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Technical Support Document to Facilitate Adoption of ASHRAE Standard 90.1 Performance Rating Method

November 2023

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U.S. DEPARTMENT OF ENERGY

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Summary

The Standard 90.1 Appendix G Performance Rating Method (PRM) is increasingly used to document minimum code compliance and in beyond-code programs. The 2022 version of Standard 90.1 includes the following improvements to the PRM in response to user feedback:

1. Added Informative Appendix I, which includes sample code language for using the PRM in conjunction with metrics other than energy cost, including site energy, source energy, and greenhouse gas emissions. These alternative metrics support adopters that seek to promote electrification or have goals for reducing greenhouse gas emissions (90.1 2019 Addendum ch).
2. Improved methodology for determining the Building Performance Factors, which sets the PRM stringency, harmonized with the PRM modeling rules.
3. Introduced an envelope backstop to limit trade-offs between envelope and building systems with shorter useful life (90.1 2019 Addendum cr).
4. Updated modeling rules to eliminate a penalty for projects connected to district heating or cooling plants (90.1 2022 Addendum a).
5. Updated modeling rules for retrofit projects differentiating between major renovations and limited alterations and reduced PRM stringency for such projects to better align with prescriptive path (90.1 2019 Addendum co).

The PRM stable and independent baseline methodology simplifies the modeling rules, minimizes variability in performance requirements depending on the configuration of the proposed design, and facilitates automation of the baseline generation in the simulation tools. However, since the baseline model does not reflect the current edition of Standard 90.1 and often has different space and service water heating fuels than the proposed design, energy use of the modeled baseline and proposed design does not readily support the common reporting requirements of beyond-code programs. This technical support document describes solutions to the common PRM adoption challenges, including calculating energy savings by fuel type and electricity demand savings relative to current code and avoiding “fuel switching” when reporting savings of the proposed design relative to the current code.

The calculations described in this technical support document are automated in the ASHRAE Standard 90.1 Performance Based Compliance Form and the Compliance Form Companion Tool, developed by the U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory, which are available on the DOE Building Energy Codes Program website.

Acronyms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BPF	Building Performance Factor
DOE	U.S. Department of Energy
ECB	Energy Cost Budget
EUI	energy use intensity
HVAC	heating, ventilation, and air conditioning
PNNL	Pacific Northwest National Laboratory
PRM	Performance Rating Method
SEEUPF	Site Energy End Use Performance Factor

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1.0 Overview of ASHRAE Standard 90.1 Performance Rating Method

ASHRAE Standard 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings" (90.1, the Standard), includes both prescriptive and performance options for demonstrating compliance. The prescriptive option is a list of requirements that apply to individual building systems and components, such as the minimum R-value of insulation or maximum lighting power allowance. The performance option requires the use of whole building energy modeling to demonstrate that the energy use of the proposed design compares favorably to performance of a reference building.

Standard 90.1 performance-based compliance options include the Energy Cost Budget (ECB) Method in Section 12[1] of the Standard and the Performance Rating Method (PRM) in Appendix G of the Standard. The ECB Method is intended for demonstrating minimum compliance with the Standard. The PRM was introduced in the 2004 edition of 90.1 as a methodology for demonstrating beyond-code performance. Starting with the 2016 edition, PRM can also be used for demonstrating minimum compliance with the Standard. At the same time, the PRM methodology was changed to introduce a stable baseline fixed at the stringency level approximately equivalent to a design minimally compliant with 90.1 2004. To demonstrate compliance, the proposed design must improve over the baseline by a set margin. The increase in stringency for each new edition of 90.1 is achieved by increasing the margin by which the proposed design must improve over this stable baseline. Buildings qualifying for beyond-code programs must exceed the compliance threshold by an even greater margin to meet the prescribed percent improvement over code. The following relationships are used to establish percentage improvement of the proposed design relative to the current code (PNNL 2016):

$$PCI = \frac{Proposed\ Building\ Performance}{Baseline\ Building\ Performance} \quad (1)$$

$$PCI_t = \frac{BBUEC + (BPF * BBREC)}{BBP} \quad (2)$$

$$\%\ Improvement\ Beyond\ Code = 100 * \frac{PCI_t - PCI}{PCI_t} \quad (3)$$

BBP = *BBUEC* + *BBREC*

PCI	=	Performance Cost Index
Proposed Building Performance	=	annual energy cost for a proposed design calculated according to 90.1, Appendix G
Baseline Building Performance	=	annual energy cost for a baseline design calculated according to 90.1, Appendix G
PCI_t	=	maximum Performance Cost Index that a proposed design must demonstrate to comply with a particular edition of 90.1
BBUEC	=	baseline building unregulated energy cost, which is the portion of the annual energy cost of a baseline building design due to unregulated energy use
BBREC	=	baseline building regulated energy cost, which is the portion of the annual energy cost of a baseline building design that is due to regulated energy use

[1] Prior to the 2022 edition of 90.1, the ECB Method was included in Section 11 of the Standard.

BPF	=	Building Performance Factor (BPF) from 90.1, Table 4.2.1.1; where a building includes multiple building area types, the BPF is calculated as the area-weighted average of each building area type
BBP	=	baseline building performance

PRM use is expected to increase due to its versatility and alignment with the ambitious performance targets set by many jurisdictions and rating authorities. It is being actively developed by ASHRAE and is perceived as the future of performance-based compliance by the Standard 90.1 Committee (PNNL 2021). The following is a summary of the key recent improvements to the PRM:

1. **Using metrics other than energy cost to determine compliance.** Using energy cost as the compliance metric in jurisdictions with a high electricity cost relative to natural gas puts projects that use electricity for space and service water heating at a disadvantage compared to projects that use fossil fuels for these end uses. Informative Appendix I in 90.1 2022 provides sample language for using the PRM in conjunction with site energy, source energy, and greenhouse gas emission metrics to support local policies and goals, such as promoting electrification and decarbonization. Appendix I also includes a table with BPF values to be used with each alternative metric.

2. **Improved methodology for determining the BPF.** The BPFs represent the minimum improvement in regulated energy use[1] of the proposed design relative to the baseline design that projects must demonstrate to comply with the energy code. The BPFs included in the 2016 and 2019 editions of 90.1 were based on the 90.1 2004 commercial building prototype models, which followed several but not all the modeling rules prescribed for the Appendix G baseline building. For example, heating, ventilation, and air conditioning (HVAC) system types modeled for some occupancies deviated from the baseline PRM system types. Starting with 90.1 2022, a new set of commercial building prototypes that more closely follow the Appendix G baseline modeling rules were created and used to establish BPFs. This group of models will be used to establish BPFs for subsequent editions of 90.1.

3. **Limiting trade-offs between envelope and building systems with shorter useful life.** Projects that use performance-based compliance often trade less efficient building envelope performance for more efficient lighting and HVAC performance (PNNL 2021). ASHRAE Standard 90.1 2022 and Addendum CR to 90.1 2019 addressed this concern by introducing an “envelope backstop” that limits the building envelope trade-offs that projects can use following the ECB Method and the PRM. The backstop requires that the specified envelope does not increase whole building energy cost of the proposed design by more than 15% for multifamily, hotel/motel, and dormitory occupancies, and by more than 7% for all other occupancies compared to a design with the envelope minimally compliant with the prescriptive envelope requirements in 90.1 Section 5. The backstop margins are based on designs with opaque surfaces and fenestration minimally complying with prescriptive requirements but with fenestration area up to 70% of above grade wall. The backstop stringency may be increased by reducing the allowed margins.

[1] Regulated energy use is the *energy* used by HVAC, lighting, *service water heating*, motors, *transformers*, vertical transportation, refrigeration *equipment*, *computer-room* cooling *equipment*, and other *building systems*, components, and processes with requirements prescribed in Sections 5 through 10 of 90.1.

4. **Updated modeling rules for projects connected to district heating and cooling plants.** Prior to adoption of a stable baseline in Appendix G, purchased heating and cooling were treated as energy neutral. With the adoption of a stable baseline and BPF factors, a proposed design using purchased heating and cooling was put at disadvantage compared to a project with onsite space heating and cooling systems and service water heating systems. Addendum a of 90.1 2022 addressed this issue by requiring the proposed design to model purchased heating and cooling as being supplied by a minimally code compliant onsite hot and chilled water plant, with the baseline design modeled the same as for projects with the onsite systems.

5. **Updated modeling rules for retrofit projects.** The prescriptive path of compliance with 90.1 includes special rules for project retrofits. In contrast, Appendix G modeling rules were the same for new construction and alteration projects, with no differences in the methodology used to establish compliance based on the simulation results for the baseline and proposed design model. As a result, retrofits were held to the same standard as new construction projects and were penalized for having existing systems that are less efficient than the current requirements for new construction projects. Addendum co to 90.1 2019 addressed this issue. For substantial renovation projects, the modeling rules are the same as for new construction but the BPF is increased by 5%, resulting in the corresponding reduction in stringency. For limited alterations, the modeling rules are similar to the ECB, requiring that the energy use of the proposed design does not exceed energy use of the design where all retrofitted systems minimally comply with the applicable prescriptive requirements.

The PRM stable and independent baseline simplifies the modeling rules, minimizes variability in performance requirements depending on configuration of the proposed design, and facilitates automation of the baseline generation in the simulation tools. However, since the baseline model does not reflect the current edition of 90.1 and often has different space and service water heating fuels than the proposed design, energy use of the baseline and proposed design models does not readily support the common reporting requirements of beyond-code programs, such as demonstrating savings by fuel (electricity, natural gas, etc.) of the proposed design relative to the current code. This technical support document describes solutions to these and several other common PRM adoption challenges.

The calculations described in Eqs. (1) through (3) are automated in the ASHRAE Standard 90.1 Performance Based Compliance Form (Compliance Form), developed by the U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL).[1] The Compliance Form is a spreadsheet-based tool that meets ECB and PRM documentation requirements. It was released in 2020 and, similar to COMcheck, is maintained to support new editions of the Standard as they are published, starting with 90.1 2016. In 2023, the Compliance Form Companion Tool (Companion Tool) was released. The Companion Tool is designed to be used in conjunction with the Compliance Form and supports local modifications to the ECB Method and PRM. Examples of the calculations supported by the Companion Tool include but are not

[1] The Compliance Form helps the modeler establish simulation inputs for the baseline/budget and proposed design models and includes a submittal checklist to ensure that all necessary supporting documentation is included in the submittal. It standardizes compliance documentation and simplifies submittal reviews by code officials and administrators of above-code program implementers. The Compliance Form may be downloaded from the DOE Building Energy Codes Program website https://www.energycodes.gov/ashrae-standard-901-performance-based-compliance-form. The website also provides the Compliance Form filled out for a sample project.

limited to expressing modeled performance using site energy, source energy, or greenhouse gas emission metrics. The Companion Tool also implements the calculations described in this technical support document, including determining energy savings by fuel and end use and demand savings of the proposed design relative to code.

2.0 Use of the PNNL Prototype Models for Setting PRM Performance Targets

The BPFs used in Eq. (2) are calculated for each edition of 90.1 using the PNNL prototype commercial building models (the prototypes),[1] which include 16 buildings that represent approximately 75% of the total square footage of new commercial construction, including multifamily buildings more than three stories tall, consistent with the scope of 90.1 (Lei et al. 2020). Versions of the prototypes have been developed for each published edition of 90.1 since 2004. When creating the compliance targets, the 90.1 Standing Standards Project Committee chose to combine the results of similar prototype buildings, resulting in eight general building types (Table 1), and the savings for the related prototype buildings were averaged to develop the building type savings.

Table 1. Mapping between Building Area Types in 90.1 Table 4.2.1.1 and PNNL Prototypes

Building Area Type	Prototype Building
Office	Small Office
	Medium Office
	Large Office
Retail	Stand-Alone Retail
	Strip Mall
School	Primary School
	Secondary School
Healthcare/hospital	Hospital
	Outpatient Health Care
Hotel/motel	Small Hotel
	Large Hotel
Warehouse	Warehouse
Restaurant	Fast Food Restaurant
	Sit-Down Restaurant
Multifamily	Mid-Rise Apartment
	High-Rise Apartment

[1] These prototypes and the procedure for quantifying the progress of 90.1 are described in detail elsewhere (Thornton et al. 2011; Goel et al. 2014) and are available for download at https://www.energycodes.gov/prototype-building-models.

BPFs in 90.1 Table 4.2.1.1 are developed according to the following equation:

$$BPF_{Year\ X} = \left(\sum \frac{Prototype\ Building\ Regulated\ Energy\ Cost_{Year\ X}}{Prototype\ Building\ Regulated\ Energy\ Cost_{2004}}\right) / N_p \quad (4)$$

$BPF_{Year\ X}$	=	Building Performance Factor for the given edition of 90.1
$Prototype\ Building\ Regulated\ Energy\ Cost_{Year\ X}$	=	portion of annual energy cost due to regulated energy use from the PNNL prototype buildings for a given building prototype, climate zone, and edition of 90.1
$Prototype\ Building\ Regulated\ Energy\ Cost_{2004}$	=	portion of annual energy cost due to regulated energy use from the PNNL prototype buildings for a given building prototype, climate zone, and the 2004 edition of 90.1
N_p	=	Number of prototype buildings of a particular building type from Table 1

3.0 Calculating Energy Savings by Fuel Relative to the Current Code

3.1 Background

Beyond-code programs are often required to report savings of the proposed design relative to code. Prior to introduction of the PRM stable baseline, these savings could be determined as the difference in energy use of the proposed design relative to the baseline. With the stable baseline method, the savings relative to code may be calculated as follows:

$$Savings = \%\ Improvement\ Beyond\ Code * BBP \quad (5)$$

Savings	=	overall savings of the proposed design relative to code expressed in a fuel-neutral metric such as energy cost, source energy, site energy, or greenhouse gas emissions
$\%\ Improvement\ Beyond\ Code$	=	calculated using Eq. (3) with metric-specific BPF
BBP	=	baseline building performance expressed in units of the selected metric

Some beyond-code programs also require reporting savings of the proposed design relative to code for individual fuels (electricity, natural gas, etc.). Applying % Improvement Beyond Code to the energy use of each fuel in the baseline implies that the percent savings is the same for all fuels. For example, if a project achieves a 10% energy cost improvement over code based on Eq. (3), the electricity and gas savings relative to code would also be assumed equal to 10% each. In reality, savings are typically different for each fuel. In some cases, there may be an increase in use of one fuel and decrease in another, such as when space heating source is changed from gas in the baseline to electricity in the proposed design.

A more accurate method would account for the change in stringency of 90.1 since the 2004 edition for individual end uses. For example, efficiency requirements of service water heaters have stayed largely unchanged in the last 20 years; thus, service water heating savings of the proposed design relative to the baseline would effectively reflect savings over code. On the other hand, there has been a significant increase in stringency of requirements for envelope and HVAC system efficiency, controls, and ancillary features such as exhaust air energy recovery, resulting in a substantial decrease in heating energy use. As a result, heating energy use in the proposed design must decrease considerably compared to the baseline just to meet the current code.

This is illustrated in Figure 1, which shows the change in site energy use of the high-rise multifamily protype meeting 90.1 2004 vs. 90.1 2016 for several climate zones by end use. As shown, heating energy use decreased by 61% to 77% depending on the climate zone, while service water heating energy use is nearly unchanged.

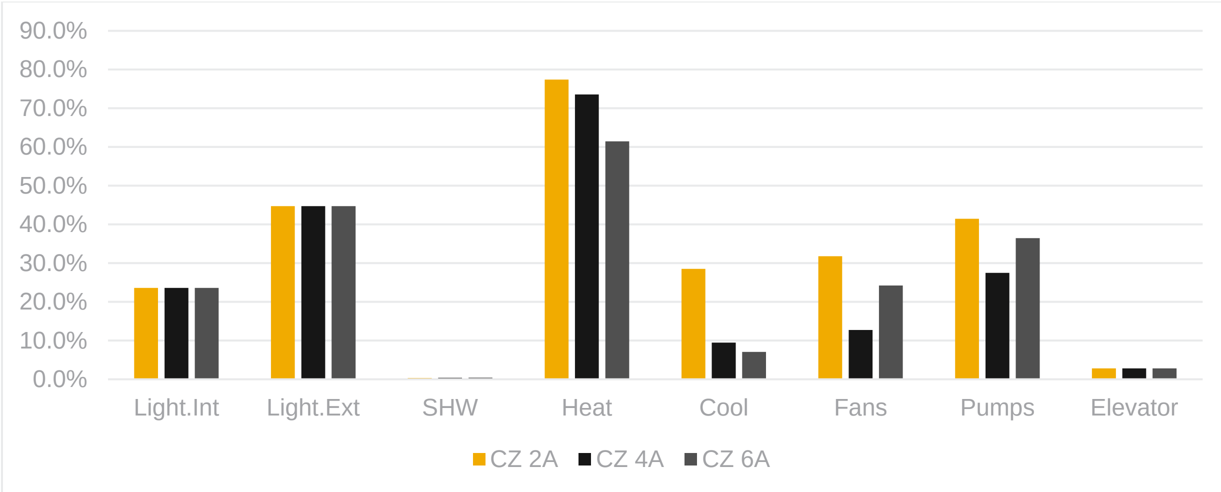

Figure 1. Change in Site Energy Use of 2004 vs. 2016 High-rise Multifamily Prototype

3.2 Calculation Methodology

Savings by fuel may be estimated by replacing the BPF with end-use-specific performance factors. To account for scenarios that use several different fuels in the prototypes for a given end use, such as when space heating is provided by water-source heat pumps that use both electricity and natural gas for heating, the end-use performance factors are expressed in units of site energy. The Site Energy End Use Performance Factors (SEEUPFs) are calculated for each regulated end use in a given building type and climate zone as a ratio of the end-use site energy use intensity (EUI) of the PNNL prototype model compliant with the current code (referred to as the proposed model in this section) to the EUI of the corresponding end uses in the 2004 PNNL prototype model (referred to as the baseline model in this section). Where multiple prototypes are used for the given building area type, as indicated in Table 1, the values are averaged.

Standard 90.1 directs use of the BPF prescribed for the “All Others” category for all building area types not listed in Table 1. The SEEUPF values for each end use in the “All Others” category are determined using weighted average values for each prototype building based on the national construction weights, except for climate zones 0A, 0B, and 1B, where straight numerical averages are used instead.[1]

This procedure was used to calculate SEEUPFs for each climate zone, building area type, and end use for the 2016, 2019, and 2022 editions of 90.1. The results are included in the Companion Tool. Table 2 shows the mapping between the end uses reported for the prototypes and default end uses included in the DOE/PNNL Standard 90.1 Section 11 and Appendix G Compliance Form.

[1] These climate zones do not exist in the U.S., and there are no national construction weights.

Table 2. Site Energy End Use Performance Factors End-Use Mapping

DOE/PNNL Standard 90.1 Compliance Form End Use	PNNL End Use
Interior lighting	Light.Int
Exterior lighting	Light.Ext
Space heating	Heat + Humidify
Heat pump supplemental heating	Heat + Humidify
Space cooling	Cool
Pumps	Pumps
Heat rejection	Ht.Rej
Fans – interior ventilation	Fans
Service water heating	SHW
Refrigeration equipment (regulated)	Refrig
Elevators and escalators	Elevator
Other regulated	Ht.Rcvy + Txfmr

The final SEEUPFs for each building area type are determined as an average of the building prototypes in each category as shown in Table 1. If an end use is not applicable for a building area type category (i.e., the end use was not modeled in any of the protypes associated with the category) then the “All Others” SEEUPFs were applied for the end use. For example, warehouse pumps, heat rejection, regulated refrigeration, elevators, and escalators are not included in the prototype models, so the “All Others” SEEUPF values are used. In several cases, this general methodology was modified as described below.

1. The highrise multifamily and large hotel prototypes have different HVAC system types in the baseline vs. proposed models. This results in significantly higher pumping energy in the proposed design relative to the baseline across all climate zones, leading to unrealistically high SEEUPFs. To address this, instead of averaging the pump SEEUPFs across multifamily highrise and midrise building area types, the midrise pump SEEUPFs were applied to both. Similarly, the small hotel pumping SEEUPF was applied to large hotel.
2. For the large office prototypes, the proposed consumption for the heat rejection energy end use was significantly higher than the baseline across all climate zones due to different HVAC system types in the baseline vs. proposed models, leading to unrealistically high SEEUPFs. To address this, the SEEUPFs were determined based on the combined heat rejection and space cooling energy use, and are applied to both the space cooling and heat rejection end uses.
3. When the average energy consumption across the baseline and proposed models of a specific end use and climate zone is below 5% of total energy consumption (i.e., low-impact end use) and the calculated SEEUPF value is greater than 2 or less than 0.1, the average SEEUPFs of all climate zones for the building type were used as the SEEUPF for the given end use and climate zone, excluding climate zones where this exception applies.

The SEEUPFs can be used in conjunction with the modeling results for the PRM baseline and proposed design models to determine savings by fuel as described in steps 1-3 below. These steps are automated in the Companion Tool.

Step 1: Multiply the modeled baseline energy consumption for each end use and fuel by the appropriate SEEUPF to estimate energy use by fuel and end use of a design minimally compliant with a given edition of 90.1.

$$CSEU_{X,\, i,\, j} = SEEUPF_{YearX,i} * BSEU_{\, i,\, j} \qquad (6)$$

$CSEU_{X,\, i,\, j}$	=	code site energy use; site energy use for end use "i" and fuel "j" of a design minimally compliant with 90.1 YearX edition
$SEEUPF_{YearX,i}$	=	Site Energy End Use Performance Factor for end use "i" and 90.1 YearX edition
$BSEU_{\, i,,\, j}$	=	modeled 90.1 Appendix G baseline site energy use for end use "i" and fuel "j"

Step 2: Calculate savings of the proposed design relative to code for each end use and fuel as a difference between $CSEU_{X\, ,i,\, j}$ and the modeled energy use of the proposed design for the same end use and fuel. Some of the savings may be negative, indicating that the proposed design uses more fuel for the given end use compared to the minimally code compliant project. For example, if the proposed design uses electricity for space heating while the baseline is modeled with natural gas following the PRM rules, the proposed design will show electricity penalty and gas savings for space heating.

$$Savings_{\, i\, j} = CSEU_{X,\, i,\, j} - PSEU_{\, i\, j} \qquad (7)$$

$Savings_{\, i\, j}$	=	site energy savings with respect to code reference YearX edition of 90.1 for end use "i" and fuel "j"
$PSUE_{\, i\, j}$	=	modeled proposed site energy use for end use "i" and fuel "j"

Step 3: Calculate the total savings by fuel of the proposed design relative to code as the sum of savings for the individual end uses for each fuel.

3.3 Limitations of the Approach

Eqs. (6) and (7) allow the calculation of site energy savings of the proposed design relative to a design minimally compliant with the applicable energy code for individual fuels. The equations may also be used to calculate the overall savings across all fuels expressed in different metrics such as source energy, greenhouse gas emissions, and energy cost by applying the appropriate site energy to the selected metric's conversion factors. When the SEEUPF method is used to determine energy cost savings, the result will be different from the value determined using Eq. (3) for the following reasons:

1. The end-use allocation in the baseline model for a given project is likely to be different than that of the prototype model used to establish the BPFs. The SEEUPF method accounts for project-specific allocation of energy use across end uses, while the BPF method is based on the end-use allocation of the PNNL prototype models used to determine the BPFs.
2. The fuel costs used in SEEUPF method may be based on utility rates applicable to the project and differ from the national average fuel costs used to determine the BPFs.

3.4 Example

A beyond-code program has technical requirements based on 90.1 2016 Appendix G. The applicable local energy code is aligned with 90.1 2016. The program must report energy savings by fuel (electricity, gas, etc.) relative to code for each project qualifying for incentives. Energy modeling results for a multifamily project participating in the program are shown in Table 3. Table 4 and Table 5 illustrate calculations to determine electricity and gas savings relative code for individual end uses. The last rows and columns in these tables shows the total electricity and gas savings. The proposed design uses electricity for both space and service water heating, while natural gas is used for both end uses in the baseline design. This “fuel switching” results in an increase in electricity use and significant natural gas savings of the proposed design compared to the baseline, as shown in the last rows of Table 4 and Table 5. These calculations are automated in the Companion Tool.

Table 3. Energy Modeling Results for a Multifamily Project

End Use	Unregulated?	Energy Type	Energy Use Units	Baseline Design	Proposed Design
Interior lighting	No	Electricity	kWh	246,093	69,999
Exterior lighting	No	Electricity	kWh	175	79
Space heating	No	Natural gas	therm	21,547	0
Space heating	No	Electricity	kWh	0	242,887
Heat pump supplemental heater	No	Electricity	kWh	0	0
Space cooling	No	Natural gas	therm	0	0
Space cooling	No	Electricity	kWh	180,255	88,142
Pumps	No	Electricity	kWh	10,195	23,240
Heat rejection	No	Electricity	kWh	0	0
Fans – interior ventilation	No	Electricity	kWh	164,551	70,000
Service water heating	No	Natural gas	therm	9,810	0
Service water heating	No	Electricity	kWh	810	230,823
Misc equipment	Yes	Natural gas	therm	0	0
Misc equipment	Yes	Electricity	kWh	344,847	325,901
Elevators and escalators	No	Electricity	kWh	4,550	3,625

Table 4. Electricity Savings Calculation Using the SEEUPF Method

Variable ID:	a	b	c	d	e	f
Calculation:	Value is in the Companion Tool	From Table 3 converted to MMBtu		=b*a	=d-e	=e*1000/3.412
End Use	SEEUPF for 90.1 2016 for Each End Use	Baseline MMBtu (BSEU for electricity for each end use)	Proposed Electricity MMBtu	Code Energy Use for 90.1 2016 MMBtu (CSEU for 90.1 2016 for electricity for each end use)	Electricity Savings MMBtu	Electricity Savings kWh
Interior lighting	0.73	839.7	238.8	613.0	374.1	109,649
Exterior lighting	0.43	0.6	0.3	0.3	0.0	-4
Space heating	0.34	0.0	828.7	0.0	-828.7	-242,887
Heat pump supplemental heater	0.34	0.0	0.0	0.0	0.0	0
Space cooling	0.67	615.0	300.7	412.1	111.3	32,629
Pumps	0.56	34.8	79.3	19.5	-59.8	-17,531
Heat rejection	0.39	0.0	0.0	0.0	0.0	0
Fans – interior ventilation	0.70	561.4	238.8	393.0	154.2	45,185
Service water heating	0.99	2.8	787.6	2.7	-784.8	-230,021
Misc equipment	1.00	1,176.6	1,112.0	1,176.6	64.6	18,946
Elevators and escalators	0.96	15.5	12.4	14.9	2.5	743
Total	-	3,246	3,599	2,632	-967	-283,290

Table 5. Natural Gas Savings Calculation Using the SEEUPF Method

Variable ID:	a	g	h	i	j	k
Calculation:	Value is in the Companion Tool	From Table 3 converted to MMBtu		=g*a	=i-h	=j*1000/100
End Use	SEEUPF for 90.1 2016 for Each End Use	Baseline MMBtu (BSEU for natural gas for each end use)	Proposed Natural Gas MMBtu	Code Energy Use for 90.1 2016 MMBtu (CSEU for 90.1 2016 for natural gas for each end use)	Natural Gas Savings MMBtu	Natural Gas Savings therm
Interior lighting	0.73	0.0	0.0	0.0	0.0	0
Exterior lighting	0.43	0.0	0.0	0.0	0.0	0
Space heating	0.34	2,154.7	0.0	732.6	732.6	7,326
Heat pump supplemental heater	0.34	0.0	0.0	0.0	0.0	0
Space cooling	0.67	0.0	0.0	0.0	0.0	0
Pumps	0.56	0.0	0.0	0.0	0.0	0
Heat rejection	0.39	0.0	0.0	0.0	0.0	0
Fans – interior ventilation	0.70	0.0	0.0	0.0	0.0	0
Service water heating	0.99	981.0	0.0	971.2	971.2	9,712
Misc equipment	1.00	0.0	0.0	0.0	0.0	0
Elevators and escalators	0.96	0.0	0.0	0.0	0.0	0
Total	-	3,136	0	1,704	1,704	17,038

4.0 Determining Fuel Savings Relative to Code without "Fuel Switching"

4.1 Background and Methodology

The example in the previous section involves a project that uses fossil fuel for space heating in the baseline and electric space heating in the proposed design. Some utility incentive programs have funding rules that do not allow credit for shifting energy use from one fuel to another. To avoid fuel switching in the program reporting without changing the PRM modeling rules, the SEEUPF method described in the previous section may be modified to allocate the code site energy to individual fuels in the same proportion as in the proposed design. For example, if electricity accounts for 30% and gas for 70% of space heating site energy in the proposed design, the heating site energy use of the code design would be similarly allocated between the two fuels. The approach is further described below.

Step 1: Calculate the prorated energy use by fuel and end use of a design minimally compliant with YearX edition of 90.1.

$$CSEUadj_{X,\,i,\,j} = (BSEU_i * SEEUPF_{YearX,i}) * (PSEU_{\,i,j} / PSEU_{\,i}) \qquad (8)$$

$CSEUadj_{X,\,i,\,j}$	=	code site energy use compliant with code reference YearX edition of 90.1 for end use "i" and fuel "j" adjusted to match the proposed fuel allocation
$BSEU_I$	=	modeled 90.1 Appendix G baseline site energy use for end use "i"
$SEEUPF_{YearX,i}$	=	Site Energy End Use Performance Factor for code reference YearX edition of 90.1 for end use "i"
$PSEU_{\,i\,j}$	=	modeled proposed site energy use for end use "i" and fuel "j"
$PSEU_{\,i}$	=	modeled proposed site energy use for end use "i" including all fuels

Step 2: Calculate savings of the proposed design relative to code for each end use and fuel as a difference between $CSEUadj_{YearX,i,j}$ and the modeled energy use of the proposed design for the same end use and fuel using Eq. (7), replacing CSEU with CSEUadj. Some of the savings may be negative, indicating that the proposed design uses more fuel for the given end use compared to the minimally code compliant project.

Step 3: Calculate the total savings by fuel type of the proposed design relative to code as the sum of savings for the individual end uses for each fuel.

4.2 Limitations of the Approach

The described methodology does not account for the minimum code-required efficiency of the equipment that uses the same fuel as equipment specified in the proposed design. For instance, when a project specifies air source heat pumps but the baseline is modeled with fossil fuel heating following the 90.1 Appendix G rules, Eq. (8) will not account for performance of the specified heat pumps relative to the minimally code-compliant heat pump.

4.3 Example

Table 6 and Table 7 illustrate how to apply this methodology to the multifamily project example included in the previous section. These calculations are automated in the Companion Tool.

Table 6. Fuel Neutral Electricity and Natural Gas Savings Calculations

Variable ID:	a	b	c	d	e	f	g	h	i	j
Calculation:	Sum of columns d and i from Table 4 and Table 5	From Table 3 converted to MMBtu	From Table 4 column c	=c/b	=d*a	=e-c	From Table 5 column h	=g/b	=h*a	=i-kg
End Use	Code Site Energy Use for 90.1 2016 MMBtu Inclusive of All Fuels (CSEU for each end use i)	Total Proposed MMBtu (PSEU for each end use i) Inclusive of All Fuels	Proposed Electricity MMBtu (PSEU for each end use i for electricity)	Electricity Proposed Percent of Total Proposed MMBtu	Code Site Energy Use for 90.1 2016 Based on Proposed Allocation Electricity MMBtu (CSEUadj for each end use for electricity)	Electricity Savings MMBtu	Proposed Natural Gas MMBtu (PSEU for each end use i for gas)	Natural Gas Proposed Percent of Total MMBtu	Code Site Energy Use for 90.1 2016 Based on Proposed Allocation Natural Gas MMBtu (CSEUadj for each end use for gas)	Natural Gas Savings MMBtu
Interior lighting	613.0	238.8	238.8	100%	613.0	374.1	0.0	0%	0.0	0.0
Exterior lighting	0.3	0.3	0.3	100%	0.3	0.0	0.0	0%	0.0	0.0
Space heating	732.6	828.7	828.7	100%	732.6	-96.1	0.0	0%	0.0	0.0
Heat pump supplemental	0.0	0.0	0.0	0%	0.0	0.0	0.0	0%	0.0	0.0
Space cooling	412.1	300.7	300.7	100%	412.1	111.3	0.0	0%	0.0	0.0
Pumps	19.5	79.3	79.3	100%	19.5	-59.8	0.0	0%	0.0	0.0
Heat rejection	0.0	0.0	0.0	0%	0.0	0.0	0.0	0%	0.0	0.0
Fans – interior ventilation	393.0	238.8	238.8	100%	393.0	154.2	0.0	0%	0.0	0.0
Service water heating	973.9	787.6	787.6	100%	973.9	186.4	0.0	0%	0.0	0.0
Misc equipment	1,176.6	1,112.0	1,112.0	100%	1,176.6	64.6	0.0	0%	0.0	0.0
Elevators and escalators	14.9	12.4	12.4	100%	14.9	2.5	0.0	0%	0.0	0.0
Total	4,335.8	3,598.6	3,598.6	-	4,335.8	737.2	0.0	-	0.0	0.0

Table 7. Fuel Neutral Total Savings by Fuel

ID	Parameter	Value	Calculation
o	Total electricity savings, kWh	216,069.0	=sum(f)*293.1
p	Total natural gas savings, therms	0.0	=sum(j)*10

5.0 Calculating Electricity Demand Savings Relative to Code

5.1 Methodology

Some beyond-code programs must report electricity demand savings of the proposed design relative to code. The savings may be determined by assuming that electricity demand of the design compliant with the code reference YearX edition of 90.1 has changed compared to the modeled baseline demand in the same proportion as annual electricity energy use (kWh) established using the SEEUPF method, as shown in Eq. (9). The demand values used in the equation may reflect the annual peak, summer peak, or peak during a specific period such as weekday summer afternoons, based on the program reporting requirements. These calculations are automated in the Companion Tool and can be completed at an individual end-use level and/or for different fuel types as required by the authority having jurisdiction.

Step 1: Multiply the total baseline electricity consumption compliant with code reference YearX edition of 90.1 (this would be calculated using the procedure in Section 3.2 or in Section 4.1if avoiding fuel switching) by the modeled peak demand of the baseline design model and then divide by the annual electricity use of the baseline design model.

$$kW_{YearX} = (kWh_{YearX} \times kW_{base})/kWh_{base} \quad (9)$$

kWh_{base}	=	annual electricity use of the baseline design, as modeled
kW_{base}	=	peak demand of the baseline design, as modeled and matching the locally defined demand period
kWh_{Yearx}	=	annual electricity use adjusted using the SEEUPF method for the code reference version of 90.1
kW_{YearX}	=	annual demand adjusted to align with the code reference version of 90.1 calculated for the locally defined demand period

Step 2: Calculate savings of the proposed design relative to code as the difference between the baseline demand compliant with the code reference YearX edition of 90.1 and the modeled demand of the proposed design. Negative savings indicate that the proposed design has a high peak demand compared to a minimally code compliant project.

$$kW_{savings} = kW_{YearX} - kW_{pro} \quad (10)$$

$kW_{savings}$	=	demand savings with respect to the code reference version of 90.1 calculated for the locally defined demand period
kW_{pro}	=	peak demand of the proposed design, as modeled and matching the locally defined demand period

5.2 Limitations of the Approach

Eq. (9) assumes that the full-year electricity usage profile shapes of the base and YearX electricity consumption results are identical. In other words, the demand of a design compliant with the code reference YearX edition of 90.1 is proportional to the difference in annual electricity energy use (kWh) established using the SEEUPF method (or other units of consumption if calculating demand for other fuels) compared to the modeled baseline kWh. This is an approximation and may vary in accuracy depending on the project. For instance, exterior lighting does not typically contribute to coincident peak electricity demand since it operates most often during unoccupied, low load hours. If a project demonstrates a significant reduction in exterior lighting energy use, this reduction will contribute toward peak demand savings determined following Eq. (9), resulting in overly optimistic savings. In addition, following this methodology, the proportional reduction in kWh between the baseline and reference YearX edition of 90.1 remains constant throughout the year based on the SEEUPFs. Because of that, even though kW_{base} and kW_{pro} may be determined for any period, the proportional reduction in kW applied to kW_{base} to convert it to kW_{YearX} will remain unchanged.

5.3 Example

The example with calculations shown in Table 8 builds off the savings by fuel calculated in the example in Section 3.4 to determine winter peak coincident demand kW savings.

Table 8. Electricity Demand Savings Example Calculations for an Example Project

ID	Parameter	Value	Calculation
a	Whole building winter peak coincident kW from the baseline model, kW_{base}	96.9	From model
b	Baseline kWh consumption, kWh_{base}	951,529.8	= sum (b) from Table 4* 293.1
c	Adjusted for minimal compliance with 90.1 2016 kWh using the SEEUPF method, kWh_{YearX}	771,449.3	= sum (d) from Table 4* 293.1
d	Whole building winter peak coincident kW adjusted to 90.1 2016, kW_{yearX}	78.6	=(c*a)/b
e	Whole building winter peak coincident kW from the proposed model, kW_{pro}	131.4	From model
f	Whole building winter peak coincident kW savings with respect to 90.1 2016, $kW_{savings}$	-52.8	=d-e

Table 8 shows winter peak coincident demand savings of negative 52.8 kW. This penalty is expected because the baseline has gas water and space heating and the proposed has all-electric systems.

6.0 References

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