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Simplified Performance Rating Method - Review of Existing Tools, Rulesets, and Programs

November 2020

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U.S. DEPARTMENT OF ENERGY

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Literature and Technical Review

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Summary

The Performance Rating Method (PRM) in ANSI/ASHRAE/IES[1] Standard 90.1[2] is a simulation ruleset used for establishing minimum code compliance and for quantifying a building's beyond-code performance. Conducting the building energy modeling (BEM) needed to demonstrate compliance with the PRM is often expensive and time consuming due to a variety of reasons that may include inadequate training, and software tool and ruleset complexity. The PRM requires the proposed building to be defined in accordance to the design documents, provide space level detail for internal loads and reflect actual building and HVAC system operation. These requirements can add additional unnecessary burden to the modeling process for small, simple buildings and has been the primary deterrent to increased use of the PRM for this segment of buildings. The goal of this report is to provide a background review that will support efforts to develop and codify a simplified PRM (S-PRM) for simple commercial buildings. The S-PRM is intended to simplify the process for defining a building energy model for analysis. This would in-turn expand the use of BEM by defining a low-cost, streamlined approach for creating robust and detailed models that support code compliance and incentive programs.

The team will engage the ASHRAE Standard 90.1 Committee during the development of the ruleset to support its seamless integration into the standard. The team will also engage with an advisory group consisting of code officials, energy efficiency program managers, and others to define use-cases where an S-PRM would increase participation in energy efficiency programs.

This report summarizes a review of (i) the more commonly used existing codes and incentive programs, and (ii) the existing simplified energy modeling tools to identify which modeling requirements are good candidates for simplification.

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[1] American National Standards Institute / American Society of Heating, Refrigerating, and Air Conditioning Engineers / Illuminating Engineering Society

[2] ANSI/ASHRAE/IES Standard 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA

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- Erik Mets, Ellen Franconi, Nora Wang– Pacific Northwest National Laboratory
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- Andrew Douglas Taylor – Duke Energy
- Gail Hampsmire, Corey Enck, Emma Hughes – Green Building Certification, Inc.

Acronyms and Abbreviations

ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	ASTM International
BEM	building energy modeling
C-PACE	commercial Property Assessed Clean Energy
DEER	Database of Energy Efficiency Resources
ECB	energy cost budget
HAP	Hourly Analysis Program
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
MPP	Multifamily Performance Program
MR	major renovation
NC	new construction
NCP	New Construction Program
NACM	Nonresidential Alternative Calculation Method
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
PRM	Performance Rating Method
PHI	Passivhaus Institute
PHIUS	Passive House Institute US
PACE	Property Assessed Clean Energy
S-BPM	simplified building performance modeling
S-PRM	simplified Performance Rating Method
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
TRM	technical resource manual
TDV	time-dependent value
TSPR	Total System Performance Ratio

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1.0 Introduction

The Performance Rating Method (PRM) in ANSI/ASHRAE/IES[1] Standard 90.1 (ASHRAE 2016; herein referred to as Standard 90.1) is a simulation ruleset for establishing minimum code compliance and for rating a building's beyond-code applications. The PRM is often referred to by its location in the Standard, Appendix G. Building energy modeling (BEM) to comply with the PRM is often expensive and time consuming due to a variety of reasons that may include inadequate training, tool complexity and lack of information. The goal of this report is to provide a background review that will support efforts to develop and codify a simplified PRM (S-PRM) for simple commercial buildings. The S-PRM will expand the use of BEM by defining a low-cost, simplified approach for creating robust and detailed models for qualification for code compliance and incentive programs for small buildings, while still using a reference baseline building approach to normalize for much of the uncertainty of building energy models.

Takeaways from this report will help ensure the S-PRM is applicable to the largest possible audience. To that end, this report primarily focuses on the applicable simplifications within existing energy modeling tools but also provides a review of simplifications used by current codes and standards and the potential applications of S-PRM in the marketplace.

Section 2.1 provides a detailed review and discussion of simplifications used by various software tools and their applicability to S-PRM. Section 2.2 provides a summary of applicable simplifications embedded within current codes and standards including the envelope trade-off approach in Standard 90.1 Normative Appendix C and the heating, ventilation, and air conditioning (HVAC) trade-off approach in the Washington State Energy Code (Washington State 2020). Section 2.3 provides a review of several energy efficiency programs that could potentially benefit from the S-PRM approach. The efficiency programs are separated into two categories: utility incentive programs and commercial Property Assessed Clean Energy (C-PACE) programs.

[1] American National Standards Institute / American Society of Heating, Refrigerating, and Air Conditioning Engineers / Illuminating Engineering Society

2.0 Overview

Energy efficiency programs commonly provide monetary incentives to offset building efficiency improvement costs. Typically, these programs include prescriptive efficiency measures with assumptions of deemed savings as well as customized measures. Examples of prescriptive measures include installing high-efficacy LED lighting, energy recovery equipment, high-efficiency air conditioners, furnaces, and heat pumps. The prescriptive approach considers each measure individually, which fails to encourage synergistic solutions, limiting the ability to achieve deep savings. Customized measures developed using whole BEM, on the other hand, can achieve deeper savings but may be cost prohibitive for simple or small buildings with modest design fees.

Similarly, energy codes and standards provide prescriptive and performance paths for demonstrating compliance. Prescriptive compliance requires adherence to the minimum prescribed efficiency of individual building elements such as envelope and mechanical system components. The whole building performance path requires the simulated energy performance of a proposed building design to be a specific percentage better than that of a “baseline building.” The prescriptive path is more commonly followed due to its ease and simplicity. It has limitations though as it doesn’t give credit to more efficient system configurations or interactions. In contrast, the performance path provides flexibility to designers by accommodating efficiency trade-offs between components and recognizes interactions that can optimize a buildings energy performance. However, the performance path can be an expensive and time-consuming option, which has proved to be a significant deterrent to its widespread adoption. A recent survey of energy code and beyond code program administrators found more than half of the respondents reporting energy modeling being used on less than 10% of project submittals (Karpman 2020).

The proposed S-PRM process aims to provide a simplified approach for whole building energy modeling that can be used for small and simple buildings to demonstrate code compliance or determine energy efficiency program incentives.

Several S-BPM tools exist in the market and a review of these has been carried out to identify the salient features of each and to understand how these tools provide simplified modeling capabilities. This report also includes a review of simplified performance-based compliance methods utilized in codes and standards and energy efficiency program designs to inform S-PRM development. The intent of this review is to answer key questions in order to guide the development of the S-PRM.

The key questions are listed in Table 2-1 Key Research Questions and organized into three categories: Simplified Building Performance Modeling Tools, Codes and Standards, and efficiency programs. The review is organized around these three categories because they represent the key areas of information that best inform a S-PRM ruleset. The primary focus of the report is on simplifications within software tools but a review of current codes and standards and efficiency programs was done to further inform S-PRM work.

Table 2-1 Key Research Questions

Category	Question
S-BPM Tools	Which current energy simulation software tools can be considered an S-BPM tool?
	Do any of these tools offer a simplified user interface?
	What simplification mechanisms are used for inputs (geometry, HVAC systems, schedules, etc.)?
	Is geometry input a GBXML import or a block like approach (Asset Score) or a capability to draw over a PDF/DWG, etc.?
	What are the salient features of current S-BPM tools?
	What are, at a high level, the input constraints of existing tools?
Codes and Standards	Which codes/standards currently incorporate simplified simulation approaches?
	What simplification mechanisms are used in these rulesets?
	What level of detail is required for specifying proposed and baseline buildings?
	What salient features of these existing approaches would be useful for S-BPM?
	What types of buildings qualify for current simplified approaches?
	What requirements or constraints exist for current S-BPM approaches?
Efficiency Programs	Which programs, requiring energy savings calculations, would benefit from S-BPM?
	Which programs require/allow the use of whole building simulation modeling?
	What compliance or reporting metrics do these programs use?
	Which building types, under current programs, might benefit most from S-BPM?
	What requirements exist for energy savings calculation methodologies?

2.1 Simplified Building Performance Modeling Tools

Twelve S-BPM tools were reviewed to identify and understand the salient features used to simplify analysis. The list includes several commercial tools such as Sefaira and cove.tool which are used quite extensively within the BEM community as well as simplified modeling tools such as RIPPLE and Praxis that are deployed across multiple States in support of utility energy efficiency programs. The BEM module of Praxis uses a custom simulation engine developed by AESC with development support from Duke Energy and has proven to be quite effective at increasing participation in whole-building incentive programs.[1,2]

The two key components of a S-BPM tool are the simulation engine that provides the calculations and the user interface. This research focused on software tools that have either a simplified simulation engine or a simplified user interface combined with a more robust simulation engine.

[1] Tock, K AESC (2020, March 5th). Telephone interview

[2] Taylor, A Duke Energy. (2020, March 11th). Telephone interview.

Each of the reviewed tools is summarized in Table 2.1-1 and a more detailed description of each tool is included in Appendix A. The reference sources included in Table 2.1-1 were all used to inform the discussion in this Section.

Table 2.1-1 Summary of S-BPM Tools

Name of Program	Simulation Engine/Methodology	Application Type	Availability	Reference Source
COMcheck	EnergyPlus	Web-based or Desktop	Freeware	US-DOE 2020
Commercial Building Energy Saver	EnergyPlus	Web-based	Freeware	LBNL 2020
cove.tool	ISO 13790 and CEN 1560	Web-based	Commercial	COVE 2020
DOE Building Energy Asset Score	EnergyPlus	Web-based	Freeware	PNNL 2020
EnergyPro	DOE2.1E, EnergyPlus	Desktop	Commercial	EnergySoft 2020
eQUEST DD Wizard	DOE2.2, DOE2.3	Desktop	Freeware	Hirsch 2020
eQUEST SD Wizard	DOE2.2, DOE2.3	Desktop	Freeware	Hirsch 2020
MIT Design Advisor	Custom	Web-based	Freeware	MIT 2020
PNNL TSPR Tool	EnergyPlus	Web-based	Freeware	U.S. Department of Energy n.d.
Net Energy Optimizer	DOE 2.2	Web-based	Freeware	
Praxis	Custom	Web-based	Not publicly available	AESC 2020 a-c, AESC 2017, Duke Energy 2020
Ripple	DOE2.2	Web-based	Not publicly available	Slipstream 2020, Hackel S and S Henry 2017
SBEM	Dutch methodology NEN 2916:1998	Desktop	Freeware	BRE Group 2020
Sefaira	EnergyPlus	Web-based	Commercial	Sefaira 2020

2.1.1 Complexity of User Inputs

Pre-defined Use Types – All of the simulation tools reviewed allow users to select a building area type that populates appropriate modeling inputs for that building type (schedules, occupancies, plug loads, temperature setpoints, lighting power densities, etc.).

Geometry, Envelope & Fenestration –Table 2.1-2 summarizes some capabilities of the different tools. The review reflects the broad range of capabilities of current software. A detailed description of each feature reviewed for this report is included in Appendix B.

Lighting & HVAC – Most tools reviewed use the area type to set a default lighting power density and allow users to enter a custom lighting power density. All of the tools reviewed use a simplified set of inputs for HVAC systems. Lighting and HVAC features of the different tools are summarized in Table 2.1-3. A detailed description of each feature reviewed for this report is included in Appendix B.

Table 2.1-2 Summary of S-BPM Tool Geometry and Building Envelope Capabilities

Name of Program	Geometry			Thermal Zoning		Space Type Definitions		Opaque Envelope					Fenestration				
	Simplified Geometry	Predefined Building Shapes (T,L,U etc.)	Custom Input for Geometry	Simplified Thermal Zoning	Custom Thermal Zoning	Building Area Types	Space Types	Simple U-Factor Input	Layered Constructions	Accounts for Thermal Mass	Can Analyze Below Grade Walls	External Shading/Blinds/Fins	Simple Window Performance	Detailed Window Performance	Window Area/ Position: Simple	Window Area/ Position: Detailed	Skylights
COMcheck	Y	N	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Commercial Building Energy Saver	Y	N	N	Y	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	N	Y
cove.tool	Y	N	Y	Y	N	Y	N	Y	Y	Y	Unsure	Y	N	Y	Y	Y	Y
DOE Building Energy Asset Score	N	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y
EnergyPro	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
eQUEST DD Wizard	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y
eQUEST SD Wizard	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y
MIT Design Advisor	Y	N	N	Y	N	Y	N	Y	Unsure	Y	N	Y	Y	N	Y	N	N
PNNL Total System Performance Ratio Tool	N	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	N	Y
NEO	Y	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	N	N
Praxis	Y	N	N	Y	N	Y	N	Y	N	N	N	N	Y	N	Y	N	N
Ripple	Y	N	N	Y	N	Y	N	Y	N	N	N	Y	N	Y	Y	N	Y
Sefaira	N	N	Y	Y	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	Y

Table 2.1-3 Summary of S-BPM Lighting and HVAC Capabilities

Name of Program	Lighting						HVAC								
	LPD Input	Other Internal Loads	Simple Lighting Controls	Detailed Lighting Controls	Daylighting Controls	Exterior Lighting	Simplified HVAC System	Detailed HVAC System	System Efficiency Input	Multizone Systems	Hydronic Systems	Heat Recovery	Demand Control Ventilation	Economizers	Supply Air Temperature Reset
COMcheck	Y	N	N	N	N	Y	Y	N	Y	Y	Y	N	N	N	N
Commercial Building Energy Saver	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
COVE Tool	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
DOE Building Energy Asset Score	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y
EnergyPro	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
eQUEST DD Wizard	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
eQUEST SD Wizard	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
MIT Design Advisor	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
PNNL TSPR Tool	Y	N	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y
NEO	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Praxis	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Ripple	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Sefaira	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N

Code Compliance – TSPR and COMcheck, are the only tools with the capability to automate code compliance. COMcheck is designed to do ASHRAE 90.1 Appendix C envelope trade-off compliance, and users can select different codes for the analysis. TSPR tool is set up for HVAC compliance for the State of Washington.

Baseline Automation – Most of the tools reviewed have some capability to automatically establish a baseline case for comparison against a proposed design case. This ability is directly related to the purpose of the tool. All of the reviewed tools establish a baseline corresponding to the minimum prescriptive criteria of a specific energy code and do not have the capability yet to evaluate a building using the PRM.

2.1.2 Usability

The usability of the reviewed tools covers a wide range but generally each one requires substantially less modeling time than tools without simplifications. Most tools have error checking that flags when inputs are incomplete. Usability was dictated by each tool's purpose.

- Ease of Data Entry

Usability was greatly increased when a tool had pre-entered defaults for each of the inputs or determined multiple model inputs based on a single user input. The most common instance of this seen across almost all the tools was the selection of building operational characteristics based on the user-selected building type. eQUEST wizard tools were the only ones that selected HVAC system types based on the user-selected building type. Though a convenient feature, this can result in energy models that have very little correlation to actual building design.

- Multiple Applications

The biggest challenge around usability is simultaneously making a tool simple but giving it enough accuracy and flexibility to be applicable across a large range of applications. Since most tools were developed for a specific application, they do not have usability beyond their intended purpose. Only a couple of the tools have broad flexibility to be very simple or very complex, allowing them to be used for a broad range of applications. eQuest is the best example of this approach where the Schematic Design Wizard has only a limited number of available inputs, but it can be transitioned into a detailed model where every input in DOE2.2 is available to the user.

To better understand usability the number of user inputs in eQUEST SD Wizard, Praxis and RIPPLE were looked at in more detail. eQUEST SD Wizard is the most mature of the tools reviewed having been available since 2001(Hirsch JJ. 2020). Ripple and Praxis are more recent tools and relevant given their current deployment as simplified BEM tools. Table 2.1-4 summarizes the representative number of user inputs that would be required for each tool. This is helpful in showing the extent to which Praxis and Ripple are similar in the number of user inputs they require. It is also notable that the inputs for schedules and loads are predominant in each of the tools.

Table 2.1-4 Number of S-BPM Tool User Inputs

User Input Category	eQUEST SD Wizard	Ripple[(a)]	Praxis
General Project Information	20	8	13

Building Geometry and Envelope	71	48	13
Operational Schedules and Internal Loads	136	33	44
HVAC	49	11	45
Total	276	100	115

(a) Inputs per Space Shell

2.1.3 Reporting Capabilities

In general, each tool's reporting capabilities primarily focused on the tool's purpose. Architectural design tools tended to be more graphical and explore more graphic rich reporting. In addition to reporting energy and cost savings, metrics like daylight and thermal comfort may be reported. Utility incentive tools and code compliance tools tended to focus more on reporting tabular energy and cost savings results and a summary of key modeling inputs. eQUEST has an integrated life cycle cost analysis feature that captures parametric energy and cost savings results during runtime. This allows for dynamic reporting of efficiency measure return on investment, simple payback and net present value.

2.1.4 Summary of Salient Features Applicable to S-BPM

Based on the review of S-BPM tools the following salient features were identified as

- Defaults for Loads and Schedules:
  - Capability to populate model inputs with operating schedule and internal load defaults based on building type and building area type
- Simplified Thermal Zoning:
  - Default single zone, or perimeter/core configuration.
  - Area weighting of internal gains and schedules as part of a simplified zoning strategy.
- Simplified Building Geometry:
  - Ability to automatically create floor layouts from gross floor area, number of stories, and a default building shape.
- Lighting
  - Input for whole building or shell lighting power density
  - Simplified lighting control options that were defined for the entire building or shell
- Envelope Parameters:
  - Standard options for envelope construction types for each opaque envelope component.
  - Ability to determine correct envelope assembly U-factor based on Standard 90.1 Appendix A criteria when insulation R-values are specified
  - Assigning fenestration area by orientation
- HVAC
  - Capability to automatically determine equipment capacities
  - Simplified HVAC performance inputs with defaults for equipment performance curves
  - Simplified assumptions and analysis of advanced control strategies – demand control ventilation, heat recover ventilation, temperature resets etc.

–

- Integrated parametric analysis and life cycle cost analysis features

2.2 Modeling Approaches in Current Codes and Standards

The authors consider Standard 90.1 Appendix G PRM to be the benchmark modeling methodology against which other methodologies are compared in terms of complexity and scope of application. Table 2.2-1 summarizes five existing energy modeling methodologies that were reviewed as part of this study, which include five for current codes or standards.

Apart from the Standard 90.1-2016 Energy Cost Budget (ECB) method, each methodology requires an annual energy simulation with a minimum of 8,760 hourly time steps. The Standard 90.1-2016 Energy Cost Budget modeling methodology allowed simulations that run at least 1,400 hours to allow software tools that only ran 3-4 representative days per month rather than a full year. Today’s computational power no longer requires running less than a full annual simulation to save time and money. The ECB methodology was amended prior to the publication of Standard 90.1-2019 and now requires a full 8,760 annual simulation.

Table 2.2-1 Summary of Codes and Standards

Name	Purpose	Simulation Method	Reported Metric(s)	Applicability
Standard 90.1 Appendix C[(a)]	Envelope performance-based code compliance	8,760 hourly simulation	Energy cost	All buildings except low-rise residential
Washington State TSPR [(b)]	HVAC performance-based code compliance	8,760 hourly simulation	Carbon emissions	Limited building types and sizes
California Title 24 Non-Residential Alternative Compliance Method[(d)]	Whole building performance-based code compliance	8,760 hourly simulation	Time-dependent value (TDV) energy	All buildings except low-rise residential
Standard 90.1-2016 Energy Cost Budget Method[(a)]	Whole building performance-based code compliance	Minimum 1,400-hour simulation	Energy cost	All building types except low-rise residential

(a) ASHRAE 2016
(b) WA Building Code Council 2019, 2020
(c) Energy Star 2020a,b
(d) California Energy Commission 2015

2.2.1 Salient Features

Standard 90.1 Appendix C and WA State HVAC System Performance are the two simplified rulesets which defined required simplifications for defining the proposed building model. The intent of these requirements is to significantly reduce the time required to create the proposed building model and hence, encourage the use of these optional compliance paths in lieu of the prescriptive paths.

The following simplifications were identified as salient features of the reviewed codes and standards, for S-PRM development. Each of these features is discussed in more detail in Appendix C.

- Automatic generation of baseline model
- Automatically generated standard output report

- Prescribed schedules and internal loads
- Simplified modeling approach for HVAC systems

2.3 Efficiency Programs

An S-PRM approach would be applicable as a methodology for both code compliance and beyond code performance calculations. In addition to codes; green building rating systems, utility incentive programs and Property Assessed Clean Energy (PACE) programs could be potential applications for the S-PRM approach.

This section of the report explores different utility incentive and PACE programs across the U.S. and summarizes their whole building simulation requirements. In total, over 40 utility incentive programs and C-PACE programs were reviewed during this research. Twenty-five incentive programs and nine PACE programs are summarized in this report. During the review, many programs were identified that did not offer a whole building simulation incentive, and for brevity they are not included in this report.

Table 2.3-1 summarizes the efficiency programs that allow whole building energy modeling. A complete list of the reviewed programs with a description of features is included in Appendix E. Each of the reviewed C-PACE programs is summarized in Table 2.3-2 with a more detailed description of features in Appendix F. The Reference Sources included in Table 2.3-1 and Table 2.3-2 were all used to inform the discussion in this Section.

The review of energy efficiency programs identified the following features for S-PRM that would it useful for a variety of utility incentive programs. Appendix D discusses the findings of our review in more detail.

- Be adaptable to a broad range of compliance metrics such as site energy, electric demand, source energy, carbon and cost
- Be adaptable to a range of state energy code and utility efficiency program requirements.
- Be applicable to a variety of building types

Table 2.3-1 Summary of Utility Incentive Programs

Name of Program	Includes a BEM Incentive	Mandates Use of a Specific Software Tool or Tool Meeting Standard 90.1 PRM	Standard 90.1 PRM or Derivative Modeling Approach	Source Reference
NYSERDA (New York State Energy Research and Development Authority) Multifamily New Construction (MPP)	✓	✓	✓	NYSERDA 2020f,g NYSERDA 2018
NYSERDA MPP – Existing Buildings	✓	✓	✓	NYSERDA 2020f,g
NYSERDA New Construction Program (NCP)	✓	✓	✓	NYSERDA 2020a,b

Name of Program	Includes a BEM Incentive	Mandates Use of a Specific Software Tool or Tool Meeting Standard 90.1 PRM	Standard 90.1 PRM or Derivative Modeling Approach	Source Reference
Eversource (Massachusetts) Non-residential	✓	✓	✓	Mass Save 2019 Mass Save 2020a,c
Eversource (Massachusetts) Multifamily	✓	Data Unavailable	✓	Mass Save 2020a,b,c
Eversource (Connecticut)	✓	✓	✓	Energize Connecticut 2020
Wisconsin Focus on Energy	✓	✕	✓	Focus On Energy (WI) 2020
COMEd Chicagoland Performance Path	✓	Data Unavailable	✓	ComEd 2019a,b
COMEd – Slipstream	✓	✓	✓	ComEd 2019a,b
Xcel Energy (Colorado)	✓	✓	✓	Xcel Energy (CO) n.d. Xcel Energy (CO) 2019
Xcel Energy (Minnesota)	✓	✓	✓	Xcel Energy (MN) 2018, 2019, 2020
Energy Trust of Oregon (Oregon)	✓	✓	✓	Energy Trust of Oregon 2020
CA Savings by Design – Whole Building	✓	✓	✕	Savings By Design 2019
Duke Energy (Florida)	✓	✕	✓	Duke Energy (FL) 2020
Duke Energy (Kentucky)	✓	✓	✓	Duke Energy (KY) 2020
AMEREN (Illinois)	✓	✓	✓	Ameren (IL) 2020

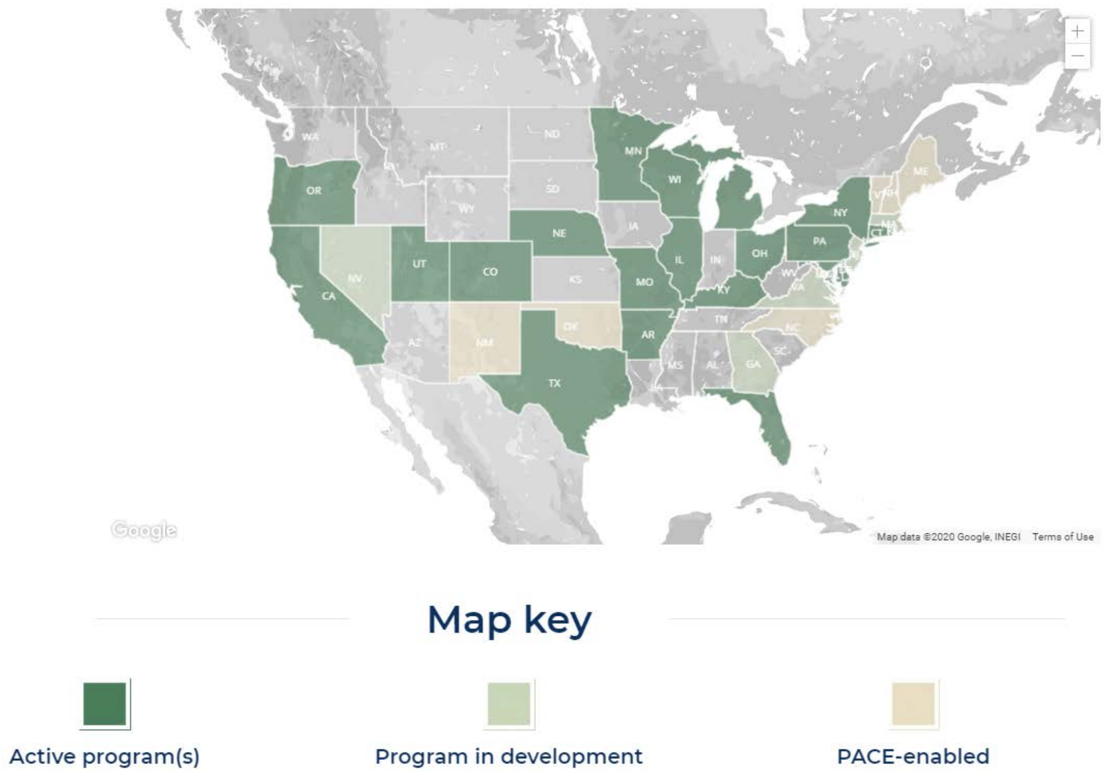

Figure 2.1. States with PACE Programs[1]

Table 2.3-2 Summary of Commercial PACE Programs

Name of Program	Allows New Construction	Allows Whole Building Modeling	Code Baseline	Reference Source
Oregon	✓	✗	Standard 90.1-2016	Property Flt Oregon 2020
New York	✗	✓	IECC 2018 or Standard 90.1-2016 + NYS amendments	NYSERDA 2020c
Wisconsin	✓	✓	Standard 90.1-2010	PACE Wisconsin 2020
Illinois	✓	✓	IECC 2018 or Standard 90.1-2016 + IL amendments	IECA 2019
Pennsylvania C-PACE	✓	✓	IECC-2015	Sustainable Energy Fund 2019
Kentucky PACE	✓	✓	IECC2012 or Standard 90.1-2010	City of Louisville 2020
Colorado PACE	✓	✓	IECC-2015	Colorado Energy Office 2020
Florida PACE	✗	✗		Florida PACE Funding Agency 2020
Connecticut PACE	✓	✓	IECC-2018	Connecticut Green Bank 2020

[1] Source: https://pacenation.org/pace-programs

3.0 Conclusion

The research shows that a robust S-PRM has the potential to improve the decision-making process for energy efficiency improvements for existing buildings as well as increase the use of BEM for code compliance for simple buildings. Duke Energy has reported that the use of a simplified BEM method significantly increased program participation by reducing analysis time and cost[1].

Current energy codes and standards provide both prescriptive and performance paths for demonstrating compliance. Prescriptive compliance is simple and straightforward, but limits flexibility and fails to account for individual building characteristics and interactions that can help optimize a buildings energy performance. A survey of energy code and beyond code program administrators indicated that the vast majority of non-residential compliance permits use the prescriptive path except in certain states like California (50%) and Florida (90%) where use of the performance path is much higher (Karpman, M 2020). This suggests a large potential to increase the use of BEM using a S-PRM to improve State energy code compliance outcomes. Research shows that a robust S-PRM has the potential to improve the decision-making process for energy efficiency improvements for existing buildings as well as increase the use of BEM for code compliance for simple buildings.

Several key research questions from Table 2-1 are specifically addressed in more detail to better inform S-PRM development.

- What would be the key criteria for determining applicable buildings for an S-PRM analysis?
  - Building use type, geometry, size, and complexity of the HVAC system could be some of the key parameters for determining the applicability of buildings for S-PRM analysis.
  - S-PRM approach would not be appropriate for some use types, such as hospitals, kitchens, natatoriums and data centers, which have complex requirements for space conditioning or ventilation. Similarly, buildings with unusual geometry might not be conducive to simplification using the S-PRM approach. Larger buildings typically have complex HVAC systems and controls that might not be appropriately represented through a S-PRM approach.
- What are the key characteristics of a simplified energy modeling tool?
  - User inputs: Table 2.1-4 suggests that fewer than 300 unique user inputs are required for a tool deploying S-PRM. Many building systems and efficiency features will need to be modeled using a prescribed approach and a user will select whether a project includes these features. For larger more complicated commercial buildings this may not be suitable but for most smaller, simple buildings it will be.
  - Geometry: Simplification of entering building geometry is an important feature of simplified modeling tools. S-PRM would need to allow geometry to be simplified Simplifications could potentially introduce variations in surface areas or conditioned volume and the S-PRM would need to identify the permissible limits for this variation.
  - Operating Schedules: Another important simplification is the use of prescribed operating schedules based on building type. Removing the burden of entering unique building schedules reduces the time required to model a building. Many of the simple modeling tools use this feature as well as several of the codes and standards that were reviewed.

[1] Taylor, A Duke Energy. (2020, March 11). Telephone interview.

- Lighting and Lighting Controls: While lighting power is quite easy to model many of the advanced lighting control strategies currently required by energy codes are much more difficult. The simplified modeling tools often do not allow detailed modeling of automatic daylighting and occupancy controls. S-PRM will need to address how to capture the requirements of lighting controls in a simple way.
- Internal Loads: Similar to occupancy schedules S-PRM can reduce modeling time by requiring prescribed internal loads based on building type. This strategy is currently used by simplified modeling tools and several codes and standards.
- HVAC Systems: Limiting S-PRM to less complex HVAC systems will reduce the number of user inputs required making S-PRM tools simple and easy to use.
- HVAC Controls: Reducing the complexity of HVAC controls is important for an S-PRM approach. Several simplified tools use either a Yes/No answer or a check box to indicate whether a building includes these advanced strategies. Capturing strategies like demand control ventilation is necessary for code compliance but it must be done with a simplified user interface.

- What constraints exist in developing a simplified PRM (S-PRM) ruleset?
  - Developing a detailed set of operational schedules and building loads, as previously discussed, present a significant opportunity to reduce unique user inputs and simplify BEM. However, this requires a robust set of schedules and loads that can referenced by the S-PRM ruleset. Developing this would be a challenge and the research team will evaluate various existing sources to identify appropriate defaults for loads and schedules.
  - The ruleset will have to define constraints for simplifying building geometry and the acceptable variation of the simplified geometry with actual building design. The various S-BPM tools reviewed use different simplification methods and among these a common approach will need to be established. Similarly, it would need to include explicit rules for simplified data entry for building envelope, HVAC, lighting and SWH systems to minimize variation in modeling tools that implement this ruleset.
  - Key stakeholders, which include software developers, energy efficiency program managers, energy modelers, and others, would need to be involved during ruleset development to feedback and guidance on key aspects of the ruleset.
- Are there existing programs that can benefit from a simplified PRM?
  - Codes and standards currently provide simplified modeling methodologies for system performance analysis (Standard 90.1 Appendix C and TSPR) but no simplified approach for whole-building compliance yet exists. A simplified PRM would provide a whole building approach and tools for implementation that could be adopted by jurisdictions for demonstrating compliance with the energy code. Given the limited use of the current PRM for compliance, a robust easy to use S-PRM would expand the ability for States and jurisdictions to use BEM.
  - While utility programs have historically adopted simplified BEM approaches for efficiency incentive programs the deployment is limited and utilities like Duke Energy anticipate phasing out of these programs over the next few years[1].

[1] Taylor, A Duke Energy. (2020, March 11). Telephone interview.

- An unexpected outcome of this research is the potential application of BEM using a S-PRM to support C-PACE financial programs. Since 2015 C-PACE financing has increased over 500% from $200M to $1,100M annually (PACENation 2020). As more States expand C-PACE offerings to include new construction the opportunity to support the financing of more energy efficient buildings with a simple to use yet robust BEM tool built on S-PRM seems obvious. To confirm this, the research team will include C-PACE stakeholders in the stakeholder group convened during the next phase of work.

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Appendix A – S-BPM Tool Details

Name of Program	Simulation Engine	User Interface	Type of Annual Simulation	Auto Baseline	Test EEMs	Tool Purpose & Availability	Complexity of User Inputs
Sefaira	EnergyPlus	Cloud-based	Dynamic hourly	Yes	Yes		
EPA Avert Tool							
PNNL TSPR	EnergyPlus	Cloud-based	Dynamic hourly	Yes	No	Compare proposed performance of an HVAC design against a prescribed baseline case. Limited to certain building types smaller than 25,000 ft^2.	Users describe simple geometry blocks based on area type and location. Select dropdown lighting and HVAC, enter efficiencies and installed power. Simple screen-based data entry.
DOE Asset Score	EnergyPlus	Cloud-based	Dynamic hourly	Yes	No	Compare whole building energy against a target baseline.	Users describe simple geometry blocks based on area type and location. Select dropdown lighting and HVAC, enter efficiencies and installed power. Simple screen-based data entry.
COMcheck	EnergyPlus	Cloud-based or standalone	Dynamic hourly	Yes	No	Document prescriptive compliance with Standard 90.1 or the IECC. Also used as implementation of Standard 90.1 Appendix C.	User input is simple for Standard 90.1 Appendix C analysis. Users enter description of envelope components, materials, and areas. No entry of HVAC, lighting, schedules, etc. Automated reporting.
eQUEST SD Wizard	DOE2.2 or DOE2.3	Standalone	Dynamic hourly	No	Yes	Simple interface for DOE2 engine.	Hierarchy of Wizard screens allows rapid setup of simple whole building energy model.
eQUEST DD Wizard	DOE2.2 or DOE2.3	Standalone	Dynamic hourly	Yes - for Title 24	Yes	Simple interface for DOE2 engine. More complex than SD Wizard.	More detailed screens than SD Wizard, can customize zoning.
SBEM (UK Tool)	Microsoft Access databases and custom modeling engine	Standalone	Monthly heat balance	Yes	No	Compliance with UK energy code. Focus is on passive design and reduction of heating and cooling loads. Does not allow detailed simulation of HVAC systems; relies on average system efficiencies.	Requires detailed entry of spaces; schedules and internal loads are determined by space type. Envelope must be described in detail.
EnergyPro	DOE2.1E or EnergyPlus	Standalone	Dynamic hourly	Yes	TB	Commercially available; designed around automated compliance with Title 24.	User input is straightforward and requires detailed entry of thermal zones.
LBNL Commercial		Cloud-based	TBD	No	Yes	Designed for existing buildings; requires utility	Only about 100 user inputs for an entire building. More if

Name of Program	Simulation Engine	User Interface	Type of Annual Simulation	Auto Baseline	Test EEMs	Tool Purpose & Availability	Complexity of User Inputs
Building Energy Saver						bills and/or interval data to work properly. Designed to create a quasi-calibrated model for testing efficiency measures.	users set up detailed schedules. Tabbed interface is easy to navigate.
MIT Design Advisor	Custom	Cloud-based	TBD	No	Yes	Simple analysis of building energy. Only allows a single zone to be modeled. Allows setup of several parametric runs to test options.	Limited user inputs, limited number of thermal zones allowed. Very simple user inputs.
COVE Tool		Cloud-based	Dynamic hourly		Yes	Simple analysis tool focused on optimizing envelope and other passive features that architects control early in concept and schematic design. Not intended as a detailed whole building simulation tool. Great user interface.	Connects to Revit/Rhino to import geometry; simple HVAC inputs do not allow complex HVAC modeling. Most modeling inputs are pre-selected based on the building type. No option for further customization.
Praxis	Custom	Cloud-based	Dynamic hourly	Yes	TBD	Simplified whole building analysis for utility incentive programs. Not commercially available as a standalone software tool. No complex HVAC modeling capability. Features are geared around efficiency measures allowed by utility.	Simple user inputs on several tabs. Inputs are predominantly selected via pre-configured drop-down boxes. Users enter peak power and efficiencies of HVAC and lighting. User selected area types sets schedules, vent, etc. Limited HVAC options.
Slipstream (RIPPLE)	DOE2.2	Cloud-based	Dynamic hourly	Yes	TBD	Simplified whole building analysis tool for utility incentive programs. Not commercially available.	

HVAC	heating, ventilation, and air conditioning
LBNL	Lawrence Berkeley National Laboratory
MIT	Massachusetts Institute of Technology
TSPR	Total System Performance Ratio

Appendix B – S-BPM Tool Feature Code Descriptions

B.1 S-BPM Tool Geometry and Building Envelope Feature Descriptions

Term	Modified definition
Geometry Feature Codes	
Simplified Geometry	This could include features which allow a user to specify a combination of inputs and defaults including total conditioned floor area, number of floors, floor to floor height and aspect ratio are used to automatically establish geometry that may (or may not) be modified further by the user. For some tools, the building shape is a default and a user can modify the building dimensions and specify fenestration dimensions or areas.
Predefined Building Shapes	Describes a feature that allows users to select from a series of default building shapes like rectangles, H-shapes, T-shapes, U-shapes, etc to create a geometric representation of their building
Custom Input for Geometry	Describes the capability to draw or import custom geometry.
Thermal Zoning	
Simple Thermal Zoning	Describes tools that automatically generate perimeter/core zoning or single zone per floor based on a default or user specified perimeter zone depth. A user cannot define any other thermal zoning layout.
Detailed Thermal Zoning	Describes capability to define custom thermal zones.
Space Type Definitions	
Building Area Type	Describes tools that allow users to define building use types by building area type definitions. Example: Office, retail, school.
Space by Space Method	Describes tools that allow users to define space types for space-by-space definition. Example: Corridors, rest rooms lobby etc.
Opaque Envelope Feature Codes	
Simple U-Factor	Describes users ability to describe opaque wall performance using only a simple U-value input for the opaque assembly. The assembly U-factors might be modeled using layered constructions, but a user is not able to specify the same through the tool user interface.
Layered Constructions	Describes users ability to describe opaque wall performance by defining the individual material layers and their thermal properties.
Accounts for Thermal Mass	Describes a capability in simulation tools to account for thermal mass, with or without direct user input.
External Shading	Describes a feature for addressing external shading through overhangs, fins or light shelves. There is no distinction between a simple input or a more detailed one.
Fenestration Feature Codes	
Simple Window Performance	Describes feature where window performance is described through a list of inputs describing the windows characteristics. For example, number of glass panes, frame type, window costing etc.
Detailed Window Performance	Describes a feature through which a user can describe glazing performance by entering glazing U-factor, SHGC and visible transmittance. Also covers ability to import window characteristics through other tools including the LBNL Windows tool.
Window Area/Position: Simple	Describes a feature that allows users to describe window areas through a simple WWR input. This could be specified for the entire building or by individual surfaces or by orientation.

Window Area/Position: Detailed	Describes capability to set custom window areas by individual wall surface or by orientation. Instead of creating a single window per surface, a more detailed layout of individual windows would be created based on user input of window dimensions etc.
Skylights	Allows modeling of skylights.
O&F - overhangs and fins:	Describes features that capture external shading of fenestration using overhangs or fins.

B.2 S-BPM Tool Lighting and HVAC Feature Code Descriptions

Term	Modified definition
Lighting Feature Codes	
LPD Input	Describes a tool feature which allows for a custom lighting power density input.
Simple Lighting Controls	Describes a feature that accounts for occupancy-based lighting control through a single input for the block/building. This does not cover daylighting controls which are all covered under a separate category.
Detailed Lighting Controls	Describes a feature which allows a user to account for lighting controls through a space-by-space adjustment of LPD or lighting schedule. This also includes the ability of a tool to analyze different lighting control types, in addition to occupancy sensors. This does not include daylighting controls.
Daylighting Controls	Describes ability to model daylighting controls. It should be noted that the reviewed simplified modeling tools had a broad range of daylight modeling capabilities.
HVAC Feature Codes	
Simplified HVAC System	Describes tools that uses a simple interface for describing or modeling HVAC systems. System capacities and airflows are auto sized by the simulation tool and a user is either not permitted to specify these values or the user specified values are not used in the analysis. The simulated HVAC systems are not explicit representations of the proposed design.
Detailed HVAC System	Describes a tool that allows users to specify as-designed system parameters like capacities, airflows, etc which are also used for the simulation.
System Efficiency Input	Describes a tool that allows users to enter rated HVAC system efficiencies for air-side or hydronic systems.
Multizone Systems	Describes capability to specify HVAC systems that serve multiple zones.
Hydronic Systems	Describes the ability to describe hydronic HVAC system performance.
Heat Recovery	Describes a tool with ability to account for exhaust air heat recovery.
Demand Control Ventilation	Describes a tool with ability to account for demand control ventilation.
Economizers	Describes a tool with ability to account for air-side economizers.
Supply Air Temperature Reset	Describes a tool with ability to account for supply air temperature reset.

Appendix C – Modeling Approaches in Current Codes and Standards

C.1 Overview

- **Standard 90.1 Appendix C** – Embedded within Standard 90.1, the Appendix C modeling methodology is used as an envelope-only trade-off method. The approach uses simplified geometry and HVAC requirements to test whether a proposed building envelope, as a complete system, meets the overall minimum efficiency requirements based on the prescriptive criteria of each component. Compliance calculations and reporting are automated.
- **Washington State Total System Performance Ratio (TSPR)** – This new code methodology evaluates a building's proposed HVAC system and tests if it meets the established performance target. The approach uses simplified geometry and is applicable to buildings with simple HVAC systems. Compliance calculations and reporting are automated.
- **CA T-24 Nonresidential Alternative Calculation Method (NACM)** – This methodology is used for commercial building performance-based compliance calculations in the State of California. NACM, which is applicable to all non-residential buildings, requires automated model generation and uses prescribed operating schedules and internal gains to streamlines analysis. Similar to PRM this approach requires a detailed model of the proposed design.
- **Standard 90.1 ECB** – The basic ECB methodology has been the performance trade-off approach within Standard 90.1 since 1999. The baseline requirements in ECB are less complicated than PRM but despite this simplification the approach still requires a detailed model of the proposed design which.

C.2 Applicable Buildings

- T-24 NACM, Standard 90.1 ECB, and Standard 90.1 Appendix C are applicable to all buildings, except low-rise multifamily while Energy Star is only applicable to a limited number of building types.
- TSPR methodology as implemented in the Washington State energy code has limited application to mid and high-rise multifamily[1] and non-residential buildings larger than 5,000 ft^2 that are office, library, retail, or educational buildings. TSPR also has many other limitations on its applicability, including but not limited to buildings that are heated only, use purchased or district energy, salient, have air-to-water or water-to-water heat pumps, or have complex systems not specifically covered by the TSPR method. Despite the seemingly limited applicability of TSPR, the systems and buildings it does cover represent a large fraction of the total building stock in the state. Although TSPR provides a simple approach for confirming HVAC system performance in a large portion of the building stock using a robust simulation-based approach.

[1] TSPR only applies to multifamily building in Seattle.

C.3 Reporting Requirements

Each of the reviewed methodologies has different reporting requirements, in terms of both the metric used for compliance and the information that needs to be reported or submitted for demonstrating compliance. Generally, the complexity of the reporting requirements is commensurate with the intended use of the tool. Title 24 and TSPR require that an output report be automatically generated by the software. The intent of the standard output report is to simplify the review process and minimize user errors or misrepresentation of results. It also simplifies the process for users by eliminating the tedious step of documenting modeling inputs and outputs in the format required by the program.

The different methods reviewed use a variety of reporting metrics, including energy cost, carbon emissions, site energy, source energy, and TDV energy – a metric unique to California Title 24.

Appendix D - Efficiency Programs

D.1 Program Goals

D.1.1 Utility Incentive Programs

Many of the utility incentive programs reviewed offer customers a custom incentive approach for whole building projects that accounts for interactions between different building systems, including envelope, HVAC, service water heating (SWH), and lighting energy efficiency measures. This gives customers designing new construction or major renovations an opportunity to achieve higher incentive levels than would otherwise be offered under prescriptive incentive programs. The whole building performance incentive offerings vary by state and utility as shown in Table 2.3-1, and broadly, based on this research, there appear to be some regional similarities:

- Northeast and Western States – Greater emphasis on performance-based analysis that captures both electricity consumption savings and electric peak demand savings and, in some cases, natural gas. Programs are more likely to use an alternate metric such as source energy, TDV, or greenhouse gas emissions.
- Southeast, Midwest, and Intermountain States – Performance programs are focused primarily on kWh savings, with a few programs offering natural gas incentives.

D.1.2 C-PACE Programs

Like utility efficiency programs, PACE programs incentivize building owners to invest in energy efficiency. There are currently over 60 PACE programs across the U.S., which funded over $1 billion in commercial building efficiency improvements in 2019 (PACE Nation 2020). Figure 2.1 shows the U.S. states that currently offer PACE programs.

PACE is unique in that it offers building owners the opportunity to use the value of their property as loan collateral to help fund efficiency improvements. The loan is tied to the property and therefore can be transferred to a new owner if a property is sold. An important aspect of PACE is the preparation of energy efficiency savings calculations to document the potential benefits of efficiency retrofits. Unlike most utility incentive programs that focus on energy savings for a specific fuel type, PACE programs allow energy savings from any fuel type to be used.

Originally, PACE programs were intended only for existing buildings with an energy baseline that could be documented through measured data like utility bills, but over time programs have expanded and rules for new construction have been created in some jurisdictions (C-PACE Alliance 2019). In 2019, 14% of C-PACE funding was for new construction projects (PACE Nation 2020).

Table 2.3-2 summarizes the whole building simulation requirements of a broad sample of current C-PACE programs throughout the U.S. Although PACE covers both residential and commercial properties this research only looked at commercial programs.

D.2 Modeling Approach & Complexity

Most energy efficiency programs offer both prescriptive and performance-based approaches for qualifying for incentives. The prescriptive path includes a suite of prescriptive incentives ranging from five to six measures to a comprehensive suite of measures covering HVAC, lighting, envelope, and process loads. While a simple modeling approach may not capture, for example, the benefit of advanced HVAC control strategies, it can capture the majority of envelope, lighting, SWH, and HVAC system efficiency benefits. The programs have the flexibility to allow more complex modeling to be used on a case-by-case basis.

At least 28 state or regional technical reference manuals (TRMs) have been adopted across the U.S. (Schiller et al. 2017). The TRM outlines the calculation methodologies for determining energy and cost savings of energy efficiency measures deployed as part of utility incentive programs. In states like New York, the TRM is approved by the Public Service Commission and is updated frequently (New York State Joint Utilities 2019). Energy savings in the TRM are generally documented on a measure-by-measure basis and outline the methods required for determining fossil fuel, electricity consumption, and electricity peak demand savings. In New York State TRM requirements are used in developing guidelines for both NYSERDA incentive programs and the state PACE programs. An exhaustive look at state-by-state TRM requirements and their potential impact on a S-PRM was not done as part of this research.

D.2.1 Utility Incentive Programs

With the exception Passive House certified projects, all of the programs surveyed (see Appendix E of this report) require an 8,760-hourly simulation for whole building models and establish the state energy code as the performance baseline.

Incentive programs in New York and Oregon are the only ones reviewed that utilize the PRM. The other programs reviewed use a modeling methodology with a baseline that is set equal to the minimum performance required by a State or local energy code (similar to the Appendix G approach prior to 2016). Programs offered by utilities in Connecticut, Oregon, and New York, have developed publicly available modeling guidelines that clarify specifics on approved simulation tools, special modeling requirements and minimum reporting criteria. The remaining programs do not have publicly available guidelines and while these guidelines may exist, they are not available on incentive program websites.

The whole building incentive programs offered by utilities in Massachusetts and California specifically exclude the use of PRM. California Savings by Design is based on the Title 24 simulation requirements and Massachusetts requirements for whole building simulation are written around the state energy code and specifically prohibit the use of Standard 90.1 Appendix G, Standard 90.1 ECB, or IECC Section 407 methodologies.

Programs offered by utilities serving multiple states tend to have similar requirements in large part because they select a single consultant to administer the different programs. Firms like NORESCO, TRC, AESC, and Slipstream have developed custom software solutions to meet the specific requirements of the utility programs they administer.

Despite each program being unique there do appear to be some similarities that align with the different regional program goals described in the previous section.

- Northeast and Western States – Strong emphasis on whole building analysis with detailed requirements for whole building simulation that are publicly available on program websites.

- Midwest and Intermountain States – Allow modeling on a broad range of projects but often rely on a simplified approach managed by a program administrator.
- Southeast States – Incentive programs are predominantly prescriptive, with modeling allowed in certain cases.

D.2.2 C-PACE Programs

Across the various C-PACE programs that were reviewed, there does not appear to be a consistent approach that all projects are required to follow. Some states are quite vague about the requirements like programs in Florida and Chicago. Programs in Pennsylvania and Wisconsin suggest using Standard 90.1 Appendix G while the pilot in Connecticut does not allow the PRM to be used. This lack of consistency may be driven in part by C-PACE being primarily geared towards existing building (86% of C-PACE funding in 2019 was for existing buildings; PACE Nation 2020) rather than new construction. Existing buildings are predominantly required to use their utility bills as the baseline for energy savings calculations. There seems to be a real opportunity to develop a low-cost simple methodology that can be more widely adopted by C-PACE programs to try to accelerate the participation of new construction projects (C-PACE Alliance 2019).

The C-PACE programs that do allow modeling are consistent in requiring between a 5-10% improvement in as-designed performance compared to the baseline in order to qualify for funding.

D.3 Applicable Buildings

D.3.1 Utility Incentive Programs

Generally, most programs limit whole building analysis to larger buildings. However, the review found no consistent size limit across the different programs. Many states have developed robust prescriptive incentives as an alternative to energy modeling. But these programs were not investigated as part of this review. A number of programs have no size minimum, several have a 5,000-ft^2 minimum, some have 10,000-ft^2 minimum, and for others the minimum is 20,000 ft^2.

D.3.2 C-PACE

Among the programs that allow modeling, there is no restriction on the type or size of non-residential buildings. Multifamily buildings appear to be treated differently among the different C-PACE programs, but this research did not dig deeply into the specifics of those differences.

D.4 Prescribed Simulation Tools

D.4.1 Utility Incentive Programs

Generally, most utilities do not prescribe which software tools can be used. Several states do have pre-approved software, including California (California Energy Commission 2020a, b) Massachusetts (Mass Save 2019), and Connecticut (Karpman Consulting 2019). Based on the summary of program details in Appendix E, software requirements vary by program but tend to be the same for a specific utility serving multiple states.

In most cases, modeling software requirements in Standard 90.1 Appendix G were referenced as needing to be met. This requirement implicitly establishes criteria like using an 8,760 hourly simulation time-step and software testing in accordance with ASHRAE Standard 140.

Duke Energy and ComEd are examples of utilities with whole building performance incentive programs where analysis is done using a S-BPM approach. Duke Energy uses Praxis and ComEd uses Ripple. Both of these tools are discussed in more detail in Section 2.3.

D.4.2 C-PACE

Several of the C-PACE programs require software to be on the pre-approved list of tools that the U.S. Department of Energy developed for the 179-D commercial building energy efficiency tax credit (PACE Wisconsin 2020; Sustainable Energy Fund 2019). None of C-PACE programs specifically reference Standard 90.1 Appendix G software requirements.

D.5 Reporting Requirements and Metrics

D.5.1 Utility Incentive Programs

Twenty of the twenty-five programs reviewed offered some type of incentive using BEM, see Table 2.2-3 . The majority of BEM incentive programs fund projects with both electricity and natural gas consumption savings when a customer is served by a participating utility. However, depending on the geographic location, programs may also prioritize peak electric demand savings. Massachusetts is unique in that peak demand natural gas use also needs to be reported. A few programs use unique metrics, California incentives are based on TDV energy and Connecticut requires reporting of source energy savings.

	Allowable Energy Savings				
	Electricity Only	Electricity and Natural Gas	Natural Gas Only	Other Metric	Not Applicable
Number of Programs	7	11	1	1	5

Most incentive programs also require that energy efficiency measures meet a cost effectiveness metric such as life cycle savings, simple payback, or return on investment (New York State Joint Utilities 2019; Schiller et al. 2017). This metric is most often based on the anticipated energy cost savings, the implementation cost, and the expected useful life of the proposed measure.

Some programs like those run by NYSERDA in New York have specific reporting requirements and templates (NYSERDA 2020e) that are available publicly, and other programs like those run by Duke Energy using Praxis have reporting embedded in the software tool. Other programs like Mass Save, and Eversource have reporting templates but they are not publicly available. Typically, these reports document the energy modeling results, cost effectiveness calculations, and post construction verification tests that must be completed.

D.5.2 C-PACE

Generally, C-PACE energy savings calculation requirements are only focused on the energy cost savings associated with proposed energy efficiency measures. The intent is that energy savings provide the source of funding to pay back a C-PACE loan. However, the rigor of the energy savings analysis requirements appears to vary by C-PACE program. Some programs require energy savings calculations to be reviewed by a third party and mandate post-construction measurement and verification while others seem to provide little oversight.

Appendix E – Utility Incentive Program Details

Name of Program	Modeling Approach	Complexity & Tool Requirements	Application	Reporting & Reporting Metrics
NYSERDA Multifamily New Construction NYSERDA MPP	Must follow Energy Star homes performance path using either Appendix G or passive house methodology.	Must uses an approved tool that complies with Standard 90.1 Appendix G requirements unless certified passive house by PHI or PHIUS.	Multifamily new construction or gut rehab with 4 or more stories. Projects must pay systems benefit charge to qualify.	Incentives are based on kWh and peak kW savings and cost effectiveness. New regulations in NYS may support a carbon-based metric in the future.
NYSERDA MPP – Existing Buildings	Incentives are based on savings of 20-40% over a calibrated baseline model.	Must uses an approved tool that complies with Standard 90.1 Appendix G requirements.	Multifamily with >5 units, 50% of heated floor area is residential and building is designated as affordable (at least 25% of units are occupied by families earning < 80% of state median income).	Incentives are based on kWh and peak kW savings and cost effectiveness. New regulations in NYS may support a carbon-based metric in the future.
NYSERDA NCP	Support Level 2 and Support Level 3 projects require Appendix G modeling analysis.	Must uses an approved tool that complies with Standard 90.1 Appendix G requirements. Results are post-processed in NCP Excel workbook for cost effectiveness and incentive determination.	All new construction and major renovation of commercial and institutional buildings. No size limits. Projects must pay systems benefit charge to qualify.	Incentives are based on kWh and peak kW savings and cost effectiveness. New regulations in NYS may support a carbon-based metric in the future.
Eversource (Massachusetts) Non-residential	Different simulation-based incentive programs based on building size: large building and small building,	eQUEST is preferred, EnergyPlus is allowed with prior approval. Trace and HAP not allowed. Modeling methodology follows Massachusetts code requirements and supplemental guidelines. Standard 90.1 Appendix G, ECB, and IECC C407 baselines are not accepted.	Large buildings: >100,000 ft^2 Small buildings: 20-100K ft^2	Incentive based on site energy reduction – includes gas and electricity savings.
Eversource (Massachusetts) Multifamily	Modeling based incentive for multifamily new construction or major renovation.	Modeling	Multifamily four stories or more	Incentive based on site energy reduction – includes gas and electricity savings.
Eversource (Connecticut)	Energy Conscious Blueprint targets whole building new construction or major renovation – advisor determines whether modeling or prescriptive path is appropriate.	Must follow Standard 90.1-2013 Appendix G approach plus program-specific modeling guidelines. eQUEST and Trane Trace are pre-approved other software approved on a case-by-case basis. Use custom reporting template.	Any non-residential or high-rise multifamily project is eligible, >30,000 ft^2.	Savings based on source energy. Savings calculated for electric demand, gas demand, electric consumption, and gas consumption.
Eversource (New Hampshire)	No modeling-based whole building incentive program, everything is prescriptive or a custom measure.	NA	NA	NA
Wisconsin Focus on Energy	New construction custom incentives using either design assist or design review process – modeling per Standard 90.1-2013 or current state code. Also detailed prescriptive incentives covering a broad range of measures.	NA	Buildings >5,000 ft^2	Electricity kWh and/or natural gas therms depending on whether utilities serving the project participate in the programs

Name of Program	Modeling Approach	Complexity & Tool Requirements	Application	Reporting & Reporting Metrics
COMEd Chicagoland – Targeted Incentives	Prescribed per ft^2 incentives for different measures incorporated during design.	No modeling required. Project must minimally meet current energy code IECC 2018.	Office, multifamily, retail and grocery, and warehouse industrial >5000 ft^2	No specific reporting requirements. Allow both electric and gas savings kWh and therms.
COMEd Chicagoland Performance Path	Applies to new construction not eligible for targeted Incentives.	Requires a model. Must show performance better than current code IECC 2018.	Buildings >5,000 ft^2 are not eligible for targeted incentives.	No specific reporting requirements. Allow both electric and gas savings kWh and therms.
COMEd – Slipstream	Savings based on a simplified whole building model.	Uses a simplified modeling methodology. Does not require App G level of complexity. Web interface to DOE2.2 engine. Simplified geometry, App C schedules, etc.		No specific reporting requirements. Allow both electric and gas savings kWh and therms.
Xcel Energy (Colorado)	Energy Efficient Building (EEB) and Energy Design Assist (EDA) programs. Only EDA uses modeling; EEB is prescriptive. Incentives are combination of prescriptive and custom analysis. New construction programs.	Modeling against Standard 90.1-2013 or more stringent local code. Three tiers – EDA Express may be best use of a simplified approach.	EEB: 10-50K ft^2 EDA: >50K ft^2	Incentives for peak kW savings and kWh savings.
Xcel Energy (Minnesota)	Multifamily whole building efficiency program commercial building design assist that includes modeling.		Minimum 20 ft^2 for Design Assist.	Electricity kWh and natural gas therms
Xcel Energy (Michigan)	Has a custom incentive option but not a specific whole building incentive program. The list of prescriptive incentives is very comprehensive.	Custom incentives allow simulation, but specifics are not provided. Custom incentives are geared towards measures not covered by comprehensive prescriptive incentives.	Any non-residential project qualifies.	Electricity kWh and natural gas therms
Rocky Mountain Power (Idaho, Utah)	Most incentives are prescriptive. Custom incentives based on annual savings only for lighting or measures not on incentive list.		Custom incentives are generally for larger customers and for measures not on the prescriptive incentive list.	Custom lighting savings based on kWh savings.
Pacificorp (Washington State)	Custom incentives for items not covered by prescriptive incentives. No clear whole building incentive program	NA	NA	NA
Pacificorp (California)	Custom incentives only allowed for larger commercial and industrial customers – no whole building programs for small/med buildings	NA	NA	NA
Energy Trust of Oregon (Oregon)	Incentives for NC and MR projects pursuing – need to beat code by at least 5%. Standard 90.1-2016 is current code.	Allows any software allowed by Standard 90.1-2016 Appendix G. Has specific reporting requirements for DOE-2, E+, Trace 700, and IES.	Any size project can apply.	Incentives are based on kWh and therm savings.

Name of Program	Modeling Approach	Complexity & Tool Requirements	Application	Reporting & Reporting Metrics
CA Savings by Design – Whole Building	Incentives for exceeding Title 24 requirements. Incentives start at 10% better than Title 24 and increase linearly until savings is 40% better than Title 24. Baseline is based on a modified Title 24 baseline set by DEER.	Recommends EnergyPro but can use other approved software as long as baseline is correctly calculated.	Applies to all new construction.	Savings are based on TDV energy.
CA Savings by Design – Systems Approach	Less complex than whole building approach. Flat incentives for different system types: • Interior lighting • Heating, ventilation, and air conditioning • Service hot water • Other systems and processes • Daylighting	NA	NA	NA
Duke Energy (Florida)	New construction program uses online tool or approved tools, Retrofit incentives can use whole building analysis with an approved tool. Projects have to minimally meet 2014 Florida energy code and meet certain electricity / demand savings ratio to qualify. Based on Standard 90.1.	Custom web-based tool used to calculate new construction. Limited combinations before it pushes user to use modeling software. Retrofit projects can use eQUEST, EnergyPlus, Trace, or HAP.	Custom incentives cover all building types, the New Construction Wizard covers: • Retail • Schools K-12 • Colleges and universities • Restaurants • Hotels and motels • Offices	Electricity cost and demand
Duke Energy (Indiana, North Carolina, South Carolina)	No custom incentives using a whole building approach; custom incentives are offered for individual measures that are unique.	Uses Praxis platform for cloud-based prescriptive incentives or older spreadsheet tools.	NA	NA
Duke Energy (Kentucky)	Yes – for NC and MR projects. Users need to document the modeling methodology in detail and calibrate to utility bills for retrofit projects.	Whole building approach using eQUEST, EnergyPlus, HAP, or Trace. Certain individual measures have custom spreadsheet tools (lighting, variable frequency drives). Other measures are prescriptive.		Incentives are only for electricity savings, but other fuel savings are required to be reported.
AMEREN (Illinois)	Custom Incentives are available.	Allows spreadsheet calculations or whole building energy model to be used. Custom program is for non-standard measures. Excel, eQUEST, Trace, HAP, and others.	All projects but geared towards larger projects.	Incentives are based on kWh and/or natural gas therm savings.

Name of Program	Modeling Approach	Complexity & Tool Requirements	Application	Reporting & Reporting Metrics
NiCOR Gas	Gas savings calculations are recommended, but not required, to submit an application for consideration. Calculations should be supplied in electronic format. Applicants must use industry-accepted engineering algorithms, simulation models, and measurement procedures from recognized technical organizations and rating agencies to estimate natural gas savings (i.e., ASHRAE, ANSI, SMACNA, ARI, ASTM, etc.). Applicants must submit documentation of sources used with the pre-approval application and final application, including clearly describing any assumptions made during calculations. Applicants must estimate the annual natural gas usage of both existing and proposed equipment based on the current operation of the facility. For assistance in completing the application, contact EnergySmart.		Applies to any project/retrofit that does not have a gas rebate. Does not apply to load shifting or renewable energy systems.	Therms

ANSI	American National Standards Institute	MR	major renovation
ARI	Air-Conditioning and Refrigeration Institute	NC	new construction
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	NCP	New Construction Program
		NYS	New York State
ASTM	ASTM International	NYSERDA	New York State Energy Research and Development Authority
DEER	Database of Energy Efficiency Resources		
ECB	energy cost budget	PHI	Passivhaus Institute
HAP	Hourly Analysis Program	PHIUS	Passive House Institute US
IECC	International Energy Conservation Code	SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
MPP	Multifamily Performance Program		

Appendix F – C-PACE Program Details

Name of Program	Modeling Approach	Complexity & Tool Requirements	Application	Reporting & Reporting Metrics
Oregon	Allows modeling.	Must be 5% better than Standard 90.1-2016 baseline to qualify.		
New York	Modeling is allowed in certain circumstances. C-PACE in NY only applies to existing commercial structures.	Savings calculations are recommended by measure and need to follow the state-approved technical resource manual. Measures not pre-approved must meet cost-benefit ratio criteria.	Only applies to existing commercial buildings in counties and cities that adopt C-PACE. Program is managed by Energy Investment Corp.	kWh, peak kW, therms. Cost of carbon is included in the cost-benefit ratio calculation.
Wisconsin	Whole building simulation is allowed in certain circumstances.	Program guidelines reference Standard 90.1 Appendix G methodology for modeling. Baseline is Standard 90.1-2010 as of July 2019 but project energy efficiency measures and building must meet state code, which is currently Standard 90.1-2013. Software needs to be DOE approved.	All commercial buildings in more than half the state's counties are eligible. New construction and existing building projects.	NA
Chicago, Illinois	New construction and existing buildings qualify.	Only requires a Level 1 ASHRAE audit or ICP protocol or feasibility study for new construction.	All commercial buildings qualify; residential (<5 units) and condominiums do not qualify.	NA
Pennsylvania C-PACE	Whole building simulation is allowed to be used to develop the baseline.	Must use a DOE-approved tool (from approved federal tax credit list). Baseline for existing buildings would be existing conditions. NC or MR projects must use Standard 90.1 Appendix G methodology to show savings over an IECC 2015 or current state code baseline. Must be 10% better than baseline to qualify.	NA	NA
Kentucky PACE	Not clear whether whole building modeling is an approved approach.	NA	NA	NA
Colorado PACE	Allows a modeled baseline when utility bill data is not available or not applicable.	15% financing is based on signed and sealed COMcheck analysis. 20% financing requires dynamic simulation modeling, Baseline is IECC 2015 and must use Report Model Table Input Workbook.	Applies to new construction and existing buildings.	NA
Florida PACE	No requirements for whole building simulation, projects only require energy audits.	NA	NA	NA
Connecticut PACE	Whole building simulation is allowed in certain circumstances.	The NC pilot requires modeling with a whole building tool like DOE2 or E+. Must establish a baseline that is equivalent to the current Connecticut code. It is not clear what methodology to use to do this. The language suggests the proposed design is adjusted to minimally meet prescriptive requirements. Would not use Standard 90.1 Appendix G or ECB. Must show minimum 10% savings over baseline to qualify.	New construction pilot and existing buildings without good baseline energy data.	NA

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	ICP	investor confidence project
C-PACE	commercial Property Assessed Clean Energy	IECC	International Energy Conservation Code
ECB	energy cost budget	MR	major renovation
		NC	new construction

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