NATIONAL BEM CERTIFICATION SCOPING STUDY

SEPTEMBER 2023

This report investigates the feasibility of forming a national certifying body that will establish and oversee the quality assurance and quality control (QA/QC) framework for code and beyond-code programs that use building energy modeling.

Prepared by:
Karpman Consulting with support from the IBPSA-USA Certification Committee

This work was funded by the U.S. Department of Energy (DOE) and the USA chapter of the International Building Performance Simulation Association (IBPSA-USA).

National BEM Certification Scoping Study

Maria Karpman and Christina LaPerle, Karpman Consulting

September 2023

Contents

Acknowledgments

This report was funded by the U.S. Department of Energy (DOE) and the USA chapter of the International Building Performance Simulation Association (IBPSA-USA). The authors would like to thank Cindy Regnier (LBNL) and Amir Roth (DOE) for providing extensive feedback on the report, and the IBPSA-USA certification committee for its input and guidance, especially Dimitri Contoyannis (Model Efficiency, committee chair), Tim Kline (ASHRAE), Allen Mei (Cyclone Energy Group) and Neal Kruis (Big Ladder Software). We also want to thank the staff of beyond-code programs for generously sharing information about their programs.

Definitions and Acronyms

AIA	- American Institute of Architects
ACM	- Alternative Calculation Method
ANSI	- American National Standards Institute
ASHRAE	- American Society of Heating, Ventilation and Air Conditioning Engineers
bEQ	- Building Energy Quotient
BEM	- Building energy modeling
BEMP	- Building Energy Modeling Professional
BPS	- Building Performance Standard
CBEC	- Commercial Building Energy Code Compliance
CBECS	- Commercial Building Energy Consumption Survey
CEA	- Certified Energy Analyst
CEC	- California Energy Commission
COMNET	- Commercial Energy Services Network
DOE	- Department of Energy
ECB	- Energy Cost Budget Method
EPA	- Environmental Protection Agency
FEMP	- Federal Energy Management Program
GBO	- Green Building Ordinance
HERS	- Home Energy Rating System
IBPSA	- International Building Performance Simulation Association
IECC	- International Energy Conservation Code
IES	- Illuminating Engineering Society
IRM	- Internal Revenue Service
MRO	- Multifamily Review Organization
NYSERDA	- New York State Energy Research and Development Authority
P4P	- Pay for Performance
PNNL	- Pacific Northwest National Laboratory
PRM	- Performance Rating Method
S-PRM	- Simplified Performance Rating Method
RESNET®	- Residential Energy Services Network
TAM	- Technical Assistance Manual
TBP	- Total Building Performance
QA	- Quality Assurance
QC	- Quality Control

Executive Summary

This report was funded by the U.S. Department of Energy (DOE) and the USA chapter of the International Building Performance Simulation Association (IBPSA-USA). It investigates the feasibility of forming a national certifying body that will establish and oversee the quality assurance and quality control (QA/QC) framework for code and beyond-code programs that use building energy modeling to help improve consistency, market acceptance and penetration of compliance modeling.

Development of the report was steered by the IBPSA-USA Certification Committee which directed the research team to review the QA/QC practices of selected jurisdictions and programs for high performance buildings to establish the industry baseline, best practices, and challenges. The research targeted programs for commercial and multifamily buildings where the need for certification appears to be the greatest. In addition, the Residential Energy Services Network (RESNET ®) Home Energy Rating System (HERS) for single family homes and low-rise multifamily buildings was reviewed as an example of successful market-based certification program. The report also covers the Commercial Energy Services Network (COMNET) which aimed to become the industry standard for providing technically credible and reliable procedures for evaluating the energy performance of nonresidential and high-rise residential buildings including certifying BEM tools and modeling providers but was discontinued due to lack of funding and industry support.

The Background section of the report describes the goals of the research and introduces the modeling-based programs that were evaluated including their geographic region and project volume (Table 1). The Elements of the Modeling-Based Programs section summarizes approaches used by the evaluated programs for the key aspects of operation including the modeling requirements (Table 2), BEM tool requirements and certification process (Table 3), modeler qualification requirements (Table 4), quality control and quality assurance process (Table 5) and the business model including certification fees (Table 6). Each of the evaluated programs is further discussed in Appendix C, The Inventory of the Modeling-Based Programs.

The Overview of the Past and Current Certification Programs section describes the key characteristics and the business models of ASHRAE Building Energy Modeling Professional (BEMP) certification, IRS Section 179D software certification, RESNET HERS and COMNET. Additional information about these programs is included in Appendix D. RESNET® dominates the residential market, with over 330,000 homes receiving HERS rating just in 2021. RESNET reliance on a large network of provider companies is the key driver of its market success and, along with the project registry, the foundation of its business model. The commercial market is much smaller and is highly fragmented which makes establishing the national certifications more challenging. Aligning certification requirements with the industry accepted standards should mitigate these challenges.

BEM Certification Body Initiative Roadmap section proposes the following strategies for establishing market-based BEM tools, modeler and reviewer certifications:

1. **BEM Tool Certification**

   90.1 defines BEM tool (simulation program) as a “computer program, including the simulation engine and the corresponding user interface, that is capable of simulating the energy performance of building systems”. 90.1 and IECC BEM tool requirements are generic in nature and represent standard of care for commercial and multifamily building modeling. Attempts by IECC and COMNET to require a compliance shell, and by COMNET to expand software testing requirements did not get

traction with the industry. Furthermore, a rigorous BEM tool approval process requires significant resources from both the BEM tool vendors and the certifying body. Based on these considerations, BEM tool certification should initially focus on verifying BEM tool compliance with the existing 90.1 simulation tool requirements and aim to make the certification applicable to most modeling-based programs. This approach will increase the likelihood of adoption by jurisdictions and beyond-code programs and reduce BEM tool vendors resistance. Even for that modest scope, the certification fees will likely not cover the certification effort, and additional public funding or revenue from other certification types may be necessary.

2. Modeler Certification

ASHRAE Building Energy Modeling Professional (BEMP) is required by several jurisdictions and beyond-code programs, but a limited number of certified professionals (371 BEMPs in the US as of summer 2022) hinders wider adoption which in turn reduces incentive for professionals to obtain the certification. However, this chicken and egg problem applies to any new certification that must convince the marketplace of its value in order to take off. ASHRAE has strong name recognition and established its BEMP certification over a decade ago, yet the certification is struggling to get traction. Association for Energy Engineers (AEE) has discontinued its Certified Building Energy Simulation Analyst (BESA) program. Given that, creating an alternative modeler certification does not appear feasible or justified. Instead, the work should focus on promoting the existing certifications, such as developing training to prepare candidates for the BEMP exam and promote adoption of the existing certifications by municipalities and programs that offer financial benefits such as IRS 179D, C-PACE and utility incentive programs. In addition, competencies not covered by the existing certifications may be identified to facilitate development of new certifications or expanding the scope of existing certifications to address these gaps.

3. Reviewer Certification and Third-Party Provider Network

The depth and rigor of model reviews varies substantially across modeling-based programs. This puts programs with rigorous quality control at a disadvantage because participants favor “easier” programs unless their credibility is affected. In addition, rigorous reviews increase program administration effort, necessitating higher certification fees.

EPA has established a network of Multifamily Review Organizations (MRO) that perform submittal reviews for its ENERGY STAR multifamily program using a market-based business model similar to RESNET. The approach shifted submittal review costs from EPA to program participants. Some incentive programs started requiring MRO reviews for the participating multifamily projects. This model may be attractive to other modeling-based programs that may choose to delegate submittal reviews to a market-based provider network managed by a well-respected national organization and will help establish a consistent review rigor.

There are many consulting companies that provide third party reviews and assist with implementation of beyond-code programs. These companies may be interested in joining a provider network to expand their business. Based on these considerations, establishing a self-sustaining third-party review framework appears feasible. Some programs already set qualification requirements for submittal reviewers (Table 5) which may be used as the basis of reviewer certification requirements. The target submittal review scope may be established based on the

ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual and utilizing the Third-Party Submittal Reviewer Scope of Work published on the Building Energy Codes Program[1] website.

The BEM Certifying Body Roadmap section outlines the following priorities for each of the three focus areas described above:

Short Term (2023-2024)

1. Perform outreach to administrators of the modeling-based programs for commercial and multifamily buildings, BEM tool vendors, modelers, training providers and energy consultants to raise awareness, demonstrate value of national certification for BEM tools, modelers and reviewers and get input on the draft documents.
2. Reviewer certification: Develop consensus document with reviewer qualification requirements and a third-party review framework. Secure at least 5 potential providers of third-party review services and at least 10 jurisdictions or beyond-code programs interested in adopting third party review framework.
3. BEM tool certification: Develop consensus document to facilitate BEM tool certification for compliance with requirements of various editions of 90.1 based on software program requirements included in each edition. These requirements focus on tool capabilities to simulate energy performance of building systems and are included in Appendices A of this report. Investigate feasibility of developing a similar document based on IECC requirements and engaging with the California Energy Commission for certifying BEM tools for compliance with CA code. Identify and secure commitments from at least 3 commonly used BEM tools interested in certification.
4. Modeler certification: Work with ASHRAE to enhance the BEMP scope and develop training to prepare modelers for the ASHRAE BEMP exam; identify other existing certifying bodies to cover the full scope of the required competencies.
5. Develop a business model including estimated effort of establishing and maintaining reviewer and BEM tool certifications and third-party submittal review framework. Recommend a fee structure and certification priorities.
6. Investigate organizations that can serve as the certifying body for BEM tools and/or third-party reviews, such as IBPSA-USA.

Medium Term (2025-2026)

1. Maintain the consensus documents for BEM tool and reviewer certification and third-party reviews.
2. Facilitate establishing a certifying body.
3. Reviewer certification: Support the certifying body in rolling out a third-party submittal review program and submittal reviewer certification.
4. BEM tool certification: Support the certifying body in rolling out BEM tool certification for compliance with various editions of 90.1.
5. Continue working with ASHRAE and other existing certifying bodies to ensure the availability of appropriate modeler certifications.
6. Refine the business model for certification programs as necessary to support market-based self-sustaining operation.

[1] ASHRAE Standard 90.1 Performance Based Compliance (Section 11 and Appendix G) | Building Energy Codes Program

Long Term (2027+)

1. Maintain the consensus documents for BEM tool and reviewer certifications and third-party reviews.
2. Continue collaboration with the certifying body(s) and outreach to raise awareness of the certification initiative.
3. Expand software certification to include compliance with ASHRAE Standard 229 for all types of software tools addressed by this standard.

Background

A Roadmap to Establishing Quality Control and Quality Assurance Infrastructure for Performance-based Compliance[2] developed as part of the DOE/PNNL and NEEA research project identified creation of a national certifying body that will oversee accreditation of building energy modeling (BEM) tools, energy modelers, submittal reviewers and training providers as the key long-term priority for improving consistency, market acceptance and penetration of compliance modeling. This report was funded by the U.S. Department of Energy (DOE) and the USA chapter of the International Building Performance Simulation Association (IBPSA-USA) to investigate the feasibility of forming a national entity to oversee the quality assurance and quality control (QA/QC) infrastructure for code and beyond-code programs that use building energy modeling.

The development of this report was guided by the IBPSA-USA Certification Committee. The committee cited RESNET, which serves low rise multifamily and single-family homes, as an example of a successful market-based certification program and steered the research team to focus on the commercial and high-rise multifamily building sector which currently lacks an industry-accepted national certifying body. The committee also identified U.S. jurisdictions, U.S. and international programs for high performance buildings, and certifying body precedents for the research team to review.

The information included in this report is based on program websites, publications, and direct communications with the programs' staff and/or professionals involved with the participating projects. It was collected in summer of 2022 and reflects data available at that time. The evaluated programs are summarized in Table 1. Additional details for each program are included in Appendix C of this report.

Table 1 includes the following columns:
Program Scope column describes the territory where the program is in effect. The entries are color-coded to highlight patterns.

- "State" indicates that a program applies to a U.S. state, e.g., is a state energy code
- "City" indicates that a program applies to a U.S. city, e.g., is a municipal energy code
- "US" indicates that a program applies nationwide in the Unites States.
- "US and International" indicates that a program originated in US and applies to both US and international projects
- "Local incentive program" designation is used for programs administered by utility companies or public entities and funded through fees collected from the ratepayers.
- "Germany and International" and "UK and International" refer to programs originated outside of the US that are also used by US-based projects.

[2] Performance-Based Code Compliance: A Roadmap to Establishing Quality Control and Quality Assurance Infrastructure, M. Karpman M. Rosenberg, April 2021

Project Volume column shows the quantity of participating projects.

Table 1: Overview of The Reviewed Modeling-based Programs

	Modeling-based Program	Program Scope	Project Volume
Code	**California 2022 Energy Code**	State	~ 50% of NC permits
	Florida 2020 Energy Code	State	~ 90% of NC permits
	Seattle 2018 Energy Code	City	~ a dozen of projects a year
	New York City 2020 Energy Code	City	~ 25 per year
	2019 Denver Energy Code and Green Building Ordinance	City	7 modeled projects in 2018-2019
Beyond Code	**IRS 179D Energy Efficiency Tax Deductions**	US	Unknown
	ENERGY STAR Multifamily New Construction	US	23 projects in 2021, 370 modeling projects since inception
	LEED NC	US and International	370 LEED NC v4 & 4.1 in 2021; 7,490 v4 & v4.1 BD+C and ID+C certified projects; 18,085 registered but not yet certified (excludes single family)
	ASHRAE bEQ As Designed	US	Unknown
	Passive House Institute (PHI)	Germany and International	5,173 pre-certified or certified projects globally including 591 MF and ~800 nonresidential; 71 certified and 137 registered in US
	Passive House US (Phius)	US and International	63 registered or certified projects in US Phius CORE 2021, Phius CORE Prescriptive 2021, Phius CORE Revive 2021 and Phius ZERO 2021
	Federal Energy Management Program	US	Unknown
	Living Future Challenge	US and International	100+ projects in 2021 with 57% of projects in US.
	AIA 2030 Commitment	US	~11,650 projects modeled in 2020
	Green Globes	US and International	205 projects in 2021
	BREEAM	UK and International	10,800 certifications 2013-2017, 83% in UK
	New Jersey Pay for Performance	Local Incentive Program	Over 200 projects since 2010, 31 in 2020-2021
	NYSERDA New Construction Programs	Local Incentive Program	~ 70 commercial and 330 housing projects annually
	California Energy Design Assistance	Local Incentive Program	Launched at the end of 2021, 140 projects in the first 12 months
	Austin Energy Green Building	Local Incentive Program	81 projects reviewed in 2022 fiscal year
COMNET		US	Not Applicable (not an active program)
RESNET Home Energy Rating (HERS)		US	313,153 rated homes in 2021, 3.3M rated homes total in US
ASHRAE Building Energy Modeling Professional (BEMP)		US and International	~500 certified professionals including ~400 in US

Elements of the Modeling-based Programs

For each program included in the report, the information was collected on the modeling and reporting requirements, BEM software acceptance practices, modeler and review qualification requirements, quality control and quality assurance process and business model. The common practices used for each of these infrastructure elements are described in the following subsections.

Modeling requirements

Most U.S. jurisdictions have energy codes based on the International Energy Conservation Code (IECC) and/or ANSI/ASHRAE/IES Standard 90.1 (90.1), often with state-specific amendments. The whole building performance compliance options that require energy modeling include 90.1 Section 11 (Section 12 in 90.1 2022) Energy Cost Budget Method (ECB), 90.1 Appendix G Performance Rating Method (PRM) and IECC Section C407 Total Building Performance (TBP). Jurisdictions may allow all three options (e.g., 2022 Connecticut State Building Code) or only some of them (e.g., 2018 Seattle Energy Code allows an

amended PRM only). Some jurisdictions also accept documented participation in an approved beyond-code program as a proxy for code compliance.

While the performance path is currently used by less than 5% of projects in most jurisdictions, these projects typically involve large buildings. For example, a Seattle code official has estimated that the 5% of new construction projects that use the performance path represent approximately 40%-50% of the permitted floor area. Use of the performance path for new commercial projects is the highest in Florida (over 90% permitted new construction area), California (over 50%) and Washington, DC (~50%)[3].

Some industry stakeholders anticipate an increase in the number of projects that use the whole building modeling for code compliance as prescriptive requirements become more stringent and projects seek flexibility of the performance approaches. There is also growing recognition that the prescriptive path does not facilitate high performance designs. The PRM is expected to become the basis of a "jurisdictional option" that will be included in the next edition of 90.1 to support jurisdictions aiming for net zero codes. PRM is also used in the 179D commercial building energy efficiency tax deductions program that has been in effect since 2006 but only recently became permanent as part of the Consolidated Appropriations Act of 2021. The Simplified Performance Rating Method (S-PRM)[4] that targets small buildings with simple designs is being considered for inclusion into 90.1. If adopted, S-PRM is expected to significantly increase use of energy modeling for such projects that currently overwhelmingly favor prescriptive path. In addition, jurisdictions increasingly rely on the Building Performance Standards (BPS)[5] to limit buildings energy use and emissions over their lifetime. Energy modeling may be used to assess future performance of new designs to avoid steep fines for failing the BPS requirements, steering more projects toward using performance path of compliance with energy code.

However, some jurisdictions view the performance path as a compliance loophole and impose strict limits on the allowed trade-offs. For example, 2018 Seattle Energy Code limits the increase in the envelope heat loss (the total UA value) in performance-based projects to no more than 10% over the prescriptive threshold to prevent designs with poor envelope from making up for the associated energy penalty with savings from systems that have much shorter useful life, such as lighting or HVAC. In addition, the Total System Performance Ratio (TSPR) and energy credits incorporated into the latest editions of IECC and 90.1 increase design flexibility without requiring whole building energy simulations. Time will show the impact of these competing trends on the market penetration of the whole building energy modeling.

Based on the DOE/PNNL/NEEA stakeholder survey, 90.1 ECB and IECC TBP paths are currently used most often for the minimum code compliance. 90.1 PRM, which was created specifically for evaluating high-performance designs, is an overwhelming favorite for beyond-code programs. Starting with the 2016 edition of Standard 90.1, the PRM may also be used for documenting the minimum compliance, and its market penetration is expected to further increase as more states switch to the newer editions of 90.1. PRM is the only whole building performance compliance option in Washington state starting with the

[3] Values are estimated by respondent to the DOE/PNNL/NEEA stakeholder survey that was administered in 2020 under a research project to facilitate performance-based compliance. The percentages reflect the permitted new construction area.

[4] A Simplified Performance Rating Method for Small Commercial Buildings (energy.gov), S Goel PNNL

[5] Building Performance Standards | Building Energy Codes Program

2018 code cycle and is expected to be the only whole building performance compliance option in the NYStretch 2023 and the NYC Energy Code 2023[6]. Conversely, TBP use is going down. Some jurisdictions (e.g., New Jersey, Massachusetts, Washington State, Rhode Island) no longer allow it.

While many reviewed programs have modeling requirements based on national standards, some develop custom rules. California Alternative Calculation Method (ACM) is an example of a custom modeling ruleset used for code compliance. Similar to the ECB, PRM and TBP, the ACM is based on the relative energy use of the two models – one representing the proposed design, and another used as a point of reference, but many other ACM modeling requirements differ from the national standards. Other custom modeling approaches such as that used by the passive house programs (PHI and PHIUS) establish compliance by comparing energy use of a single model to a prescribed numeric target.

Modeling protocols used by the evaluated programs are summarized in Table 2 which includes the following columns:

- "90.1 PRM", "90.1 ECB" and "IECC TBP" indicate whether the respective whole building performance option is allowed by the program, the adopted edition, and whether there are changes (amendments) to the national rules. 2016 edition of 90.1 and 2018 edition of IECC are highlighted in green. More recent editions are highlighted in blue. Editions prior to 90.1 2016 are highlighted in brown.
- "Other" column applies to programs that have modeling requirements that are not based on either 90.1 or IECC. Custom protocols that require two models are highlighted in pink. Protocols that are based on comparing energy use of a single model to a fixed target are highlighted in yellow. The brown color is used for programs that allow both the single model and two model options.

[6] Based on the NYStretch 2023 second public comments draft

Table 2: Modeling Requirements

	Modeling-based Program	90.1 PRM	90.1 ECB	IECC TBP	Other
Code	California 2022 Energy Code				Title 24 ACM, 2-model
	Florida 2020 Energy Code	90.1 2016	90.1 2016	2018 IECC amended	
	Seattle 2018 Energy Code	90.1 2019 amended			
	New York City 2020 Energy Code	90.1 2016 amended	90.1 2016 amended		
	Denver Energy Code	90.1 2016 amended		2018 IECC amended	
Beyond Code Programs	IRS 179D Tax Deductions	90.1 2007 amended			
	ENERGY STAR Multifamily New Construction	90.1 2010 or 2016, depending on state code			
	LEED NC	90.1 2016 for LEED v4.1	90.1 2016 for v4.1 Prerequisite allowed		
	ASHRAE bEQ As Designed	90.1 2016			
	Passive House Institute (PHI)				custom 1-model
	Passive House US (Phius)				custom 1-model
	Federal Energy Management Program	90.1 2019			
	Living Future Challenge				custom 1-model; final certification based on actual consumption
	AIA 2030 Commitment				custom 1-model, optional
	Green Globes	90.1 2010			custom 1-model
	BREEAM	90.1 2013			Other, TBD
	New Jersey Pay for Performance	90.1 2016			PHI, Phius and LEED v4.1
	NYSERDA New Construction Programs	90.1 2016			PHI, Phius
	California Energy Design Assistance				2-model, T24 modified to reflect local standard practice
	Austin Energy Green Building	90.1 -2019			
COMNET		90.1 2007			
RESNET Home Energy Rating (HERS)					ICC/RESNET Standard 301

BEM Tool Requirements

Modeling and Reporting Capabilities

Most of the programs with the modeling requirements based on the 90.1 or IECC allow BEM tools that meet the software requirements of these standards. The 90.1 2019 PRM and 2021 IECC software requirements are similar and are included in Appendices A and B of this report. Both require that simulations are performed at an hourly timestep, that the tools are capable of modeling 10 or more thermal zones and hourly variations in the operating schedules, are able to report the number of hours when heating or cooling loads are not met and show energy consumption broken out by the key end uses (heating, cooling, fans, lighting, etc.).

RESNET HERS® and CA ACM require the approved BEM tools to have a capability to automatically create the baseline design model based on the user-entered proposed design. Such automation, referred to as a "compliance shell" in this report, is not required by either 90.1[7] or IECC. Florida Energy Code requires such automation for all the allowed modeling-based compliance options, but no other jurisdiction is known to require it.

[7] There is an informative note in 90.1 Section 11 Energy Cost Budget Method (ECB) recommending that the BPS software tools do have the compliance shells to improve submittal consistency and a similar note will be included in the 2022 edition of the 90.1 PRM.

Physics and Sensitivity Testing Requirements

Physics and sensitivity tests evaluate the impact of modeling parameters and assumptions on simulation results. For example, testing may evaluate the sensitivity of annual heating energy use to thermal properties of building envelope. Both 90.1 and IECC require the approved BEM tools to be tested following ANSI/ASHRAE Standard 140[8]. However, Standard 140 does not currently cover systems that are ubiquitous in commercial building designs such as water-side HVAC systems and controls (e.g., boilers, chillers, fluid loops, pumps); air-side HVAC system and controls such as heat pumps, fans, exhaust air energy recovery, supply air temperature reset and static pressure reset; service water heating systems and daylighting. A comprehensive report outlined additional physics and sensitivity tests that should be developed in support of compliance modeling of commercial buildings[9].

COMNET and RESNET HERS® have the acceptance ranges for the Standard 140 tests. Historically, Standard 140 did not include such ranges, but they were added in addendum b[10] to Standard 140-2020. The adopted ranges were set so that most commonly used software programs would pass, and allow high variability in results – for example, one test allows a plus-or-minus 14% variation in heating energy[11], which means that a BEM tool that passes at the high end of the allowed range could show 28% higher heating use than a tool passing at the low end of the range.
While none of the reviewed programs that are based on 90.1 and IECC prescribe physics and sensitivity testing in addition to Standard 140, both CA ACM and RESNET® HERS expand on the 140 testing requirements. CA ACM 2020 defines over a hundred additional tests based on the DOE/PNNL prototype building models of medium and large offices, retail and strip mall buildings modified to comply with Title 24. To pass the tests, the candidate BEM tool must be within 0.5% of the reference result and match the direction of the change (energy penalty or savings).

RESNET HERS® requires Standard 140-2017 Class II Tier 1 tests which include 15 heating load tests and 11 cooling load tests for designs representative of the residential homes targeted by the program and sets the annual heating and cooling load acceptance ranges for each test. In addition, RESNET® HERS prescribes a suite of HVAC system tests covering common residential system types, duct distribution system efficiency tests and service hot water system tests.

Ruleset Tests

California Title 24 ACM, RESNET HERS® and COMNET require tests to verify BEM tool capability to automatically generate the properly configured baseline models for a given building design. CA ACM prescribes twenty-seven test cases that are based on the DOE/PNNL prototype models and include permutations of the small, medium, and large office, warehouse, retail and hotel.

RESNET HERS prescribes four ruleset tests representing common single-family designs in different climates – with crawlspace or basement foundations, attic, furnace or heat pump heating of varying efficiency, varying number of bedrooms, mechanical ventilation strategies, and home appliances. In addition, RESNET® HERS requires BEM tool method tests to verify that it correctly determines the HERS Index for given modeling results.

---

[8] Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
[9] Building Performance Modeling Tools Physics and Sensitivity Testing in Support of Compliance Modeling, September 2022, PNNL-33183, M Karpman, C LaPerle, M Rosenberg, S Goel.
[10] ANSI/ASHRAE Addendum b to ANSI/ASHRAE Standard 140-2020
[11] Standard 140 Addendum b Table A3-1, Case 600 Range Case.

COMNET prescribed twenty ruleset tests for the 90.1 PRM. The test cases were based on the DOE/PNNL prototype models including small, medium and large office buildings, retail, supermarket, manufacturing facility, warehouse and a mixed-use retail/office/multifamily building in Chicago, Denver and Miami.

ASHRAE Standard 229P (Std. 229P), Protocol for Evaluating Ruleset Application in Building Performance Models[12] that is currently under development uses a novel approach for ensuring adherence to the ruleset requirements. Traditionally, BEM tools are certified based on a limited number of ruleset tests, and it is then assumed that any project that uses a certified BEM tool is modeled correctly. Std. 229P approach involves establishing a framework for verifying compliance of individual projects with the applicable ruleset requirements. The key components of this framework include a BEM tool neutral schema that includes the elements of the building models pertinent to code compliance and the Ruleset Checking Tool software that can parse energy models in the Std 229P schema format and automatically verify their compliance with the ruleset. The first edition of the standard is expected to be published in 2024 and will support 90.1 2019 PRM. In the future, the Std. 229P framework may also be used to facilitate certification of BEM tools by helping define a comprehensive suite of ruleset tests and using the Ruleset Checking Tool to vet BEM tool compliance with these tests.

BEM tool acceptance process

90.1 and IECC require BEM tools to be approved by the jurisdiction or rating authority administering the program. Some of the reviewed programs, such as the IRS Section 179D, have a list of approved tools, but most programs have no formal process for verifying BEM tool compliance with the capabilities and testing requirements of these standards.

The 179D software acceptance process requires vendors to fill out a form itemizing software capabilities, perform the Standard 140 tests required by the PRM and submit input files, output files, weather data, modeler reports, and the executable version of the software used to conduct the tests to the National Renewable Energy Laboratory which reviews the submittal for completeness and maintains the list of the approved tools.

In Florida, BEM tool acceptance is administered by the Florida Building Commission. Prior to 2020 code cycle, BEM vendors were required to submit an application demonstrating that the tool meets simulation capabilities, reporting and testing requirements outlined in Energy Simulation Tool Approval Technical Assistance Manual. Starting with 2020 code cycle, the approval is based on a vendor self-certification letter confirming that the tool meets requirements of 90.1 and IECC applicable to the supported compliance options. The Florida Building Commission Energy Technical Advisory Committee (TAC) charged with vendor application reviews still requires BEM tools to have a compliance shell, however there are no formal testing requirements. The approved tools are listed on the publicly available website.

The RESNET® HERS software certification process requires vendors of the BEM tools to submit an application with results of the required tests, the corresponding modeling files and the software program used to conduct the tests. The submittal may be released by RESNET® for review by any party, including competing software developers. There is a process in place for handling exceptions and appeals. The approved tools are listed on a publicly available website[13].

[12] ASHRAE Standard 229P Development | Department of Energy

[13] https://www.resnet.us/providers/accredited-providers/hers-software-tools/

California 2019 Nonresidential Alternative Calculation Method Reference Manual describes the BEM approval process which includes submitting a formal application, the software, modeling files for the required tests, test results and help and/or User's Manual. Vendors are also required to provide ongoing user and enforcement agency support. California Energy Commission administers software certification and publishes the list of the approved tools on its website.

BEM tool requirements and acceptance processes of the reviewed programs are summarized in Table 3 which includes the following columns:

- "Multiple Tools Allowed?" column indicates whether a program allows different BEM tools and includes the following answer options:
  - "Yes" for programs that formulate the minimum required capabilities and/or testing requirements but do not have a list of approved tools.
  - "Yes, list" for programs that have a list of approved tools, with the number of approved tools at the time the report was written shown in parentheses, where available.
  - "No" for programs that require use of a single prescribed BEM tool.
- "Minimum Modeling Capabilities" and "Minimum Reporting Requirements" columns include the following answer options:
  - "Yes, verified" for programs that formulate the relevant requirements and verify compliance through an established BEM tool acceptance process.
  - "Yes, 90.1" for programs that adopt 90.1 BEM tool requirements by virtue of using 90.1 modeling protocols, but do not verify compliance with these requirements through a formal software acceptance process.
  - "No" for programs that do not prescribe BEM tool capabilities or reporting requirements.
  - "NA" for programs that require use of a single prescribed BEM tool.
- "Compliance Shell Required?" column indicates whether the approved BEM tools are required to automatically generate the baseline model based on user-entered model of the proposed design.
  - "Yes, verified" indicates that compliance shell capability is required, and that the software acceptance process includes ruleset tests to verify that the automation is implemented correctly.
  - "No (90.1)" indicates that such automation is not required, which is aligned with 90.1 and IECC.
  - "NA" for programs that establish compliance based on results of a single model and do not require such automation.
- "Standard 140 Tests" column describes program requirements in respect to Standard 140 testing.
  - "Yes, verified" indicates that the program requires Standard 140 testing based on the edition of Standard 140 referenced in the adopted modeling protocol; sets the acceptance ranges for the required tests; and verifies compliance through the acceptance process.
  - "Yes, 90.1" indicates that the program requires Standard 140 tests prescribed in the 90.1 edition used as the basis of modeling requirements and includes no acceptance ranges.
  - "Yes, 140-20XX" indicates that the program references the specified edition of Standard 140 (e.g., 140-2007) with no acceptance ranges.
  - "Yes, Other" is used for PHI and Phius and develop their own BEM tools and use Standard 140 testing as part of tool development

- "No" indicates either that the program does not require Standard 140 testing or prescribes a single BEM tool.

- "Additional Physics Tests" column indicates if there are physics and sensitivity testing requirements in addition to Standard 140.
  - "Yes, verified" indicates that there are additional tests with the prescribed acceptance criteria verified through the BEM tool acceptance process.
  - "No, 90.1" indicates that the program aligns with 90.1 testing requirements and do not prescribe tests in addition to Standard 140
  - "No" indicates that there no other physics and sensitivity testing requirements.
  - "Yes, Other" is used for PHI and Phius and develop their own BEM tools and use testing as part of tool development

Table 3: BEM Tools Requirements and Acceptance Process

	Modeling-based Program	Multiple Tools Allowed?	Minimum Modeling Capabilities	Minimum Reporting Requirements	Compliance Shell Required?	Standard 140 Tests	Additional Physics Tests
Code	California 2022 Energy Code	Yes, list (3)	Yes, verified	Yes, verified	Yes, verified	Yes, 140-2007	Yes, verified
	Florida 2020 Energy Code	Yes, list (2)	Yes (90.1)	Yes (90.1)	Yes, verified	Yes (90.1)	No (90.1)
	Seattle 2018 Energy Code	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	New York City 2020 Energy Code	Yes, list (5)	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	Denver Energy Code	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
Beyond Code	IRS 179D Energy Efficiency Tax Deductions	Yes, list (13)	Yes, verified	Yes, verified	No (90.1)	Yes, 140-2014	No (90.1)
	ENERGY STAR Multifamily New Construction	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	LEED NC	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	ASHRAE bEQ As Designed	Yes	Yes (90.1	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	Passive House Institute (PHI)	No	Yes (Other)	Yes (Other)	NA	Yes (Other	Yes (Other
	Passive House US (Phius)	No	Yes (Other)	Yes (Other)	NA	Yes (Other	Yes (Other
	Federal Energy Management Program	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	Living Future Challenge	Yes	No	No	NA	No	No
	AIA 2030 Commitment	Yes	No	No	NA	No	No
	Green Globes	Yes	No	No	NA	No	No
	BREEAM	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	New Jersey Pay for Performance	Yes, list (3)	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	NYSERDA New Construction Programs (except PHI and Phius)	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
	California Energy Design Assistance	Yes	Yes	Yes	No	Yes, 140	No
	Austin Energy Green Building	Yes	Yes (90.1)	Yes (90.1)	No (90.1)	Yes (90.1)	No (90.1)
COMNET		Yes, list (Note 1)	Yes, verified (Note 1)	Yes + schema, verified	Yes, verified	Yes, verified (Note 1)	No (90.1)
RESNET Home Energy Rating (HERS)		Yes, list	Yes, verified	Yes, verified	Yes, verified	Yes, verified	Yes, verified

Note 1: Since the COMNET is not an active certification program, the inputs indicate the intent rather than the adopted policy.

Modeler Qualification Requirements

All reviewed jurisdictions require a licensed design professional to sign off on the compliance documentation. In addition, 2018 Seattle Energy Code calls for the modelers to either have the ASHRAE Building Energy Modeling Professional (BEMP) certification or at least two years of experience modeling buildings of similar scale and complexity. NYStretch Energy Code 2023 and MA Stretch Energy Code 2023 that are going through public comment period as of the writing of this report require modelers to have either BEMP certification or applicable modeling experience. At least two California jurisdictions require Certified Energy Analyst (CEA) designation for professionals who prepare the compliance

documentation for the 2019 energy code. CEA is also required by several incentive programs administered by CA Investor-Owned Utilities.

IRS Section 179D requires sign off by a contractor or engineer licensed in the jurisdiction where the building is located.[14] ASHRAE bEQ As-Designed requires that either a licensed professional or BEMP signs off on the submittal. Several other reviewed beyond-code programs required either a specialized certification or modeling experience. Some utility and state incentive programs have pre-approved modeling providers such as NYSERDA Primary Energy Consultants[15]. However, qualification requirements often apply to the company and not the individuals doing the modeling, – e.g., that the company employs professionals having the specified certifications or work experience. Due to staff turnover, this may result in modelers with insufficient experience being assigned to projects.

Table 4: Modeler Qualification Requirements

	Modeling-based Program	Licensed Professional	Modeling Experience or Special Certification
Code	California 2022 Energy Code	Yes (Note 1)	No
	Florida 2020 Energy Code	Yes (Note 1)	No
	Seattle 2018 Energy Code	Yes (Note 1)	modeling experience or BEMP
	New York City 2020 Energy Code	Yes (Note 1)	No
	Denver Energy Code	Yes (Note 1)	modeling experience or BEMP
Beyond Code Programs	IRS 179D Energy Efficiency Tax Deductions	Yes (Note 1)	No
	ENERGY STAR Multifamily New Construction	No	No
	LEED NC	No	No
	ASHRAE bEQ As Designed	Yes (Note 1, 2)	BEMP
	Passive House Institute (PHI)	No	No
	Passive House US (Phius)	No	Certified Phius Consultant
	Federal Energy Management Program (FEMP)	Unknown	Unknown
	Living Future Challenge	No	No
	AIA 2030 Commitment	No	No
	Green Globes	No	No
	BREEAM	No	modeling experience
	New Jersey Pay for Performance	No	modeling experience or BEMP
	NYSERDA New Construction Programs	No	requires a credential but some options are unrelated to modeling
	California Energy Design Assistance	Yes (Note 1, 2)	Modeling experience or CEA
	Austin Energy Green Building	No	No
COMNET		No	Yes
RESNET Home Energy Rating (HERS)		No	HERS rater or HERS modeler

Note 1: A licensed professional must sign off on the submittal.
Note 2: Professional licenses is one of several allowed modeler qualifications.

Quality Control and Quality Assurance Process

Enforcing performance-based compliance is notoriously difficult due to BEM complexity and the lack of a clear connection between the model inputs and the building design. Mistakes include the proposed design model not reflecting specified systems and components, misinterpreted or overlooked ruleset modeling requirements, and incorrect use of the simulation tool.

Review of modeling-based submittals is complicated by the use of multiple simulation tools which have different capabilities, nomenclature, and format and content of simulation reports. There are over a dozen tools on the IRS Section 179D approved software list. Furthermore, until recently there was no standardized format for submitting model results, and the reporting forms included in the 90.1 Users' Manual did not meet the reporting requirements of the standard. These issues were addressed by

[14] IRS Notice 2006-52, retried from https://www.irs.gov/pub/irs-drop/n-06-52.pdf
[15] https://www.nyserda.ny.gov/All-Programs/Programs/New-Construction-Program/Become-a-Vendor

development of the DOE/PNNL 90.1 Section 11 and Appendix G Compliance Form[16] and updates to the 90.1 2019 Users' Manual.

Based on the DOE/PNNL/NEEA survey, review rigor varies significantly among jurisdictions. Large cities tend to provide more thorough submittal reviews than the smaller ones. In some jurisdictions, reviews may take over 40 hours and three or more iterations before approval. Others spend less than 2 hours per project, and some automatically accept any submittal stamped by a licensed professional.

Review scope also varies widely across the programs. Some perform only a cursory review, such as to verify that the modeled floor area is reasonably aligned with the floor area reported on design documents and that the unmet load hours do not exceed the allowed limits. Others look for a general alignment between efficiency improvements in the proposed and the change in energy consumption by end use – for example, that the simulated reduction in the annual lighting energy of the proposed design is approximately proportional to the reported reduction in lighting power of the specified fixtures relative to code requirements. Some review simulation input and output files – e.g., to confirm that the exterior wall U-factor in the proposed design model reflects envelope construction shown on architectural drawings and that the modeled baseline U-factor reflects requirement of the ruleset. Starting with 2022 edition, 90.1 explicitly allows requesting energy modeling files. Some beyond-code programs already require that modeling files are submitted and use them in reviews.

The ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual[17] published on the Building Energy Codes Program website includes a comprehensive list of review checks, interpretation of 90.1 modeling requirements, common mistakes, a methodology for prioritizing reviews, and annotated simulation reports for common BEM tools with tips on performing specific checks. However, performing the review steps described in the Manual requires experienced staff that many jurisdictions and some beyond-code programs lack. To address this, some program administrators use external, independent third-party reviewers.

The EPA ENERGY STAR® Multifamily New Construction Program established a network of pre-approved third-party reviewers referred to as the Multifamily Review Organizations (MROs). Projects must select and contract with an MRO that reviews the submittal for a fee that is negotiated between the MRO and the client. The fee structures are set by the MROs and may depend on project size, number of review iterations, submitter qualifications or other factors. EPA oversees the MROs, maintains a review checklist to ensure that review scope and rigor meets the program requirements and is consistent across the MROs, and re-reviews a sample of projects approved by each MRO as part of QA.

RESNET® HERS has market-based QA designees performing third-party review of a sample of approved projects to confirm that they adhered to the program rules. Similar to the EPA, RESNET® staff re-reviews a sample of projects approved by the QA designees.

Some programs partially automate the review process. For example, RESNET® HERS requires the approved BEM tools to flag user inputs that are outside of the expected ranges such as the number of bedrooms for a home of a given size, ceiling height (the values less than 7 ft or over 15 ft are flagged), floor area not equal to ceiling area, etc. It also requires that the software tools have capability to save project information, including the input flags, to an XML file in the prescribed format. The files are

[16] ASHRAE Standard 90.1 Performance Based Compliance Form | Building Energy Codes Program

[17] ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual V03 September 2022, M Karpman, C LaPerle

uploaded to the central project registry to facilitate QA. The submittal review policies of the reviewed programs are summarized in Table 5.

- "Reviewer Qualification Requirements" column indicates whether the professional that reviews modeling-based submittals is required to have modeling-related work experience or certifications or receive specialized training. The answer options included "Yes", "No" or "NA". NA is used for programs that do not have modeling submittals reviewed.
- "Reviewed by Program Staff" column indicates whether the modeling submittals are reviewed by the program staff or contractors hired by the program and assigned to projects. The answer options included "Yes", "No" or "NA". For example, for programs involving energy code compliance, "program staff" includes code officials and plan examiners employed or contracted by a jurisdiction. "NA" is used for programs that do not review modeling submittals.
- "Reviewed by 3rd Party" column indicates whether modeling submittals are reviewed by independent providers selected by project teams from a list of pre-approved reviewers. The answer options included "Yes", "No" or "NA". NA is listed for programs with modeling submittals not reviewed.
- "Quality Assurance" column indicates whether the program has QA procedures in place, such as re-review of a subset of submittals completed by third party providers by the program staff, automated quality control, or requirement for all third party reviews to be additionally approved by the internal program staff. "Yes" indicates that the program has one of these processes in place. "No" indicates that there is no QA. "NA" is listed for programs that do not have modeling submittals reviewed.

Table 5: Submittal Review Practices

	Modeling-based Program	Reviewer Qualification Requirements	Reviewed by Program Staff	Reviews by 3rd party	Quality Assurance
Code	California 2022 Energy Code	No	Yes	Yes	No
	Florida 2020 Energy Code	No	Yes	Yes	Yes
	Seattle 2018 Energy Code	Yes	Yes	Yes	No
	New York City 2020 Energy Code	Yes	Yes	No	No
	Denver Energy Code	Varies	Yes	No	Unknown
Beyond Code Programs	IRS 179D Energy Efficiency Tax Deductions	Unknown	No	No	Yes
	ENERGY STAR Multifamily New Construction	Yes	No	Yes (MRO)	Yes
	LEED NC	Yes	Yes	No	No
	ASHRAE bEQ As Designed	No	Yes	No	No
	Passive House Institute (PHI)	Yes	Yes	Yes	No
	Passive House US (Phius)	Yes	Yes	No	No
	Federal Energy Management Program (FEMP)	NA	NA	NA	NA
	Living Future Challenge	Unknown	Yes	No	No
	AIA 2030 Commitment	NA	NA	NA	NA
	Green Globes	Yes	No	Yes	Yes (Note 2)
	BREEAM	Yes	No	Yes	Yes
	New Jersey Pay for Performance	Yes	Yes	No	Yes
	NYSERDA New Construction Programs	No	Yes	Yes, via MRO or Phius/PHI proxy	Yes
	California Energy Design Assistance	Varies	Yes	No	Yes
	Austin Energy Green Building	Yes	Yes	No	Yes
COMNET (Note 1)		Yes	No	Yes	Yes
RESNET Home Energy Rating (HERS)		Yes	No	Yes	Yes

Note 1: Since the COMNET is not an active certification program, the inputs indicate the intent rather than the adopted policy.

Note 2: While Green Building Initiative (GBI) reviews the report generated by the assigned third-party assessor, according to IBPSA Certification Committee member who completed many energy models in support of the Green Globes certification, the submitted models appear to not be independently reviewed.

Business Model of Modeling-based Programs

The modeling-based programs currently perform many of the functions that may be delegated to a national certifying body, such as establishing modeler and reviewer qualification requirements, approving BEM tools and submittal QA/QC. This section describes the revenue sources of the modeling-based programs which may inform development of the certifying body business model. Allocation of the programs' budget between different tasks is often not publicly available. The following activities may require funding:

1. Establishing and maintaining modeling and reporting requirements.
   The associated effort is small for programs that adopt existing modeling protocols (e.g., 90.1 PRM) and utilize the available tools such as DOE/PNNL ASHRAE 90.1 Section 11 and Appendix G Compliance Form. There is no existing reporting template for IECC TBP. For programs that adopt custom modeling rules such as CA Title 24 ACM, substantial funding may be required to develop and maintain the modeling rules and reporting templates.
2. Maintaining a list of the approved BEM tools
   Most of the modeling-based programs adopt BEM software requirements included in the modeling ruleset (e.g., software requirements of 90.1 PRM) but do not verify BEM tool compliance with these requirements. Some use a list of simulation tools approved by another programs, such as IRS Section 179D, as a proxy. California Energy Commissions establishes software certification process and administers certification. Manual review of BEM software for compliance involves substantial effort. Automating the certification process would require an initial investment but should pay off as testing requirements become more comprehensive and additional BEM tools enter the market. The following areas may require funding:
   a. Developing BEM software certification requirements and process.
   b. Developing automation framework for software certification.
   c. Administering software certification.
3. Developing energy models
   In most cases, energy modeling costs are passed on to the building owner or developer. Utility program incentives may offset or fully cover the cost of modeling on projects participating in such programs. In some cases, modeling is completed by utility program staff with the work funded by the program.
4. Submittal review and approval
   In most jurisdictions, submittal reviews are funded through permit fees which are independent of the actual review effort on a given project. For example, in NYC the permit fee is $220 for all projects irrespective of the floor area and the compliance path and covers both plan reviews and site inspections necessary to issue occupancy permit. In Seattle reviews of modeling submittals developed for demonstrating code compliance take 16-40 hours, with the applicants charged based on the time spent by reviewer at approximately $300/hr. For beyond-code programs such as LEED, submittal reviews are covered by the project certification fees.
5. Marketing, advocacy, and outreach to ensure project participation.
   Beyond-code programs often measure success by the number of enrolled projects, which requires communicating the value of the program to the marketplace, differentiating from competition, and

striking a balance between the rigor of program requirements and quality control, hard and soft costs associated with program participation, and perceived value from program certification.

Code enforcement programs typically get the bulk of required funding from public sources. For example, in New York City, where the average per-project modeling submittal review time is reported to be 35 hours, the $220 permitting fee is supplemented from the city budget to cover the actual effort.

Beyond-code programs often have high certification fees. For example, the 2022 LEED BD+C certification for projects over 500,000 square feet is $25,700, and the Living Future minimum certification cost for a 500,000 – 750,000 square feet project is $40,000. While some of these fees may cover aspects of the programs unrelated to energy modeling such as water conservation, site and material selection, Phius is focused exclusively on energy hand have certification fee of $24,000 for a large project. Many programs offer options paid services such as expedited reviews and appeals.

Table 6 summarizes the funding sources for various program activities and includes the number of participating projects and example certification fees where available. COMNET is not shown since it is currently not active. The table includes the following columns:

- "Technical Requirements and Outreach" column indicates the funding sources used to establish program modeling and reporting requirements, BEM tool requirements and certification process (where applicable), and market outreach to raise awareness of the program.
  - "Public" indicates the predominant use of federal, state or municipal funds or, in case of utility incentive programs, fees collected from ratepayer.
  - "Market based" indicates the predominant use of private sector funds, such as fees collected from participating projects and providers.
- "Submittal Review" column indicates source of funding used to pay for submittal reviews.
  - "Market Based" source means that projects bear the review cost, such as for code compliance model review in Seattle and MRO reviews for the EPA ENERGY STAR Multifamily New Construction Program.
  - Examples of "Public" source include submittal reviews in New York City, where permit application fee falls far short of the cost of labor by Department of Buildings staff, or reviews performed using utility incentive program operating budget.

Table 6: Funding Source

	Modeling-based Program	Technical Requirements and Outreach	Submittal Review	Project Volume	Certification Cost
Code	**California 2022 Energy Code**	Public	Public	~50% of NC permits	In San Francisco, $6,670 for $1M project valuation
	Florida 2020 Energy Code	Public	Public	~90% of NC permits	$134 + $0.36/SF in Tallahassee
	Seattle 2018 Energy Code	Public	Market Based	~dozen projects a year	Model review takes 16-40 hours at $300/hour
	New York City 2020 Energy Code	Public	Public	~ 25 per year	$220 permit fee
	Denver Energy Code	Public	Public	7 projects	Based on project valuation, $5,385 for 1M project
Beyond Code Programs	**IRS 179D Energy Efficiency Tax Deductions**	Public	Public	Unknown	None
	ENERGY STAR Multifamily New Construction	Public	Market Based	23 projects in 2021, 370 modeling projects since inception	None
	LEED NC	Market Based	Market Based	370 LEED NC v4 & 4.1 in 2021; 7,490 v4 & v4.1 BD+C and ID+C certified projects; 18,085 registered but note yet certified (excludes single family)	$1.2k-$1.5k registration, $4k-$5k precertification, $0.030/sf - $0.073/sf certification (min. $2,850 for buildings < 250KSF and $25.7K for building > 500K SF.
	ASHRAE bEQ As Designed	Market Based	Market Based	Unknown	Free except fees for some reports via online portal
	Passive House Institute (PHI)	Market Based	Market Based	5,173 pre-certified or certified projects globally including 591 MF and ~800 nonresidential; 71 certified and 137 registered in US	
	Passive House US (Phius)	Market Based	Market Based	803 projects are registered or certified. 681 of these projects are in US, 302 are single-family residential and 291 are multifamily	From $4,000 for a small simple project to $24,000 for a large project; additional fees for expedited reviews
	Federal Energy Management Program (FEMP)	Public	NA	Unknown	NA
	Living Future Challenge	Market Based	Market Based	100+ projects in 2021 with 57% of projects in US.	Varies depending on track. For Core certification, $7000 min ($0.13/SF) for projects under 75K SF to $40,000 min ($0.07/SF) for projects 500K-750K SF
	AIA 2030 Commitment	Market Based	NA	~11,650 projects modeled in 2020	None
	Green Globes	Market Based	Market Based	205 projects in 2021	$10,235 - $32,5000
	BREEAM	Market Based	Market Based	10,800 certifications 2013-2017, 83% in UK	$6,295 for projects 50K-500K SF
	New Jersey Pay for Performance	Public	Public	31 projects approved in 2020-2021	None (Incentive Program)
	NYSERDA New Construction Programs	Public	Hybrid	~70 commercial, 330 housing annually	None (Incentive Program)
	California Energy Design Assistance	Public	Public	140 projects in the first 12 months since end of 2021	None (Incentive Program)
	Austin Energy Green Building	Public	Public	81 projects in 2022 fiscal year	None (Incentive Program)
RESNET HERS		Market Based	Market Based	313,153 homes in 2021	$7.50 per rating submitted to RESNET Registry

Overview of Past and Current Certification Programs

Review of the modeling-based programs for commercial buildings indicates that most programs set their own qualification requirements for modelers and reviewers, independently establish the accepted BEM

tools, and develop and implement model quality assurance and quality control process. The existing certifications that are used by multiple programs include ASHRAE BEMP for modeler qualifications (Table 4), and the IRS 179D for the approved BEM tools. Table 7 provides the certification fees and volume for these two programs and includes various RESNET certifications for comparison.

Table 7: National Certification Precedents Fees and Volumes

Certifying Body	BEM Tool Certification		Modeler Certification		Reviewer Certification		Training Provider Certification		Project Certification	
	Annual Fee	Qty of Certified Tools	Fee	Qty of Providers	Annual Fee	Qty of Providers	Annual Fee	Qty of Providers	Fee	Qty of Projects
ASHRAE BEMP	NA	NA	$595 certification, $299 recertification (Note 3)	~500 including ~370 in US	NA	NA	NA	NA	NA	NA
IRS Section 179D	$0	13 unique tools, 1-7 versions of each	NA	NA	NA	NA	NA	NA	NA	NA
RESNET HERS[18]	$1,750	3	Modeler (professional): $0 (Note 1)	142	Rating Provider, $1750 min. annually	85	$1750 min. annually	28	$7.50	>330,000 in 2021
			Rater (professional): $0 (Note 1)	5,934 (Note 2)						

Note 1: RESNET doesn't charge a fee for rater, modeler, and Rating Field Inspectors (RFI) certification. Rating Providers are responsible for managing these professional certifications and establish and charge fees, if any. RESNET charges Rating Provider, Training Provider and Software annual accreditation fees of $1,750 annually.

Note 2: While 5,934 raters maintain their certification, only 1,982 raters submit ratings for HERS projects according to RESNET staff[19]. Many raters and RFIs maintain the certifications to be eligible for performing other tasks such as duct and envelope leakage testing for code compliance.

Note 3: Discounts are available for ASHRAE members.

The ASHRAE Building Energy Modeling Professional (BEMP) certification is an ANSI-accredited professional certification program. To get certified, candidates must meet prerequisites that include a combination of education and work experience and pass a multiple-choice test. In addition to the initial certification fee, a recertification fee must be paid every three years. The ASHRAE expense of maintaining the certification program includes marketing, application intake and processing, exam hosting and delivery fees, and the ANSI National Accreditation Board (ANAB) annual fee.

The 179D software certification requires vendors to fill out an application listing the software capabilities in the selected areas, perform the Standard 140 tests and submit the required documentation to the National Renewable Energy Laboratory (NREL). NREL reviews submittals for

[18] Providers - RESNET

[19] Based on authors conversation with Ryan Meres, RESNET Program Director.

completeness and maintains the list of the approved tools. The certification is publicly funded as there is no vendor application fee.

RESNET scope includes developing standards and guidelines for the Home Energy Rating System, program marketing, quality assurance, maintaining a network of RESNET Accredited Providers and the project registry. HERS is governed by the RESNET Mortgage Industry National Home Energy Rating System Standards which cover a broad range of quality assurance and quality control topics including BEM tool capabilities, testing and accreditation process, HERS rater training and certification and quality assurance.

There are 163 RESNET Accredited Providers in the US including Rating Providers, Rating Sampling Providers, Rater Training Providers, Energy Smart Contractor Education and Qualification Providers, and Approved WaterSense Providers. HERS Software Tools are also categorized as providers by RESNET, as the vendors of accredited tools essentially provide a product that must be used in order to rate a home. Each provider company pays RESNET an annual fee of $1,750 and may purchase additional services such as the RESNET HERS Rater company premium directory listing for up to $3,995/year for the national membership[20]. In addition, there is a $7.50 fee for uploading projects to RESNET registry. The provider accreditation fees and uploading rated projects to registry generates approximately 3M in annual revenue for RESNET based on the recent program participation data.

Becoming a provider creates new business opportunities for companies. For example, the Accredited Rating Providers are responsible for administering rater certification; the Accredited Training Providers deliver the training that rater candidates are required to complete in order to become certified by an accredited rating provider; HERS scores must be determined using an accredited software tool, etc. Ultimately, the costs are passed to homeowners who value HERS ratings for their independent construction oversight, opportunity to lower energy bills, increased property value and recognition by major rating authorities and agencies, including ENERGY STAR, the U.S. Green Building Council, utility energy efficiency programs, and by the Internal Revenue Service and the U.S. Department of Energy as a basis for tax credits for residential energy efficiency.

COMNET offers important lessons for the certification initiative. It aimed to set industry standards for evaluating the energy performance of nonresidential and high-rise multifamily buildings. Its intended scope included BEM tools certification, a portal through which all the accredited energy analysis would pass, credentialing and training modelers, and periodic internal quality control audits. The initial efforts focused on enhancing the 90.1 PRM requirements, such as adding the acceptance criteria for the Standard 140 tests, introducing a requirement for an automated compliance shell and publishing a suite of ruleset tests to verify the automation. The work also included defining an XML schema to enable data export from the BEM tool to facilitate QC and piloting a portal for uploading simulation results to LEED Online, with the intent to offer this service for a fee. In addition, the “Modeling Guidelines and Procedures” were developed to clarify and interpret requirements of multiple 90.1 editions.

COMNET development was funded by grants from The Energy Foundation. However, the efforts were not embraced by the industry and COMNET was ultimately suspended due to lack of funding. Some of the COMNET documents led to advances in the field – for example, the Energy Modeling Guidelines became the basis of the PNNL’s Performance Rating Method Reference Manual[21].

[20] Membership - RESNET

[21] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26917.pdf

BEM Certification Body Initiative Roadmap

Lessons Learned from Previous Certification Efforts

The completed research offers several important lessons on the strategies for establishing a national certification program.

1. RESNET® dominates the residential market, with over 330,000 homes receiving HERS ratings just in 2021. On the other hand, there are multiple competing programs for commercial and high-rise multifamily buildings including LEED (370 LEED v4 & 4.1 projects in 2021), Green Globes (205 projects in 2021), Phius (63 projects for 2021 family of programs), ENERGY STAR Multifamily New Construction (23 projects in 2021), and many others. That puts RESNET® in a better position to dictate the requirements and rigor compared to any one program for commercial and high-rise multifamily buildings. It appears unlikely that national programs like LEED or EPA ENERGY STAR would adopt a certification program that does not include popular BEM tools or that does not have enough providers, as it may steer projects toward other programs that do not impose these restrictions. Fragmentation of the commercial market will complicate creation of a national certifying body.
2. RESNET® develops its own standard (ANSI/RESNET/ICC Standard 301) that sets the modeling rules and BEM tool requirements. Many large scale national and local modeling-based programs for commercial and multifamily buildings are based on the model energy codes including 90.1 and IECC (Table 2), which results in some uniformity of technical requirements across these programs. Aligning certification efforts with modeling and BEM tool requirements of the model energy codes will help mitigate negative impacts of commercial market fragmentation.
3. Certifications cannot succeed if they are not embraced by the key market actors. For example, IECC requirement for BEM tools to have a compliance shell[22] was removed starting with the 2012 edition because most of the BEM tool vendors did not implement the automation and jurisdictions continued to accept submittals with manually created reference designs. COMNET attempt to require a compliance shell and enhance software testing requirements also did not get traction. Given this history, certification efforts should initially focus on verifying compliance with the requirements that are already embraced by the industry, such as the existing 90.1 BEM tool requirements.
4. RESNET operation relies on the extensive network of provider companies which depend on continued success and growth of RESNET HERS and thus actively promote the program. RESNET recognizes the importance of this synergy, with many of the RESNET 2022 priorities revolving around providing new business opportunities for "RESNET professionals". On the other hand, COMNET focused on developing technical documents and mostly targeted jurisdictions and beyond-code programs with its outreach, without trying to actively engage with businesses operating in the field. To replicate RESNET business model in the commercial sector, the certifying body should demonstrate the business value of certifications to consulting companies implementing utility incentive programs and performing third party submittal reviews.

[22] 2009 International Energy Conservation Code (IECC) - CHAPTER 5 (iccsafe.org)

The following sections discuss potential strategies for BEM tool, modeler, and submittal reviewer certifications.

BEM Tools Certification

Both 90.1 and IECC prescribe the BEM tools' minimum simulation and reporting capabilities and testing requirements. However, there is currently no national, program-neutral process for BEM tools to demonstrate compliance with these requirements. IRS 179D is the only national program that maintains a list of BEM tools compliant with 90.1, but it is based on 90.1 2007 with amendments, and no other reviewed program follows this edition of 90.1.

90.1 and IECC BEM tool requirements are generic in nature and represent standard of care for commercial and multifamily building modeling. ASHRAE Standard 209, Energy Simulation Aided Design for Buildings except Low-Rise Residential Buildings, references 90.1 PRM software requirements, making these requirements applicable to projects and programs following Standard 209. Programs like AIA 2030 Commitment, Living Building Challenge and Green Globes use modeling to estimate post-occupancy performance, and would benefit from having the industry-standard BEM tool requirements which they currently lack (Table 3).

The RESNET annual fee of $1,750 for accrediting BEM tools seems modest compared to the cost to license some of the popular BEM tools used for 90.1 modeling such as IESVE (~$5,500 a year[23] for a single-user network license) and TRACE 3D (approximately $3,700 a year for similar licenses). For such tools, even a small increase in sales will cover the certification fee and, depending on the requirements rigor, the effort of meeting certification requirements. However, some of the popular tools including eQUEST and OpenStudio do not have licensing fees and all vendors are likely to oppose stricter regulations.

Currently, only the California Energy Commission has a rigorous BEM tool approval process that reportedly requires significant resources from both the BEM tool vendors and the state. Florida BEM tool certification that was based on the COMNET framework was discontinued and replaced by vendor self-certification after a vendor raised concerns about potential conflict of interest in the existing procedures. 179D certification is limited to having vendors submit the required materials and does not include in-depth verification.

Developing additional certification tests and administering rigorous software certification similar to California Energy Commission requires substantial effort that is unlikely to be covered by the certification fees. RESNET currently has three approved BEM tools which brings in only $5,250 per year based on the current $1,750 certification fee. While there are over a dozen BEM tools on the IRS Section 179D, only a handful of them are commonly used for commercial modeling.

Based on these considerations, BEM tool certification should initially focus on verifying BEM tool compliance with the existing 90.1 simulation tool requirements to make the certification applicable to most modeling-based programs. This approach will increase the likelihood of adoption by jurisdictions and beyond-code programs and reduce resistance from BEM tool vendors. Even for that modest scope, the certification fees will likely not cover the certification effort and the work would need to be subsidized either through public funding or revenue from other certification types. IBPSA-USA has

[23] Based on a quote received by the author from the software vendor.

secured DOE funding for implementing a portal to verify compliance with the ASHARE Standard 140 acceptance ranges introduced by addendum b. This work will contribute toward establishing the BEM tool certification framework.

Modeler Certification

A modeler certification helps consumers identify competent practitioners. Minimum modeler qualifications are included in the ASHRAE Standard 209 and required by some of the evaluated programs such as Seattle 2018 Energy Code, ASHRAE bEQ As-Designed and BREEAM (Table 4). ASHRAE BEMP is the most cited certification. A limited number of certified professionals (371 BEMPs in the US as of summer 2022)[24] is the main obstacle for a wide adoption. Only around a third of RESNET HERS raters submit project ratings. Assuming a similar proportion of active BEMPs, there are around 125 US-based certified modelers who are available to work on projects. This is insufficient given that the AIA 2030 Commitment program alone reported 11,650 modeled projects in 2020.

ASHRAE has strong name recognition and established its BEMP certification over a decade ago, yet it is struggling to get traction. Association for Energy Engineers (AEE) has discontinued its Certified Building Energy Simulation Analyst (BESA) program but is very successful with its other professional certifications – there are over 11,500 AEE Certified Energy Managers in the US[25]. Given that, creating an alternative modeler certification does not appear feasible or justified. Instead, the work should focus on promoting the existing certifications, such as ASHRAE BEMP. For example, a certifying body may help ASHRAE develop training to prepare candidates for the BEMP exam and work to promote adoption of the applicable existing certifications with the initial focus on forward-looking municipalities and programs that offer financial benefits such as IRS 179D, C-PACE and utility incentive programs. The certifying body may also identify competencies that are not sufficiently covered by the existing certifications and facilitate developing new certifications or expanding the scope of existing certifications to address these gaps. However, it is unclear whether these activities can be sustained using market-based funding.

Reviewer Certification and Third Party Provider Network

The depth and rigor of model reviews varies across programs. For example, LEED reviews are typically more rigorous than reviews for programs such as Green Globes and Enterprise Green Communities which often provide no comments on the submitted models. This puts programs with high quality standards at a disadvantage because the marketplace often favors programs with lower participation cost if the difference in rigor is not apparent and does not impact program credibility. In addition, a more rigorous review process increases program administration costs and, as a result, necessitates higher certification fees.

RESNET QA/QC is carried out by Rating Providers that perform third party project oversight following RESNET requirements. The QA/QC rigor was reportedly much lower when the program rolled out but has steadily increased overtime. The change was largely driven by the providers who view RESNET HERS credibility as integral to the success of their businesses.

For the last 5 years, the EPA has been using a similar market-based submittal review model for its ENERGY STAR multifamily program. While there are currently only four approved Multifamily Review Organization (MRO), this number seems appropriate given a significantly smaller scale of the EPA

[24] ASHRAE BEMP Directory (ashrae.org)
[25] AEE Certified Professionals Directory | Association of Energy Engineers (aeecenter.org)

program compared to RESNET HERS. EPA does not charge MROs any fees but benefits from their services because previously the reviews were funded from the program budget and performed by in-house staff and contractors. The MRO framework helped shift these costs to program participants. This approach may be attractive to other modeling-based programs that may choose to delegate submittal reviews to a market-based provider network managed by a well-respected national organization.

There are multiple consulting companies involved with helping jurisdictions and beyond-code programs (e.g., utility incentive programs) in performing model QA/QC on commercial projects. Based on these considerations, it appears that establishing a third-party review framework may be self-sustaining and have a good likelihood of adoption by modeling-based programs. Some programs already set qualification requirements for submittal reviewers (Table 5) which may be used as the basis of reviewer certification requirements. The target submittal review scope may be established based on the ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual and utilizing the Third-Party Submittal Reviewer Scope of Work published on the Building Energy Codes Program[26] website.

The Roadmap for Establishing a Certifying Body

Short Term (2023-2024)

1. Perform outreach to administrators of modeling-based programs for commercial and multifamily buildings, BEM tool vendors, modelers and training providers to raise awareness, demonstrate value of national certifications and get input on the draft documents.
2. Develop reviewer qualification requirements and a third-party review framework.
    a. Develop a consensus document outlining the submittal review scope which may be based on the ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual.
    b. Develop a consensus document describing reviewer qualification requirements.
    c. Secure at least 5 potential providers of third-party review services.
    d. Secure at least 10 jurisdictions and beyond code programs interested in requiring participants to use the third-party review services.
3. Develop a BEM tool certification framework for demonstrating compliance with the existing software requirements of 90.1 2016, 2019 and 2022 including:
    a. Develop a consensus document outlining application and appeals process.
    b. Develop a consensus document with procedures for verifying BEM tool compliance with the requirements (e.g., self-certification versus active review).
    c. Investigate the feasibility of developing similar documents for IECC Section C407.5 BEM tool compliance and opportunities to engage with the California Energy Commission for certifying their software tools.
    d. Identify and secure commitments from at least 3 commonly used BEM tools interested in participating in the certification.
    e. Create prototype software certification infrastructure for verification of ASHRAE Standard 140 2023 acceptance ranges.

[26] ASHRAE Standard 90.1 Performance Based Compliance (Section 11 and Appendix G) | Building Energy Codes Program

4. Work with ASHRAE to enhance BEMP scope and develop training to prepare for the BEMP exam. Identify other existing certification programs that may be referenced to address gaps in the BEMP scope.
5. Develop a business model for the certification body, including the following:
    a. Estimate effort of establishing submittal reviewer and BEM tool certifications and a third-party submittal review framework.
    b. Investigate opportunities for creating project registry.
    c. Establish initial fee structure for each certification type.
    d. Prioritize certification efforts based on market demand and feasibility of achieving self-sustained market-based operation.
    e. Develop a short-, medium- and long-term business plan for each certification type.
6. Investigate organizations that can serve as the certifying body for BEM tools and/or third-party reviews, such as IBPSA-USA.

Medium Term (2025-2026)

1. Maintain the consensus documents for BEM tool certification, reviewer certification and third-party reviews.
2. Facilitate establishing a certifying body.
3. Support the certifying body in rolling out a third-party submittal review program.
    a. Implement the third-party review framework.
    b. Publish the list of approved providers. Have at least 5 provider companies certified.
    c. Work with jurisdictions and beyond-code programs to promote adoption. Have at least 10 jurisdictions and beyond-code programs require the use of certified providers and following the review process outlined in the consensus documents.
4. Support the certifying body in rolling out BEM tool certification for compliance with various editions of 90.1.
    a. Implement BEM software certification framework including an on-line portal for uploading documentation and displaying a list of certified BEM tools.
    b. Certify at least 3 popular BEM tools used for compliance modeling.
    c. Have at least 10 jurisdictions and beyond-code programs reference the certification list.
5. Continue working with ASHRAE and other existing certifying bodies to ensure availability of appropriate modeler certifications.
6. Refine business model for certification programs as necessary to support market-based self-sustaining operation.

Long Term (2027+)

1. Maintain the consensus documents for BEM tool and reviewer certification and third-party reviews.
2. Continue collaboration with the certifying body and outreach to raise awareness of the certification initiative.
3. Expand software certification to cover software tools regulated by ASHRAE Standard 229P, including the Ruleset Checking Tools and the tools used to convert model files to the 229P schema. Std 229P is currently under development and will establish a framework for automating review of projects modeled following 90.1 2019 PRM. The following editions of the standard may also include certifying BEM tools compliance shells that automatically generate energy models as required by

PRM, ECB or other compliance rulesets. Compliance with Standard 229 may be included in 90.1 2028 PRM.

Appendix A: ASHRAE 90.1 2019 Appendix Modeling and Reporting Requirements

G1.3.2 Application Documentation

Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information shall be submitted in a report and shall include the following:

…….

l. Input and output reports from the *simulation program* or compliance software, including a breakdown of *energy* use by at least the following components: lights, internal *equipment* loads, *service water-heating equipment*, *space*-heating *equipment*, *space*-cooling and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.

G2.2.1

The *simulation program* shall be approved by the *rating authority* and shall, at a minimum, have the ability to explicitly model all of the following:

a. 8760 hours per year.

b. Hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat set points*, and *HVAC system* operation, defined separately for each day of the week and holidays.

c. Thermal mass effects.

d. Ten or more thermal zones.

e. Part-load performance curves for mechanical *equipment.*

f. Capacity and *efficiency* correction curves for *mechanical heating* and *mechanical cooling equipment*.

g. *Air economizers* with integrated *control*.

h. *Baseline building design* characteristics specified in Section G3.

G2.2.2

The *simulation program* shall have the ability to either directly determine the *proposed building performance* and *baseline building performance* or produce hourly reports of *energy* use by an *energy* source suitable for determining the *proposed building performance* and *baseline building performance* using a separate calculation engine.

G2.2.3

The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and air and water flow rates in accordance with *generally accepted engineering standards* and handbooks (for example, *ASHRAE Handbook—Fundamentals*) for both the *proposed design* and *baseline building design*.

G2.2.4

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8 of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program along with the results of the other simulation programs included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

G2.3 Climatic Data

The *simulation program* shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the *construction* site. The selected weather data shall be approved by the *rating authority*.

Appendix B: IECC 2021 Simulation Software Requirements

C407.5 Calculation software tools.

Calculation procedures used to comply with this section shall be software tools capable of calculating the annual energy consumption of all building elements that differ between the *standard reference design* and the *proposed design* and shall include the following capabilities.

1. Building operation for a full calendar year (8,760 hours).
2. Climate data for a full calendar year (8,760 hours) and shall reflect *approved* coincident hourly data for temperature, solar radiation, humidity and wind speed for the building location.
3. Ten or more thermal zones.
4. Thermal mass effects.
5. Hourly variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads.
6. Part-load performance curves for mechanical equipment.
7. Capacity and efficiency correction curves for mechanical heating and cooling equipment.
8. Printed *code official* inspection checklist listing each of the *proposed design* component characteristics from Table C407.4.1(1) determined by the analysis to provide compliance, along with their respective performance ratings, including but not limited to *R*-value, *U*-factor, SHGC, HSPF, AFUE, SEER and EF.

C407.5.1 Specific approval.

Performance analysis tools complying with the applicable subsections of Section C407 and tested according to ASHRAE Standard 140 shall be permitted to be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall be permitted to approve tools for a specified application or limited scope.

C407.5.2 Input values.

Where calculations require input values not specified by Sections C402, C403, C404 and C405, those input values shall be taken from an *approved* source.

C407.5.3 Exceptional calculation methods.

Where the simulation program does not model a design, material or device of the *proposed design*, an exceptional calculation method shall be used where approved by the *code official*. Where there are multiple designs, materials or devices that the simulation program does not model, each shall be calculated separately and exceptional savings determined for each. The total exceptional savings shall not constitute more than half of the difference between the baseline building performance and the proposed building performance. Applications for approval of an exceptional method shall include all of the following:

1. Step-by-step documentation of the exceptional calculation method performed, detailed enough to reproduce the results.
2. Copies of all spreadsheets used to perform the calculations.
3. A sensitivity analysis of energy consumption where each of the input parameters is varied from half to double the value assumed.
4. The calculations shall be performed on a time step basis consistent with the simulation program used.
5. The performance rating calculated with and without the exceptional calculation method.

Appendix C: Inventory of the Modeling-based Programs

This section provides an overview of US and international programs that target commercial and high-rise multifamily buildings and that require energy modeling. The programs were identified by the IBPSA-USA Certification Committee. The information reflects the state of each program as of summer 2022 unless noted otherwise.

Energy Code Compliance

Title 24 Alternative Compliance Method (Commercial)

California energy code is administered by the California Energy Commission (CEC). The performance-based compliance path was introduced in 1978 and was initially based on comparing a model of proposed design to a fixed performance target that depended on a project's climate zone and whether the building was heated only, cooled only or both heated and cooled. In 1992, the fixed target method was replaced with a comparative method with the compliance outcome determined based on the performance of the proposed design that reflected the specified systems and components relative to a standard reference design meeting mandatory and prescriptive code requirement.

Concurrent to this change, a requirement was introduced for the BEM tools to have a capability to automatically generate the standard reference design model, produce compliance reports and perform prescribed testing to demonstrate general alignment in simulation results to the results of a state-approved, public domain BEM tool. In 2013, CEC developed a new reference software tool called California Building Energy Code Compliance (CBECC) – Com.

The current modeling and software requirements and software approval process are described in the 2022 Nonresidential and Multifamily Alternative Calculation Method Reference Manual (ACM)[27]. The following software tests are required:

- Ruleset implementation tests demonstrating BEM tool capability to automatically generate the standard reference design for prescribed building designs.
- Physics and sensitivity tests to verify accuracy of the simulation algorithms. The requirements include testing following the ASHRAE Standard 140-2007 with no acceptance criteria, and a test suite developed by the CEC based on the modified DOE/PNNL prototype models of small, medium and large offices, stand-alone retail and strip mall in 5 of the 16 CA climate zones. Most tests include permutations of the base cases with one or two parameters modified in each permutation – e.g., decreasing lighting power by 20% or decrease the overall U-value of roof by 20% compared to the base case. Tests cover the opaque envelope, glazing, lighting, daylighting, receptacle loads and HVAC systems. The passing ranges for all tests are ± 0.5% of the CBECC-Com result. The change in use must also show the same trend (penalty or savings) relative to the base case as the CBECC-Com.

The ACM framework gives the CEC control over the entire analysis process from user input to reporting, a reasonable assurance that all the approved tools produce the same compliance outcome for identical design, and ability to continuously fix bugs and add features to the CBECC-Com. However, it is very resource-intensive for both the CEC and the BEM tool vendors. Also, the certification tests cover a small

[27] 2022 Nonresidential And Multifamily Alternative Calculation Method Reference Manual June 2022 CEC-400-2022-009 https://efiling.energy.ca.gov/GetDocument.aspx?tn=243495

subset of possible building designs, so do not ensure consistency of compliance outcomes for untested configurations. The approach also limits ability to model new features not supported by CBECC-Com. [28] The currently approved BEM tools for commercial and high-rise multifamily buildings include CBECC-Com, EnergyPro, and IES Virtual Environment.

At the state level, there are no minimum modeler and submittal reviewer qualification requirements. Some jurisdictions that adopt reach/stretch codes require a Certified Energy Analyst (CEA) credentials for professionals who prepare energy code compliance documentation.[29] CEA certification is administered by the CA Association of Building Energy Consultants and requires passing an exam. The curriculum is updated for each code cycle, covers all aspects of the energy code and is not specific to the whole building performance path.

Some California jurisdictions use 3rd parties for all aspects of code reviews. For example, 3rd parties may be engaged on complex new construction permit applications irrespective of the compliance path[30]. CA Compliance Manual used to include the checklists for plans examiners and inspectors. For the last several code cycles, the checklists are developed by the Energy Code Ace (an initiative led by the California Investor-Owned Utilities), reviewed by the State and published on the Energy Code Ace website. Using checklists is not required, but they are reported to be widely used.

The permitting fees vary by jurisdictions. For example, in San Francisco the fee depends on project valuation. For a project valued at $1M, the plan review fee is $6,670.55 irrespective of the compliance path followed[31]. Approximately 50% of commercial new construction projects in California use the performance path[32].

Florida Energy Code

Florida energy code has included a performance-based compliance option for over 40 years. The original approach involved a standard HVAC sizing methodology modified to calculate annual energy use rather than peak loads. In the 1980s, the method was implemented in a DOS software that was converted to Windows in the mid-1990s. The reference building method and hourly simulation based on DOE2 were adopted in the early 2000s. Since the 2010 code cycle, preapproved third party BEM tools are allowed. Performance-based compliance remains dominant in Florida and is reportedly used for over 90% of commercial new construction permits.[33]

The 2020 Florida Energy Code is approximately equivalent in stringency to 2018 IECC and ASHRAE 90.1-2016[34]. The whole building performance compliance options include IECC Total Building Performance,

[28] Larry Froess, P.E. 2019. Automating Compliance Modeling: California Energy Commission Software Certification Process. Presented at the 2019 Building Performance Analysis Conference, Denver, Colorado, September 25-27 "Automating Compliance Modeling – Challenges, Opportunities and Path Forward" Bing Liu, Maria Karpman, Larry Froess, Muthusamy Swami, Amir Roth, presented at 2019 Building Performance Analysis Conference
[29] Waiting for Sally Blair to provide examples of such jurisdictions.
[30] Examples of companies that provide such services in CA include Bureau Veritas and Shums Coda.
[31] TABLE 1A-A - BUILDING PERMIT FEES (amlegal.com)
[32] Based on DOE/PNNL/NEEA stakeholder survey
[33] Based on stakeholder surveys included in Appendix A of PNNL report.
[34] https://www.energycodes.gov/status/states/florida

90.1 2016 ECB and PRM[35]. All new construction and renovation projects involving the state buildings must follow the guidelines of LEED, Green Globes or other green building rating system.

Florida Building Commission oversees code development and implementation. Prior to the 2020 code cycle, the state maintained the Energy Simulation Tool Approval Technical Assistance Manual[36] (TAM) which prescribed the BEM tools testing and approval process. The TAM BEM tool requirements expanded over 90.1, calling for a capability to automatically generate the baseline model for a user-entered proposed design and creating compliance reports with prescribed content. The software testing requirements included a suite of ruleset tests to verify the BEM tool's capability to automatically generate the baseline model which included sixteen test cases based on the COMNET Manual 2010 - Commercial Buildings Energy Modeling Guidelines and Procedures with some modifications. The TAM also described the certification procedures included the application process, documentation and recertification requirements and appeal process.

Starting with the 2020 code cycle, the TAM was discontinued in lieu of vendor self-certification that does not include any testing requirements but minimizes the certification effort for both the Commission and BEM tool vendors. The BEM tools currently approved for commercial code compliance include Energy Gauge Summit and, for the 90.1 2016 Appendix G compliance path, the Integrated Environmental Solutions – Virtual Environment (IES-VE)[37].

Chapter 553 of the Florida Building Construction Standards allow permit applicants to engage a private provider to perform plan reviews and site inspections. Providers must be licensed as a building code administrator, engineer, or architect, hold professional liability insurance, and perform services that are within the disciplines covered by their licensure. Provider must be an independent third party not associated with companies that provided design or construction services.

Permit applicants chose a provider that performs review at an agreed-upon fee. The main reason for hiring an external provider is to speed up the permitting process. The jurisdictions reduce permitting fees for projects that engage a 3rd party reviewer to reflect reduction in the in-house effort. Jurisdictions either issue a permit based on the private provider's affidavit certifying that plans comply with the applicable codes or provides a written notice of deficiencies that the permit applicant may either dispute or correct. Permitting fees vary by jurisdiction. For example, in Tallahassee there is $134 application fee plus $0.36/SqFt of floor area[38].

Seattle Energy Code

There are two whole building compliance options in 2018 Seattle Energy Code[39], both based on the 90.1 2019 PRM. The first option[40] has modeling rules aligned with the PRM but requires a greater improvement over the baseline compared to the native 90.1 rules and uses greenhouse gas emissions metric instead of energy cost. This path is used for about 5% of new construction permits. However,

[35] https://codes.iccsafe.org/content/FLEC2020P1/chapter-6-re-referenced-standards
[36] 2017TAM-Final_Feb_2018.pdf (floridabuilding.org).
[37] http://www.myfloridalicense.com/DBPR/building-codes-and-standards/energy/
[38] Growth Management Department Schedule of Permit and Review Fees (talgov.com)
[39] Seattle SDCI - 2018 Seattle Commercial Energy Code Chapter 4, Commercial Energy Efficiency
[40] Section C407

since these projects usually involve large buildings, it is estimated to account for about 50% of the permitted new construction floor area.

The second option is the Target Performance Path[41] and is reported to be very rarely used. The modeling rules for this option are also aligned with the PRM but the required margin of improvement in regulated loads is relaxed by 12% compared to the first option. Projects that follow this path must perform sensitivity analysis to evaluate the impact of the key modeling assumptions not inherent in design, such as occupancy, receptacle and hot water loads, on energy use. In addition, after one year of occupancy, projects must provide metered energy data to the code official using Portfolio Manager and are penalized for not meeting the projected performance[42].

Energy modeler qualification requirements[43] include at least two years of experience modeling buildings of similar scale and complexity. The modeling documentation must be signed either by a licensed professional engineer who is qualified by training and experience to perform energy modeling or by professional holding ASHRAE BEMP certification. All performance-based projects are required to use the DOE/PNNL Compliance Form for reporting.

Modeling submittals are reviewed by either internal staff or outside consultants assigned by the jurisdiction. Review usually takes 16-40 hours and may be performed either by the staff or by an external consultant. In either case, the permit applicant pays for submittal review based on the actual time spent by the assigned reviewer at $300/hour. The review cost is in addition to the regular permit fee[44]. In 2021 about a dozen projects used energy modeling to document compliance.

New York City Energy Code (2020 NYCECCC)

2020 New York City Energy Code whole building performance options include the amended 90.1 Section 11 and Appendix G. Out of 2,500 filings, modeling accounted for 2% of permits and 25% of construction area. The permit fee is $220 for all projects irrespective of the floor area and the compliance path followed. [45]

Modeling submittals are reviewed by the New York City Department of Buildings staff. While there are no formal reviewer qualification requirements, reviews are assigned to staff with background in energy modeling. Several staff members have attended multi-day trainings on energy modeling and modeling submittals review. There is a performance-based submittals checklist that examiners follow, and additional items are often reviewed based on project specifics. Reviews take an average of 35 hours from submission to approval. 3rd parties cannot perform plan reviews due to local regulations but are allowed to perform site inspections.

Projects using the performance path must submit either an internally developed compliance form or DOE/PNNL Performance-based Compliance Form[46]. Simulation tool requirements are aligned with 90.1.

---

[41] Section C401.3.1
[42] Section C401.3.6
[43] Section C401.3.5
[44] Presentation by Duane Jonlin at the DOE/PNNL Performance-Based Compliance Research Project stakeholder webinar on 5/1/2022
[45] Presentation by Emily Hoffman, PE, CEC, director of Energy Code Compliance at the DOE/PNNL Performance-Based Compliance Research Project stakeholder webinar on 5/1/2022
[46] Energy Code Forms - Buildings (nyc.gov)

Specific tools must be approved by the Secretary of State of New York and the Building Commissioner[47]. The approved tools include DOE2.1E, VisualDOE, EnergyPlus, eQUEST and IESVE (for PRM only).

Denver Green Building Ordinance

Denver's Green Buildings Ordinance (GBO), in effect since November 2018, requires developers and property owners to select from a menu of strategies aiming to increase green space, improve water and storm water management, increase the use of solar and other renewable energies, foster the design of more energy-efficient buildings, and increase adoption of national green building programs, such as LEED. The ordinance applies to new buildings and additions of 25,000 square feet or larger and roof permits for existing buildings 25,000 square feet or larger[48].

Several GBO compliance options for new construction projects require performing energy modeling to demonstrate that design improves over the applicable Denver Building and Fire Code by 2.5% - 12% depending on the chosen compliance path. The whole building compliance options allowed in the 2019 Denver Building and Fire Code include the amended 90.1 2016 PRM and 2018 IECC TBP. The PRM amendments include expressing performance using source energy with prescribed site to source conversion factors instead of energy cost and increased performance target stringency.[49] Projects may also comply with the Green Building Ordinance by participating in green building programs some of which, such as LEEC NC and Enterprise Green Communities, require energy modeling[50].

Any modeling tool compliant with 90.1 is allowed. 2022 Denver Energy Code requires modeler to have a BEMP certification or equivalent, and this requirement now also applies to the GBO. Prior to that, there were no modeler qualification requirements. Reviews are completed by internal staff with various credentials including PE, AIA, BEMP and HERS rater.

Permit fees are based on project valuation. For example, the permit fee for a project valued at $1,000,000 is $5,385[51]. Out of 18 new construction projects that were subject to GBO with permit issues from November 2018 to December 2019, several used a compliance path that requires energy modeling including one that chose a green building certification option.[52]

Beyond Code Programs for Commercial and High-rise Multifamily

179D Commercial Buildings Energy Efficiency Tax Deductions

The 179D commercial buildings energy efficiency tax deductions program has been in effect since 2006 and became permanent as part of the Consolidated Appropriations Act of 2021. For 2022 tax year, new and existing buildings may earn tax deduction of $1.88 per square foot for 50% improvement in regulated energy cost compared to the baseline, or $0.63 per square foot deduction for demonstrating 10% improvement in regulated energy use due to just the improved envelope, 15% improvement from just HVAC and hot water heating, and 25% improvement from just lighting[53].

---

[47] Energy Conservation Code - Buildings (nyc.gov)
[48] Denver's Green Buildings Ordinance - City and County of Denver (denvergov.org)
[49] 2019 Denver Building and Fire Code (denvergov.org)
[50] Rules and regulations governing the green building requirements June 8 2021 (denvergov.org)
[51] Building and Land Development Fees - City and County of Denver (denvergov.org)
[52] GBO 2019 Annual Report (denvergov.org)
[53] 179D Commercial Buildings Energy-Efficiency Tax Deduction | Department of Energy

Projects placed in service before 12/31/2026 must use energy modeling following 90.1-2007 PRM with addenda supplement package[54] and the program's Energy Modeling Guidelines[55] in order to get the maximum tax deduction. Projects put in service after that date must use 90.1 -2019 PRM[56]. The Guidelines prescribe certain modeling assumptions such as occupant density, receptacle and service hot water loads and schedules, mechanical ventilation rates and thermostat setpoints depending on building and space types.

The 179D software certification process[57] was established by U.S. DOE and is based on the PRM BEM tool requirements. Tool vendors must fill out a form itemizing software capabilities, perform the Standard 140 tests required by PRM and submit input files, output files, weather data, modeler reports, and the executable version of the software with which the tests were conducted to the DOE and the National Renewable Energy Laboratory (NREL). Software not capable of modeling some of the listed HVAC systems is allowed on projects that do not have such systems. NREL reviews the submitted materials, coordinates any needed revisions and, once verification is completed, adds the version of the software to the DOE list of approved BEM tools. At the time this report was written, thirteen BEM tools were included on the Qualified Software List[58].

In addition to energy modeling, the program requires inspecting the building systems used for tax deduction. The inspections must be completed by a contractor or engineer licensed in the jurisdictions where the building is located. Submitters must use the compliance forms included in the 90.1-2007 User's Manual package or equivalent.

ENERGY STAR Multifamily New Construction Program

The EPA's ENERGY STAR Multifamily New Construction program was established in 2006. Program rules have evolved over time and currently include three paths to earning the label:

- ERI Path involves using an approved rating software to determine unit-by-unit energy savings based on the ERI target (or savings above Title 24 in California) and additionally meet prescriptive requirements developed by the EPA for common spaces.
- ASHRAE Path requires using an approved BEM tool to determine energy cost savings of the building design compared to ASHRAE 90.1 (or Title 24 in California)
- Prescriptive Path requires specifying a package of energy efficient measures developed by EPA. This option is not available in California.

[54] Standard 90.1-2007 is defined by the PATH Act of 2015 as "Standard 90.1–2007 of ASHRAE and IESNA (as in effect on the day before the date of the adoption of Standard 90.1–2010 of such Societies).", which includes 90.1-2007 and the Addenda Supplement Package (Addenda a, b, c, g, h, i, j, k, l, m, n, p, q, s, t, u, w, y, ad, and aw) and Addendum r, plus all published errata.

[55] https://www.energy.gov/sites/default/files/2016/09/f33/Energy%20Savings%20and%20Modeling%20and%20Inspection%20Guidelines%20NREL%202016.pdf

[56] Announcement 2023-1 (irs.gov)

[57] https://www.energy.gov/sites/default/files/2016/06/f32/179D%20FederalTaxDeduction%20QualifiedSoftware_2016v2.pdf

[58] https://www.energy.gov/eere/buildings/qualified-software-calculating-commercial-building-tax-deductions

Requirements of each path are intended to result in a design that is at least 15% more energy efficient than required by the applicable energy code. With each path, buildings must also meet certain mandatory requirements and compliance must be verified in the field by an approved Rater.

The modeling requirements of the ASHRAE Path are based on 90.1 PRM supplemented by the ENERGY STAR ®Multifamily New Construction Simulation Guidelines. Depending on the stringency of the applicable local code, either 90.1 2010 or 2016 edition of Appendix G must be used[59], and there are the versions of the Simulation Guidelines for projects using 90.1 2016 Appendix G[60] and 2010 Appendix G[61].

Modeling and site work must be completed by an Energy Rating Company that has signed a Partnership Agreement with the EPA acknowledging their roles and responsibilities in providing the energy analysis and/or on-site inspections and testing. The Energy Rating Companies must have a certified Rater, an approved inspector, and/or functional testing agent on staff, as applicable to the Energy Rating Company's role. The approved providers are listed on the Energy Rating Companies page, and there is also directories of the approved Functional Testing Agents and the HVAC Credentialed Contractors. For the ASHRAE Path, energy modelers must complete the ENERGY STAR MFNC online orientation and be listed in the EPA ASHRAE Modeler Directory[62]. Modeler qualifications are not required on projects in California that use Title 24 compliant software.

In 2017, EPA began phasing out its internal submittal reviews and now requires that all projects following the ASHRAE or prescriptive path are reviewed by a recognized Multifamily Review Organization (MRO). The MROs' roles and responsibilities were developed based on the requirements of similar oversight models used by the ENERGY STAR program for single-family and low-rise multifamily homes adapted for the specific needs of the Multifamily Program. The program applicant must select one of the MROs that will review the submittals on behalf of the EPA at an agreed-upon market-based fee[63]. There are currently four MRO companies.

In order to perform project reviews, a professional must be employed by an MRO and approved by the EPA. In order to be approved, the candidate must submit an independently completed review of an actual project to the EPA and have the EPA verify that the review meets its standards. In addition, EPA performs quality assurance reviews of a randomly selected sample of projects approved by each MRO.

Multifamily projects that follow either the ASHRAE Path or Prescriptive Path are listed on the EPA website[64]. According to the EPA program staff, 370 projects were certified using the ASHRAE Path and 11 projects (3%) were certified using the prescriptive path since program inception. 24 projects received the label in 2021.

LEED

The Leadership in Energy and Environmental Design (LEED®) is an international certification program that was created in 1994 by the U.S. Green Building Council (USGBC) with the goal to encourage

[59] https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/multifamily_ashrae_national_page

[60] https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_MFNC_Simulation_Guidelines_AppG2016_Version_1_Rev02_v2.pdf

[61] NERGY STAR MFNC Simulation Guidelines - October 2020

[62] Multifamily New Construction Certification Process | ENERGY STAR

[63] Multifamily Review Organizations (MROs) | ENERGY STAR

[64] https://www.energystar.gov/partner_resources/residential_new/program_reqs/mfhr/certified_units

sustainable practices in building design and construction. The current version, LEED v4.1, was rolled out in January 2019 and includes Building Design + Construction (BD+C), Interior Design + Construction (ID+C), Operations + Maintenance, Residential, and Cities and Communities tracks. Residential, BD+C, and ID+C tracks have modeling-based whole building performance options for meeting the prerequisites and earning points towards LEED certification[65].

The modeling requirements are described in the rating systems' Reference Guides. Commercial and multifamily projects in the scope of 90.1 may demonstrate the minimum compliance using either 90.1 2016 ECB or PRM. Only the PRM is allowed for demonstrating performance beyond the required minimum. The PRM rules are kept largely intact with a few exceptions. For example, there are special rules for projects connected to district cooling or heating plants, and compliance is determined using both the energy cost and greenhouse gas emissions metrics.

LEED v4.1 allows using either the DOE/PNNL Compliance Form or internally developed LEED v4.1 Minimum Energy Performance Calculator for reporting. Simulation tool requirements are aligned with ASHRAE 90.1 Appendix G. There are no minimum qualifications for energy modelers. Submittal reviews are conducted by USGBC staff and contractors. Reviewers undergo a rigorous internal training and apprenticeship before performing reviews independently.

According to the LEED project directory[66], there are over 7,300 certified projects across LEED v4 and v4.1 BD+C and ID+C in US, and approximately 18,000 projects that have registered but are not yet certified excluding single-family homes. 370 commercial and multifamily projects achieved different levels of LEED NC certification in 2021.

LEED fees include a $1.2k-$1.5k registration fee, $4k-$5k precertification fee, and a certification review fee of $0.030/sf - $0.073/sf depending on building gross floor area bracket, with a higher per square foot fees for smaller buildings. The minimum certification review fee ranges from $2,850 for building less than 250,000 square feet to $27,500 for buildings over 500,000 square feet. The fees are higher for non-USGBC members. There is an additional $10,000 fee for expedited reviews and separate fees for appeals.[67]

ASHRAE bEQ As-Designed

The ASHRAE Building Energy Quotient (bEQ) includes two different types of evaluations. bEQ In Operation is based on comparing the actual metered energy use of a building to its peers. bEQ As Designed evaluates building energy use based on its physical characteristics and systems and requires energy modeling to determine the bEQ As-Designed score. In order for the building to receive the final approval, a qualified professional must perform site inspections to verify as-built conditions. bEQ As Designed may be used for both new and existing buildings.[68]

Until recently, the bEQ score was based on comparing a modeled source energy use index of the candidate building at the standard conditions to a median EUI source energy usage index determined

[65] LEED v4.1 (usgbc.org)
[66] LEED project profiles | U.S. Green Building Council (usgbc.org)
[67] https://www.usgbc.org/tools/leed-certification/fees

based on the Commercial Building Energy Consumption Survey (CBECS)[69]. In April 2022, the methodology was changed to align with the 90.1 2016 Appendix G, except the simulation results must be expressed in units of source energy with the prescribed site-to-source conversion factors instead of energy cost. There is no list of approved BEM tools, thus any tool compliant with the PRM requirements may be used.

The reporting is done through the ASHRAE bEQ Online Portal which accepts the key building characteristics, summary of the model inputs and simulation results from the BEM tool. The bEQ As-Designed score is determined based on the simulation results and includes normalizing unregulated energy use to align the baseline building with CBECS 2003. Projects must also submit simulation reports that may be reviewed if needed.

Projects must be submitted by a practitioner registered with the bEQ portal and who either holds an ASHRAE Building Energy Modeling Professional (BEMP) certification or is a professional engineer licensed in the jurisdiction where the building is located. There is a one-time credential verification fee of $15 - $25 except for professionals holding BEMP certification.

The submittals are reviewed by ASHRAE staff with the focus on completeness and out of range values. The review does not typically include checking the simulation details, as the program relies on the professionalism of the credentialed user for ensuring that the modeling rules are implemented correctly and that the model reflects the actual design parameters. There is no fee for submitting a project via the Portal, but there is a fee for generating some of the reports.

Passive House Institute[70]

The Passive House Institute (PHI) was founded in 1996 in Germany and is an independent testing and certification provider for buildings and building components such as windows, doors and ventilation systems. PHI also offers professional certifications including Certified Passive House Designer and Certified Passive House Tradesperson. There are over 5000 certified designers globally, and PHI recommends engaging a certified professional on every project.

According to the Passive House Database[71], there are 5,173 pre-certified or fully certified projects including 591 multifamily or apartment projects and approximately 800 nonresidential projects. The remaining projects are single-family. There are 71 certified and 135 registered projects in the US, mostly single-family homes. Certification options for new construction projects include Certified Passive House at Classic, Plus, and Premium levels and PHI Low Energy Building. In addition, there is EnerPHit Certified Retrofit program targeting existing buildings.

All projects must use the Passive House Planning Package (PHPP), which is an Excel-based BEM tool that must be purchased from PHI. The technical requirements are included in the Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standards[72]. The five key measures emphasized by the certification include Passive House windows, thermal insulation, mitigation of thermal bridging and including an adequate ventilation strategy. The certification criteria include limits on heating and cooling

[69] CBECS – Commercial Building Energy Consumption Survey

[71] Passive House Buildings (passivehouse-database.org)

[72] https://passiv.de/downloads/03_building_criteria_en.pdf

demand as well as the whole building site energy consumption normalized by building area. Projects must also meet a variety of mandatory requirements such as meeting the envelope air leakage allowances. Certified Passive House Plus and Premium tracks also have on-site renewable energy requirements.

In addition to using PHPP, projects must submit documentation with the construction details to demonstrate program requirements have been met, site inspection reports and progress photographs.

Certifications may be issued by the Passive House Institute itself or by accredited Passive House Certifiers[73]. PHI has approved certifiers throughout the world who can review and certify passive house projects. The accredited certifiers are listed at the PHI website and must have the following qualifications[74]:

- Participation in at least three certified Passive House/EnerPHit projects. Preference is given to candidates who have worked on at least one nonresidential project.
- PHPP knowledge such as PHPP Expert Seal certification which requires passing the PHPP expert exam.
- Passive House Designer/Consultant certification which requires passing an exam.
- Fluency in English or German

The certification fees are negotiated between the Certifier and building owner and typically depend on project size, construction cost, prior Passive House experience of the design team and project schedule. The cost also accounts for a fee that every Certifier pays to the Passive House Institute to cover expenses for the ongoing support and provided resources.

Passive House Institute US (Phius)

Phius was founded in 2003 as a non-profit community housing development organization that designed and built demonstration passive homes for the affordable housing market. In 2007, the organization shifted focus to setting standards for passive-buildings and became a certification institute for new construction projects. Retrofit projects may also participate and, with a few exceptions, must meet the same performance criteria as the new construction projects. Even though Phius is based in North America, its standard is designed to be globally applicable.

According to the database of the certified projects[75] there are 803 registered or certified projects. 681 of these projects are in US, 302 are single-family residential and 291 are multifamily. Participating non-residential buildings are usually small – for example, the largest of the 10 certified office buildings is less than 18,000 square feet. 63 U.S. projects have registered or received certification for Phius CORE 2021, Phius CORE Prescriptive 2021, Phius CORE Revive 2021 and Phius ZERO 2021.

There is both a prescriptive and performance path to certification. Modeling requirements for the performance path are included in the Passive Building Standard Certification Guidebook and involve creating a model reflecting specified components with prescribed operating conditions such as plug loads and schedules. The performance targets include limits on heating and cooling energy use and the

[73] https://passiv.de/downloads/03_building_certification_guide_2021.pdf
[74] https://cms.passivehouse.com/en/training/certificates/building-certifier/
[75] https://www.phius.org/certified-project-database

annual whole building source energy use normalized by floor area. Different performance targets are set for residential versus nonresidential buildings and may be further adjusted depending on specific project characteristics. Projects must also meet mandatory requirements such as the air leakage allowance.

Certification requires on-site inspection and testing which must be performed by either a PHIUS Certified Rater or PHIUS Certified Verifier. Projects must also obtain ENERGY STAR certification based on post-occupancy energy use, if eligible.

Energy modeling must be completed using WUFI® Passive BEM tool developed by Fraunhofer IBP in Partnership with PHIUS and Owens Corning. Reporting requirements include providing the WUFI® Passive energy model and a PHIUS Certification Quality Assurance Workbook. The modeling must be performed by a PHIUS Certified Consultant (CPHC®). PHIUS offers professional certifications including CPHC®, PHIUS Certified Builder (CPHB), PHIUS Certified Rater, and PHIUS Certified Verifier. Submittals are reviewed in-house by PHIUS staff. Reviews are reported to be rigorous[76].

For the performance path, certification fees are based on the project's floor area and are higher for mixed use projects that require two energy models. For projects over 10,000 square feet the fees range from approximately $4,000 for a small and simple project to $24,000 for a large project with additional fees for expedited reviews.

Federal Energy Management Program (FEMP)

Energy Conservation and Production Act requires DOE to establish building energy efficiency standards for all new Federal buildings. The associated regulations call for commercial and high-rise multifamily federal building designs to achieve energy consumption levels that are at least 30% below the levels set by the most recently adopted version of ASHRAE Standard 90.1. A lower margin of improvement is allowed if meeting the 30% target is not cost effective. Improvement over code must be determined using 90.1 PRM. As of June 2022, 90.1 2019 version of Appendix G must be used.

Each federal agency is individually responsible for implementing the energy efficiency standards for Federal buildings and meeting any applicable statutory and regulatory requirements. Accordingly, Federal agencies are considered their own "authority having jurisdiction," "building official," and/or "code official".

Living Future Challenge

The International Living Future Institute (ILFI) was created in 2009 aiming to become the built environment's most rigorous performance standard. It currently offers certification programs for buildings (Living Building Challenge), products (Living Product Challenge) and Communities (Living Community Challenge). The program offers Living Future Accreditation (LFA) professional credential which recognizes proficiency with the Living Buildings Standard.

The Living Building Challenge, Core Green Building, Zero Carbon, and Zero Energy Certifications are performance-based, whole building design and construction standards. In 2021, over 100 projects in 18 countries (including 57% in U.S), accounting for over 11 million square feet, have registered for one of these certifications, which represents 87% growth compared to 2020. 57% of these projects were in US.

[76] Based on authors' communications with energy modelers active in the program.

Zero Carbon and Zero Energy certifications account for over half of the registered gross building floor area[77,78].

The Living Building Challenge (LBC)[79] defines seven performance categories, or "Petals": Place, Water, Energy, Health + Happiness, Materials, Equity and Beauty. Core Green Building, Living Building Challenge Petal, and Living Building Challenge Living Certifications all require meeting a set level of compliance for each of the Petals. The Zero Energy Certification standard focuses exclusively on energy. Zero Carbon (ZC) Certification addresses both operational and embodied carbon. With all programs, the final certification is based on measured energy performance rather than predicted outcomes, recognizing buildings that operate efficiently, phase out combustion, and use renewable energy. Projects must be operational for at least twelve consecutive months prior to audit to verify compliance.

The Core Imperative of the Energy Petal requires achieving a set reduction in energy use (70% for new buildings, 50% for existing buildings, 35% for building interiors) relative to a baseline established using Zero Tool, World Bank EDGE or another approved method. Projects must also meter energy that they use, which is the basis for final certification. New and existing buildings must additionally demonstrate a 20% reduction in the embodied carbon or primary materials compared to an equivalent baseline.

Zero Energy and Zero Carbon Certifications are awarded through a two-part process consisting of an audit upon completion of construction to verify that the intended systems are installed and a final audit after a 12-month performance period including performance-based verification to ensure that intended outcomes are achieved. The certification documentation emphasizes synergy between Zero Energy and Zero Carbon certification and PHI and Phius. The 2022 certification fees vary depending on the program and size of the building. ZE and ZC certifications fees varies from $3,750 for buildings less than 75,000 SF to over $20,000 ($0.035/SF) for buildings over 500,000 SF. Core certification fees vary from the minimum of $7,000 for buildings less than 75,000 SF to 0.07/SF for buildings over 500,000 SF. Fees for the Living Building Certification range from the minimum of $10,000 to $0.11/SF for buildings over 500,000SF.

Architecture 2030 Challenge

The Architecture 2030 is a non-profit research organization established in 2002. It's Architecture 2030 Challenge was adopted by the American Institute of Architects (AIA) in 2006 and forms the basis of the AIA's 2030 Commitment[80]. 73% of the 20 largest Architecture / Engineering (A/E) firms, responsible for over $100 billion in construction annually, have now adopted and are implementing the 2030 Challenge. According to a recent poll of design industry leaders by the Design Futures Council, approximately 40% of all U.S. architecture firms have adopted the Challenge.

The Architecture 2030 Challenge calls for all new and major renovation projects to be carbon neutral by 2030, with intermediate targets of 80% reduction in carbon emissions by 2020 and 90% by 2025. In 2007 the AIA, ASHRAE, Architecture 2030, the Illuminating Engineering Society of North America (IESNA), and the U.S. Green Building Council (USGBC), supported by representatives of the U.S. Department of Energy, agreed to define the baseline starting point for their common target goals as the

[77] 2021 Project Registration Recap | Trim Tab (living-future.org)
[78] ILFI Public Project Registrations Map 2021 | Tableau Public
[79] Zero Energy Standard 1.0 International Living Future Institute February 2021
[80] FAQs – Architecture 2030

national average/median site energy consumption of existing U.S. commercial buildings as reported by the 2003 Commercial Building Energy Consumption Survey (CBECS)[81].

These targets may be met by implementing innovative sustainable design strategies, generating on-site renewable energy, and/or purchasing off-site renewable energy[82]. There is a 20% cap on contribution of purchased off-site renewable energy toward compliance. The 2030 Challenge requires the following steps:

- Establish an EUI baseline and set the target using the Zero Tool[83].
- Apply low/no cost passive design strategies to achieve maximum energy efficiency.
- Integrate energy efficient technology and systems.
- Incorporate on-site and/or off-site renewable energy to meet the remaining energy demands.
- Performs iterative energy modeling throughout the entire design process to understand the interactive effects of various design decisions and to assess progress towards meeting the EUI target.

There are no rules for estimating building energy use, but energy modeling is encouraged. The program references the IBPSA-USA Building Energy Software Tools (BEST) directory for the software that may be used[84]. Projects participating in 2030 Challenge use a web-based portal for reporting[85]. Out of 22,002 projects that were reported by the participating architecture firms in 2020 and included in the 2020 Summary of the AIA 2030 Commitment report, which is the most recent available, whole building energy modeling was used on 53% of projects that accounted for 77% of the reported project floor area.[86]

Green Globes

Green Globes for Existing Buildings was developed in 2000 by the ECD Energy and Environmental Canada. Green Globes for New Buildings Canada followed shortly thereafter, with the support of the Canadian Department of National Defense and Public Works and Government Services. In 2004, the system was adapted for the US. The Green Globes brand and associated rating systems are administered in the US by Green Building Initiative (GBI) [87] which is a nonprofit organization accredited by the American National Standards Institute (ANSI).

Green Globe certification has New Construction, Core & Shell, Sustainable Interiors (does not require energy modeling), Existing Buildings (does not require energy modeling), Multifamily New Construction and Multifamily Existing Building tracks. Projects may earn points in several areas including Project Management, Site, Energy, Water, Material & Resources, Emissions and Indoor Environment. There are

[81] CBECS data is a set of whole-building energy use measurements gathered by the DOE's Energy Information Administration, which can be used to determine a national energy use intensity using kBtu/sq. ft.-yr as the metric. ENERGY STAR is planning on changing the baseline to CBECS 2012.
[82] The 2030 Challenge – Architecture 2030
[83] Zero Tool
[84] https://www.buildingenergysoftwaretools.com/
[85] https://2030ddx.aia.org/account/login
[86] 2030 by the Numbers, The 2020 Summary of the AIA 2030 Commitment
[87] http://www.greenglobes.com/about.asp#history

four certification levels from one to four Globes. To become Green Globes certified, each project must achieve a minimum of 35% of the total applicable points.

Based on the Green Globes Technical Reference Manual[88], the New Construction track requires completion of the Green Globes NC survey, Stage I Design Review and a Stage II On-site Assessment. The Stage I Design Review involves an assigned third-party Green Globes Assessor reviewing the design document and developing a Design Review report that lists the verified points, points that need further verification, a preliminary score, projected rating, and recommendations for the project. GBI reviews the report and issues it to the client along with a preliminary rating.

To be eligible for the final rating, the Stage I Design Review must be followed by the post-construction Stage II On-site Assessment. Whenever possible, GBI assigns the same assessor for both the Stage I Design Review and Stage II On-site Assessment. The duration of the site visit varies depending on the project scope and size. After the visit, the assessor documents findings in a report and recommends the Green Globes score and rating. GBI reviews the report and issues it to the project along with the final rating.

Third-party Green Globes Assessors are licensed professionals, generally with more than 10 years of applicable industry experience, who have successfully completed GBI's Green Globes Assessor Training Program[89]. Once certified, Green Globes Assessors are authorized to perform Green Globes and Guiding Principles Compliance assessments for GBI as independent contractors. GBI assigns Green Globes Assessors to projects, however the assessor decisions and recommendations are not revised or redirected by GBI to ensure their autonomy and third-party status.

Green Globes Energy category accounts for 390 out of 1000 points, including 100 points for energy performance. There are four energy performance options for documenting compliance that all require energy modeling:

- Path A: ENERGY STAR® Target Finder (100 points)
- Path B: ASHRAE 90.1-2010, Appendix G (100 points)
- Path C: ANSI/GBI 01-2010 Energy Performance Building Carbon Dioxide Equivalent (CO2e) Emissions (100 points, plus 50 bonus points)
- Path D: ASHRAE Building Energy Quotient (bEQ) (100 points, plus 25 bonus points)

For Paths A, C, and D, energy modeling results are entered into ENERGY STAR Target Finder or bEQ tool to determine compliance.

Based on the GBI directory[90], 1190 new construction projects received different levels of Green Globes certification in US since 2006, including 205 projects in 2021. In 2022, the total fees for a new construction projects included $1,500 registration, $4,635 - $15,500 for design review and $4,100 – 15,500 for the final certification depending on project size. In addition, there is a $2,000 assessor travel fee for on-site assessments[91].

[88] GREEN GLOBES FOR NEW CONSTRUCTION (thegbi.org)
[89] Green Building Initiative : GGA (thegbi.org)
[90] Green Building Initiative : Certified Buildings Directory (thegbi.org)
[91] Green Building Initiative: What It Costs (thegbi.org)

BREEAM

BREEAM is an international suite of validation and certification standards that are owned by BRE, a UK-based company. The BREEAM tracks available in the US include New Construction, Refurbishment & Fit Out (does not require energy modeling) and In-Use (uses a simplified modeling approach). Interim BREEAM rating may be issued based on design documents, but the final rating is based on performance of the building after construction is completed.[i92]

BREEAM for New Construction has 11 credit categories including Energy. The Ene 01 credit awards points for demonstrating improvement in the building energy performance above the minimum required by applicable codes. One of the allowed Ene 01 compliance options for commercial and multifamily buildings is to use energy modeling following 90.1 2013 PRM[93] (CN3.3[94]). The Ene 01 score is based on performance determined using an approved building modeling software and expressed using three metrics including heating and cooling demand, total primary (source) energy and emissions. The simulation results must be entered into BREEAM Ene 01 calculator, which is included in the BREEAM assessment scoring and reporting tool, to determine the number of achieved credits.

There is no list of approved BEM tools. In countries with an existing National Calculation Methodology, the tool(s) approved by such methodology may be used provided that the software can assess building envelope, heating, cooling and ventilation systems, lighting, building orientation, thermal mass effects, natural ventilation, and indoor climatic conditions.

Modeling must be performed by a professional with at least 3 years of relevant experience in building energy modeling within the last 5 years and experience and expertise covering all required technical aspects. The energy models must be submitted to BRE and may be used for quality assurance at the post occupancy stage. The submittal reviews are done by the independent BREEAM Assessors who are trained and licensed by BRE Global. There is a $500 annual assessor licensing fees.

The completed assessments are reviewed by BRE Global which issues a BREEAM certificate.
2022 BREEAM certification fees include $1,430 registration fee plus $3,235 for buildings less than 50,000 SF, $9,240 for buildings over 500,000 SF and $4,865 for projects 50K-500K square feet. Multifamily buildings are charged per dwelling unit, ranging from $5/dwelling for buildings with over 1000 units and $34/dwelling for buildings with 100 or less dwelling units[95].

Out of the approximately 10,800 certificates issued between 2013 and 2017, 83% (just over 9,000) were issued to projects in the UK[96]. Majority of certifications were for new commercial buildings including 2008 schools, 1595 offices, 971 industrial and 870 multifamily buildings.

---

[92] BREEAM USA New construction - BRE Group

[93] BREEAM International New Construction 2016 Technical Manual SD233 2.0

[94] Certain criteria in BREEAM require compliance with specified standards or best practice documents. In countries where there are equivalent local standards, BRE Global staff, with support from assessors and the project team, may review the local standards against BREEAM specified requirements and confirm their equivalence.

[95] FS094-BREEAM-International-Programs-Fee-Sheet-USA.pdf (bregroup.com)

[96] The Digest of BREEAM New Construction and Refurbishment Statistics 2013 to 2017 Volume 2, 2019 Josephine Prior, Matt Holden and Christopher Ward

New Jersey Pay for Performance Program

The New Jersey Pay for Performance New Construction program was introduced in 2009 and offers tiered incentives on a $/ft^2 basis depending on the percent improvement beyond New Jersey energy code projected using energy modeling. A bonus incentive is available for early design energy modeling following ASHRAE Standard 209. After the building is put into operation, additional incentives are awarded to projects for achieving ENERGY STAR® certification based on the actual utility bills. Building types not supported by the ENERGY STAR program may use the ASHRAE bEQ In Operation path.

The original version of the P4P New Construction program was based on 90.1 2007 Appendix G. In 2016 the New Jersey state energy code switched to 90.1 2013 and the program modeling requirements were updated to align with the 90.1 2013 Addendum bm package that largely reflected simulation requirements of 90.1 2016 Appendix G, making the P4P one of the first adopters of the new PRM stable baseline method. Several program versions also allowed ASHRAE bEQ legacy single model approach, but it was rarely used.

Historically, P4P has allowed projects participating in the national modeling-based programs such LEED and IRS Section 179D to use models developed for these programs to qualify for incentives. A mapping was developed to account for differences in the modeling rules followed by these programs compared to 90.1 2016 Appendix G and the P4P simulation guidelines, to ensure that projects that participate in P4P via a proxy program qualify for equivalent incentives as projects following the native P4P rules. The 2023 version of the program is expected to allow PHI, Phius and LEED v4.1 proxy paths and rely on submittal reviews completed by these programs in lieu of internal P4P reviews.

To qualify for incentives, applicants must contract with one of the pre-approved providers referred to as P4P Partners. Responsibilities of P4P Partner firms include performing energy modeling, commissioning, developing the required program documentation and addressing comments made by the P4P program staff. The fee for the services is negotiated between the building owner and the P4P Partner. To become a partner, the firm must have employees who have taken the program orientation and either hold the ASHRAE BEMP certification or have completed at least five energy models.

The submittal requirements include the DOE/PNNL Compliance Form, the P4P tool, modeling files, simulation reports and equipment cutsheets. The P4P tool is largely populated by importing data from the DOE/PNNL Compliance Form and is used to calculate project incentives and energy savings by fuel relative to 90.1 2016, which is the current NJ state code. After construction is completed, a commissioning report must be submitted to confirm that all measures have been installed and that equipment and systems are operating as intended.

Building energy modeling software must comply with the PRM requirements and be pre-approved by the program. Submittal review is conducted by the members of P4P program implementation team. The lead reviewers have BEMP certification and modeling experience. The program staff also performs post installation inspections. Over 200 new construction projects qualified for P4P incentives since 2010, including 31 projects in 2020-2021.

NYSERDA New Construction Programs[97]

The NYSERDA New Construction Programs for commercial and multifamily buildings includes several compliance options all of which require whole building energy simulation. Around 70 commercial and 330 housing projects participate in the program annually.

The Commercial New Construction program requires using 90.1 2016 PRM. The New Construction – Housing program relies on third party certification standards including EPA ENERGY STAR Multifamily New Construction Program, Passive House Institute (PHI) and Phius. Projects following the ENERGY STAR path must perform modeling following 90.1 2016 PRM, and have submittals reviewed by an EPA-approved Multifamily Review Organization (MRO). Since the NYSERDA program has some additional requirements compared to the ENERGY STAR® program, the MROs approved to perform NYSERDA reviews are trained to check for the additional items. All projects that use 90.1 2016 PRM must submit the DOE/PNNL 90.1 Compliance Form.

California Energy Design Assistance[98]

California Energy Design Assistance (CEDA) was launched in late 2021 and serves mid and high-rise multifamily, agricultural, industrial, commercial, and public new construction and major renovation projects in the service territories of California's investor-owned utilities (PG&E, SCE, SCG, SDG&E). The program is designed to encourage electrification and energy efficiency beyond the standard practice. 140 projects have enrolled in the program in the first 12 months, with the target participation goal of 200 projects a year going forward.

Modeling rules involve comparing the proposed design to the California Public Utility Commission's (CPUC) Standard Practice Baseline which is based on the CA Title 24 adjusted to account for the standard practice for that building type, region, and client absent a CPUC energy efficiency program.

The allowed BEM tools must have engines that are approved by the CPUC and must meet the minimum modeling capabilities and reporting requirements. There is no requirement to automatically generate the baseline design since the baseline is not uniform across all building types and differs depending on building type, developer and location. Standard 140 testing is required except for the BEM tools used on industrial and agricultural projects where energy use is driven by process applications. BEM tools using DOE2.3, IESVE, and EnergyPlus engines are allowed. Other tools are considered on a case-by-case basis.

Modeling may be done by a CEDA implementation team at no cost to participant or 3rd party professionals hired by the participant. In that case, participants receive a flat rate modeling stipend. When modeling is provided by the program implementer, either the modeler or reviewer or both have the Certified Energy Analyst designation. When modeling is completed by a 3rd party consultant, the following qualifications are required:

- Professional Credentials: The energy model shall be performed by or under direct supervision of a licensed Professional Engineer (PE), or Certified Energy Analyst (CEA) as defined by the California Association of Building Energy Consultants (CABEC) or other documented qualification for modeling experience.
- Previous Project Experience: Experience on three (3) or more projects of similar type in the California within the past 5 years.

[97] Presentation by Gwen McLaughlin and Pat Fitzgerald (NYSERDA) at the 5/11/2022 DOE/PNNL Performance-Based Compliance Research Project webinar.

[98] https://ceda.willdan.com/ and information provided by Christopher Baker

- Third Party Validation: The CEDA Energy Consultant must provide an example of an energy analysis report completed within the past 5 years that has been submitted to a 3rd party for review. Acceptable third parties include but are not limited to LEED® and other or previous utility rebate programs.

Modeling-based submittals are reviewed by the program implementer staff, PG&E Technical Reviewer, and CPUC. Projects are reviewed at multiple points during project development and prior to delivery to CPUC. The review includes checks to verify building geometry, system design and inputs, and results. In addition, reviews confirm that CPUC policy, project regulations, contract provisions and program procedures have all been followed.

Austin Energy Green Building

Austin Energy Green Building (AEGB)[99] is a green building rating program established in the 1990's and administered by Austin Energy, a municipal utility. Approximately 80% of the projects participating in the AEGB programs have development agreements that require either the AEGB or LEED rating. The AEGB Commercial and Multifamily Ratings offer a prescriptive path and an energy modeling path, but many buildings use energy modeling because they either don't meet the prescriptive requirements (usually due to high glazing area or lack of continuous insulation) or look to achieve a higher rating by earning energy performance points.

In 2021, Austin adopted the 2021 IECC with local amendments which allows using 90.1-2019 Appendix G. At that time, the AEGB was updated to require 90.1 2019 Appendix G modeling for commercial projects and multifamily projects greater than 4 stories, while multifamily projects 4 stories or less follow the 2021 IECC Section R405 Standard Reference Design (SRD). Before the rating is awarded (and prior to Certificate of Occupancy for projects with AEGB in the zoning requirement) Austin Energy staff review model submissions for compliance with Appendix G or SRD rules and verify that the modeled systems and components align with the construction documents. There are typically 2-3 review iterations before a project is approved in the design phase and 1-2 reviews in the construction phase. The program allows using any simulation tools compliant with 90.1. Out of 154 current and recently approved projects, 42% were modeled in Trace 700, 21% in eQuest, 18% in Carrier HAP, 11% in IES-VE, 4% in OpenStudio, 3% in Trace 3D Plus and 1% in EnergyPlus. In the 2022 fiscal year, 81 projects were approved.

In 2017, AEGB launched an elective incentive program to incorporate energy modeling early in the design process through post-occupancy verification. The Integrated Modeling Incentive (IMI)[100] program was based on 90.1-2013 and utilized the DOE NREL developed Energy Design Assistance (EDA) framework[101] including the Energy Design Assistance Project Tracker (EDAPT) which facilitated automated model input and output checks and centralized online project tracking[102]. The automated checks included unmet load hours, energy use intensity outside of expected values, and others. Austin Energy offered training to participants on using EDAPT and OpenStudio, which was the only allowed modeling tool and that most local modelers had no prior experience with. The complex program had many challenges. The program requirement to model multiple design alternatives delayed project approval and increased review and modeling effort. The incentives were set based on summer peak

[99] Austin Energy Green Building
[100] Integrated Modeling Incentive (austinenergy.com)
[101] Microsoft Word - EDA Program Manual 2018.docx (eda-pt.org)
[102] Welcome to EDAPT | Energy Design Assistance Program Tracker (eda-pt.org)

demand that was verified after full occupancy by comparing metered to modeled demand normalized for difference in weather which required considerable analysis and verification effort and delayed payments to the owner. Design teams did not receive any payments from the program directly. While the program was attractive to the participating owner-occupied and multifamily affordable housing developments, improvements to the incentive structure and program requirements were needed to grow participation. The program was closed to new applications in 2020.

Appendix D: Certifying Body Precedents

This section provides an overview of US national certification programs. The information reflects the state of each program as of summer 2022 unless noted otherwise.

COMNET

The Commercial Energy Services Network (COMNET) was formed in 2010 as a commercial-sector equivalent of the RESNET®, with the goal of becoming the industry standard for providing technically credible and reliable procedures for evaluating the energy performance of nonresidential and high-rise residential buildings[103]. The procedures were to be used for documenting compliance with building energy codes, in green building ratings such as ENERGY STAR Target Finder™ and ASHRAE bEQ As Designed, and in government and utility programs. COMNET aimed to build consensus among software developers, rating authorities, and energy modelers, and through this process, develop and maintain a quality assurance program consisting of the following elements:

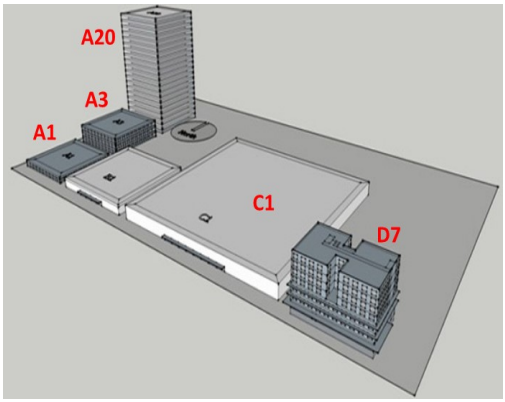
- Modeling guidelines and procedures (MGP) for accreditation of BEM software including a detailed specification for energy analysis and requirements for automated generation of baseline building and standard output reports.
- Ongoing review and quality assurance of accredited energy modeling software.
- Updates and enhancements to the accreditation requirements and software re-accreditation.
- A portal through which all the accredited energy analysis would pass, to facilitate the basic automated quality assurance checks of every project and allow selecting a subset of projects for detailed quality assurance.
- Official interpretations on how the MGP specification applies to specific projects.
- Periodic internal quality audits to evaluate compliance with the COMNET procedures and the effectiveness of current processes, per ISO 9000.
- Credentialing and/or training of energy modelers.

BEM tool testing requirements included the following:

- ASHRAE Standard 140-2007 physics and sensitivity tests with the acceptance ranges based on the reference results from BLAST, TRNSYS, DOE2 and EnergyPlus at 99% confidence interval. The confidence interval was chosen because a narrower interval (e.g., 95% or 90%) did not cover the range of reference results. Acceptance ranges for some tests were further adjusted to include the maximum and minimum reference result with +/- 5% margin of the range.

- Twenty ruleset tests for 90.1 PRM based on the DOE/PNNL prototype models including small, medium and large office buildings, retail, supermarket, manufacturing facility, warehouse and a mixed-use retail/office/multifamily building in Chicago, Denver and Miami (Figure 1). Prior to adopting a self-certification process, the ruleset testing required by Florida Energy Code was based on COMNET with some modifications and included 16 test cases in two climate zones.

[103] Baker et al (2014). *Automating Energy Modeling, In Principal and In Practice* [Published by the American Council for an Energy-Efficient Economy]. Retrieved from https://aceee.org/files/proceedings/2014/data/papers/3-628.pdf.



Format	Building Type	Number of Floors	Total Floor Size, ft²
A1	Office	1	22,500
A3	Office	3	67,500
A20	Office	20	450,000
B1	Retail, Supermarket	1	40,000
C1	Manufacturing, Warehouse	1	160,000
D7	Mixed use Retail/Office/Multifamily	7	179,400

Figure 1: COMNET Ruleset Tests Building Typologies

COMNET described software accreditation requirements but not the process of obtaining the certification. It did not itself accredit any tools and no other organization stepped in to implement COMNET vision nationally.

The MGP was published in 2010 and was based on the ASHRAE Standard 90.1 2007 PRM. The versions covering other editions of the PRM including 90.1-2001, 2007, 2010, and 2016 were also published[104]. In 2012, the COMNET Energy Modeling Portal was launched to allow design teams to directly upload building energy modeling information to LEED Online. The portal supported importing from eQUEST output reports (.sim files). In addition, the COMNET XML schema was developed and implemented by Trane TRACE™ 700 and EnergyPro v5.1. The goal was for the portal to streamline LEED documentation for design teams, provide basic quality assurance features to reduce errors in LEED submittals, and generate revenue to support continued COMNET development.

However, the initiative did not generate enough industry support and the funding dwindled. The COMNET Portal was discontinued. The MPG formed the basis of the PNNL's Performance Rating Method Reference Manual[105].

RESNET Home Energy Rating System (HERS)

The Residential Energy Services Network (RESNET®) Home Energy Rating System (HERS) Standard is a modeling-based protocol widely used in the U.S. to evaluate the performance of single-family homes and low-rise multifamily buildings. It has been recognized by major rating authorities and agencies, including ENERGY STAR, the U.S. Green Building Council, utility energy efficiency programs, and by the Internal Revenue Service and the U.S. Department of Energy as a basis for tax credits for residential energy efficiency. In 2015, the RESNET® Standard became the foundation of the Energy Rating Index (ERI), which is an energy code compliance option in over a dozen states and is included in the 2015, 2018, and 2021 versions of International Energy Conservation Code.

The program was conceived in the early 1980s, when a group of mortgage industry stakeholders sought to establish the financial merit of the energy efficiency of a home in a mortgage loan. The RESNET® HERS

[104] https://www.comnet.org/modeling-guidelines

[105] Goel, Supriya, Rosenberg, Michael I., & Eley, Charles. *ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual*. United States: N.p., 2017. doi:10.2172/1398228. Retrieved from https://www.osti.gov/biblio/1398228-ansi-ashrae-ies-standard-performance-rating-method-reference-manual.

Index[106] is determined following ANSI/RESNET/ICC Standard 301, Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using an Energy Rating Index. The modeling methodology is based on relative performance of two models. HERS is governed by the RESNET® Mortgage Industry National Home Energy Rating System Standards,[107] which cover a broad range of quality assurance and quality control topics including BEM tool capabilities, testing and accreditation process, HERS rater training and certification and quality assurance.

The RESNET® software accreditation requirements are covered in the Procedures for Verification of RESNET® Accredited HERS Software Tools. The following tests are required:

- Physics and Sensitivity tests including the following:
  - Standard 140-2011 Class II Tier 1 tests with the base cases representative of the residential homes targeted by RESNET® HERS (Figure 2)
  - Additional tests for HVAC (for furnaces, air conditioners, and air source heat pumps), duct distribution system efficiency, and hot water system performance. The tests are based on Standard 140 base cases with the additional details provided in the RESNET publication.

  The acceptance criteria for all physics and sensitivity tests are set based on the results of multiple tools with 90% confidence interval.[108] The duct distribution system efficiency tests have acceptance ranges based on ASHRAE Standard 152 calculation.
- Four ruleset tests representing common single-family home designs in different climates with crawlspace or basement foundations, attic, furnace or heat pump heating of varying efficiency, varying number of bedrooms, mechanical ventilation strategies, and home appliances. The software must generate a Reference Home model for each test case and report its configuration.

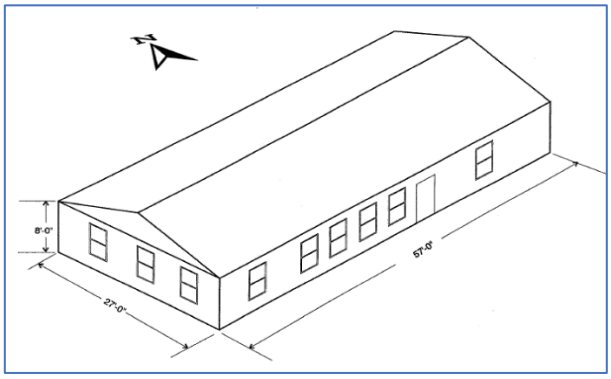


Figure 2: RESNET HERS Std 140 Base Case

- HERS method test to confirm that the HERS Index is calculated correctly based on the modeling results.

[106] https://www.hersindex.com/hers-index/what-is-the-hers-index/

[107] *RESNET Standards - Continuous Maintenance Version.* Residential Energy Services Network. Accessed August 2019. Retrieved from https://standards.resnet.us/index.htm#t=minhers_adv%2FHome%2FHome.htm.

[108] Home Energy Rating System Building Energy Simulation Test (HERS BESTEST): Volume 1; Tier 1 and Tier 2 Tests; User•s Manual (nrel.gov)

In addition to modeling capabilities and testing requirements, all approved BEM tools must generate a report using the RESNET® National Registry XML format. Data files for each project are uploaded into a central database to enable project tracking and quality assurance. BEM tools must also have a capability to generate quality control flags to alert modelers and reviewers when certain simulation inputs or outputs are outside of the expected ranges. User inputs subject to such flags include the general building attributes (e.g., floor and wall areas, ceiling height, number of stories) and inputs related to mechanical ventilation and appliances. All tools are required to use hourly calculations after January 2021. REM/Rate, Ekotrope, and EnergyGauge are currently accredited.

Each project must engage with an accredited Rater. Raters must complete a training course from a RESNET® Accredited Training Provider and pass the national HERS Rater Tests, Combustion Appliance Simulation Tests, and Rater Simulation Practical Test. In addition, they must complete five probationary ratings with a Rating Quality Assurance Provider overseen by a RESNET® certified Candidate Field Assessor.

RESNET® certified Quality Assurance Designees perform file review of a minimum of 10% of all HERS rater modeling files and conduct in-person field review of 1% of all rated homes. In addition, RESNET® staff conducts an annual review of all quality assurance reports and inspects a minimum of 25% of accredited Rating Quality Assurance Providers' files. In 2015, over 20,000 HERS rated homes received quality assurance oversight.

RESNET maintains a network of RESNET Accredited Providers that administer professional certifications such as Home Energy Rater, HERS Modeler and Rating Field Inspector, and establish and collect fees from professionals for their services. There are 163 RESNET Accredited Providers in the US including HERS Software Tools, Rating Providers, Rating Sampling Providers, Rater Training Providers, Energy Smart Contractor Education and Qualification Providers, and Approved WaterSense Providers. Each provider company pays RESNET an annual fee of $1,750 and is offered additional services such as the RESNET HERS Rater company premium directory listing for up to $3,995/year for the national membership across USA[109]. In addition, there is a $7.50 fee for uploading project to the RESNET registry. RESNET had about 4 staff members until 2017 and now has 8 employees and 8 contractors.[110] Its

313,153 homes received HERS rating in 2021, bringing the total number of HERS rated homes in U.S. to over 3.3 million.[111] The majority of the RESNET stated priorities for 2022[112] focus on further increase in recognition of the HERS rating system and standards and growing demand and business opportunities for RESNET professionals, such as positioning HERS Raters as the preferred source for verification of IECC compliance for code officials and builders.

ASHRAE Building Energy Modeling Professional

The ASHRAE Building Energy Modeling Professional (BEMP) certification is an ANSI-Accredited Personnel Certification Program under ISO/IEC 17024 (#1139). It validates competency to model new and existing buildings and systems with the full range of physics; and evaluate, select, use, calibrate and interpret the

[109] Membership - RESNET
[110] Information provided by Ryan Meres, RESNET Program Director
[111] Number of HERS® Rated Homes in U.S. in 2021 Tops 300,000 Mark - RESNET
[112] RES - 2022 RESNET Mission, Goals and Priorities v5 - Handout

results of energy modeling software as applied to building and systems energy performance and economics. The certification prerequisites include the following components[113]:

1. Education and work experience requirements that may be satisfied by a combination of education, professional licenses, and hands on experience. The available options range from having professional engineer or architect license and 2 years of building energy modeling experience to a High School diploma or equivalent and a minimum of ten years' energy-related HVAC, architecture, lighting, or renewable energy experience, including a minimum of two years' building energy modeling experience.
2. Acceptance of a Code of Ethics
3. Passing the BEMP certification exam which is a closed book, two and a half hours test that includes 115 multiple-choice questions.

The certification requirements were developed based on a job task analysis (JTA) that identified the knowledge, skills and abilities required for safe and effective job performance. Reliance on JTA ensures that the correct competencies are assessed on a certification exam and protects the certifying body in case results are challenged.

The certification fees are $595 for the first attempt, $225 for the first retake and $595 for the second retake, with a discount available to ASHRAE members. There are approximately 500 certified professionals worldwide including under 400 in the US.

Based on input of ASHRAE staff involved in BEMP certification[114], a job task analysis, exam development, and standard setting study (passing score workshop) cost approximately $50,000 - $75,000. This does not include marketing, staffing/application intake and processing, program management and exam hosting and delivery fees. The ANAB accreditation fee in Year 1 is approximately $8,000 - $10,000. The JTA and exam development would take approximately one year.

[113] BEMP CandidateGuidebook.pdf

[114] Information was provided by Tim Kline, ASHRAE's Certification Manager