 | 5% |
| Cooling | 0.5 | 0.5 | 1% |
| Interior lights | 3.8 | 3.2 | 14% |
| Exterior lights | 4.1 | 2.0 | 51% |
| Interior equipment | 12.8 | 12.8 | 0% |
| Ventilation | 0.6 | 0.6 | 1% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 12.8 | 12.5 | 2% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 42.9 | 39.6 | 8% |
| Electricity (kWh/sf) | 8.8 | 7.9 | 10% |
| Gas (therms/sf) | 0.129 | 0.126 | 2% |

| Hospital | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 55.3 | 52.7 | 5% |
| Cooling | 13.9 | 15.0 | -8% |
| Interior lights | 15.7 | 16.2 | -3% |
| Exterior lights | 2.4 | 1.2 | 52% |
| Interior equipment | 25.2 | 24.4 | 3% |
| Ventilation | 17.2 | 16.8 | 3% |
| Pumping | 3.5 | 3.6 | -3% |
| Hot water | 4.7 | 4.2 | 11% |
| Other | 19.1 | 19.0 | 0% |
| Total (kBtu/sf) | 157.1 | 153.1 | 3% |
| Electricity (kWh/sf) | 28.0 | 27.7 | 1% |
| Gas (therms/sf) | 0.616 | 0.587 | 5% |

| Lodging - Hotel | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 7.6 | 7.4 | 3% |
| Cooling | 1.8 | 1.6 | 12% |
| Interior lights | 11.3 | 10.3 | 9% |
| Exterior lights | 1.8 | 1.2 | 33% |
| Interior equipment | 13.5 | 12.7 | 5% |
| Ventilation | 8.1 | 7.9 | 2% |
| Pumping | 0.1 | 0.1 | 11% |
| Hot water | 17.2 | 14.9 | 13% |
| Other | 17.5 | 17.5 | 0% |
| Total (kBtu/sf) | 78.9 | 73.6 | 7% |
| Electricity (kWh/sf) | 14.0 | 13.2 | 6% |
| Gas (therms/sf) | 0.311 | 0.287 | 8% |

| **Lodging - Motel** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 4.9 | 4.2 | 14% |
| Cooling | 3.0 | 2.8 | 5% |
| Interior lights | 7.3 | 6.4 | 12% |
| Exterior lights | 1.4 | 0.8 | 41% |
| Interior equipment | 13.7 | 12.9 | 6% |
| Ventilation | 3.6 | 3.5 | 4% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 13.9 | 12.2 | 12% |
| Other | 9.3 | 9.3 | 0% |
| Total (kBtu/sf) | 57.0 | 52.1 | 9% |
| Electricity (kWh/sf) | 9.2 | 8.3 | 9% |
| Gas (therms/sf) | 0.257 | 0.237 | 8% |

| **Office - Large** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 2.0 | 2.0 | -3% |
| Cooling | 1.9 | 1.9 | 0% |
| Interior lights | 8.1 | 6.2 | 24% |
| Exterior lights | 4.2 | 1.8 | 57% |
| Interior equipment | 29.1 | 28.0 | 4% |
| Ventilation | 4.0 | 3.8 | 4% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 1.0 | 1.0 | 0% |
| Other | 3.6 | 3.6 | 0% |
| Total (kBtu/sf) | 54.0 | 48.5 | 10% |
| Electricity (kWh/sf) | 15.3 | 13.7 | 11% |
| Gas (therms/sf) | 0.018 | 0.019 | -2% |

| **Office - Medium** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 2.1 | 2.1 | 1% |
| Cooling | 2.2 | 1.9 | 13% |
| Interior lights | 8.3 | 6.7 | 19% |
| Exterior lights | 5.2 | 2.2 | 57% |
| Interior equipment | 14.3 | 13.3 | 7% |
| Ventilation | 4.6 | 4.4 | 5% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 1.4 | 1.4 | 2% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 38.0 | 31.9 | 16% |
| Electricity (kWh/sf) | 10.6 | 8.8 | 17% |
| Gas (therms/sf) | 0.019 | 0.019 | 1% |

| **Office - Small** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 4.6 | 3.9 | 14% |
| Cooling | 0.9 | 0.8 | 14% |
| Interior lights | 8.5 | 7.3 | 14% |
| Exterior lights | 1.8 | 0.9 | 52% |
| Interior equipment | 9.1 | 8.3 | 9% |
| Ventilation | 2.6 | 2.4 | 9% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 3.1 | 3.1 | 0% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 30.6 | 26.8 | 13% |
| Electricity (kWh/sf) | 7.8 | 6.8 | 12% |
| Gas (therms/sf) | 0.040 | 0.035 | 14% |

| **Residential Care** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 5.0 | 3.8 | 25% |
| Cooling | 2.6 | 2.6 | 1% |
| Interior lights | 11.6 | 12.7 | -9% |
| Exterior lights | 1.2 | 0.6 | 48% |
| Interior equipment | 9.0 | 9.0 | 0% |
| Ventilation | 4.8 | 4.8 | -2% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 10.0 | 9.9 | 0% |
| Other | 19.8 | 19.8 | 0% |
| Total (kBtu/sf) | 63.9 | 63.2 | 1% |
| Electricity (kWh/sf) | 8.9 | 8.9 | -1% |
| Gas (therms/sf) | 0.337 | 0.327 | 3% |

| **Restaurant – Full Service** | | | |
|---|---|---|---|
| **End Use (kBtu/sf)** | **2014** | **2019** | **% Savings** |
| Heating | 73.7 | 72.4 | 2% |
| Cooling | 3.9 | 3.6 | 6% |
| Interior lights | 14.3 | 12.5 | 12% |
| Exterior lights | 4.9 | 2.6 | 46% |
| Interior equipment | 72.0 | 71.9 | 0% |
| Ventilation | 16.9 | 16.8 | 1% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 73.2 | 73.1 | 0% |
| Other | 91.2 | 91.2 | 0% |
| Total (kBtu/sf) | 349.9 | 344.2 | 2% |
| Electricity (kWh/sf) | 36.4 | 35.1 | 4% |
| Gas (therms/sf) | 2.258 | 2.245 | 1% |

| Restaurant – Quick Service | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 116.6 | 113.1 | 3% |
| Cooling | 6.9 | 6.6 | 6% |
| Interior lights | 11.7 | 11.1 | 6% |
| Exterior lights | | | |
| Interior equipment | 5.3 | 2.7 | 49% |
| Ventilation | 89.1 | 89.0 | 0% |
| Pumping | 25.3 | 25.1 | 1% |
| Hot water | 0.0 | 0.0 | 0% |
| Other | 72.4 | 72.3 | 0% |
| Total (kBtu/sf) | 194.6 | 194.6 | 0% |
| Electricity (kWh/sf) | 521.9 | 514.4 | 1% |
| Gas (therms/sf) | 48.0 | 46.9 | 2% |

| Retail – Stand-Alone (large) | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 20.1 | 19.6 | 3% |
| Cooling | 2.0 | 1.7 | 13% |
| Interior lights | 15.7 | 12.4 | 21% |
| Exterior lights | 2.1 | 1.1 | 46% |
| Interior equipment | 7.4 | 7.3 | 0% |
| Ventilation | 5.0 | 4.6 | 8% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 3.1 | 3.1 | 0% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 55.3 | 49.9 | 10% |
| Electricity (kWh/sf) | 10.1 | 8.6 | 14% |
| Gas (therms/sf) | 0.209 | 0.204 | 2% |

| Retail – Strip Mall (small) | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 18.7 | 17.1 | 9% |
| Cooling | 2.3 | 2.0 | 15% |
| Interior lights | 15.1 | 12.3 | 19% |
| Exterior lights | 3.5 | 1.8 | 48% |
| Interior equipment | 6.2 | 6.2 | 0% |
| Ventilation | 5.8 | 5.3 | 9% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 3.3 | 3.3 | 0% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 54.9 | 47.9 | 13% |
| Electricity (kWh/sf) | 10.5 | 8.8 | 16% |
| Gas (therms/sf) | 0.193 | 0.178 | 8% |

| School - Primary | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 11.0 | 12.3 | -12% |
| Cooling | 2.3 | 1.9 | 15% |
| Interior lights | 8.5 | 5.7 | 33% |
| Exterior lights | 0.5 | 0.3 | 48% |
| Interior equipment | 15.8 | 13.9 | 12% |
| Ventilation | 5.8 | 4.3 | 25% |
| Pumping | 0.1 | 0.1 | 10% |
| Hot water | 2.0 | 2.0 | 1% |
| Other | 5.5 | 5.5 | 0% |
| Total (kBtu/sf) | 51.5 | 46.0 | 11% |
| Electricity (kWh/sf) | 10.2 | 8.2 | 19% |
| Gas (therms/sf) | 0.168 | 0.181 | -7% |

| School - Secondary | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 4.0 | 5.6 | -39% |
| Cooling | 1.6 | 1.5 | 9% |
| Interior lights | 9.5 | 7.0 | 26% |
| Exterior lights | 0.5 | 0.2 | 48% |
| Interior equipment | 10.8 | 10.0 | 8% |
| Ventilation | 4.0 | 3.6 | 9% |
| Pumping | 0.1 | 0.0 | 10% |
| Hot water | 4.0 | 4.0 | 0% |
| Other | 3.1 | 3.1 | 0% |
| Total (kBtu/sf) | 37.6 | 35.1 | 7% |
| Electricity (kWh/sf) | 8.1 | 6.9 | 14% |
| Gas (therms/sf) | 0.100 | 0.115 | -15% |

| Warehouse | | | |
|---|---|---|---|
| End Use (kBtu/sf) | 2014 | 2019 | % Savings |
| Heating | 7.1 | 8.0 | -13% |
| Cooling | 0.0 | 0.0 | -5% |
| Interior lights | 7.7 | 4.3 | 44% |
| Exterior lights | 1.3 | 0.8 | 38% |
| Interior equipment | 2.2 | 2.2 | 2% |
| Ventilation | 1.4 | 1.4 | 0% |
| Pumping | 0.0 | 0.0 | 0% |
| Hot water | 0.5 | 0.5 | 0% |
| Other | 0.0 | 0.0 | 0% |
| Total (kBtu/sf) | 20.3 | 17.2 | 15% |
| Electricity (kWh/sf) | 4.3 | 3.2 | 26% |
| Gas (therms/sf) | 0.146 | 0.167 | -15% |