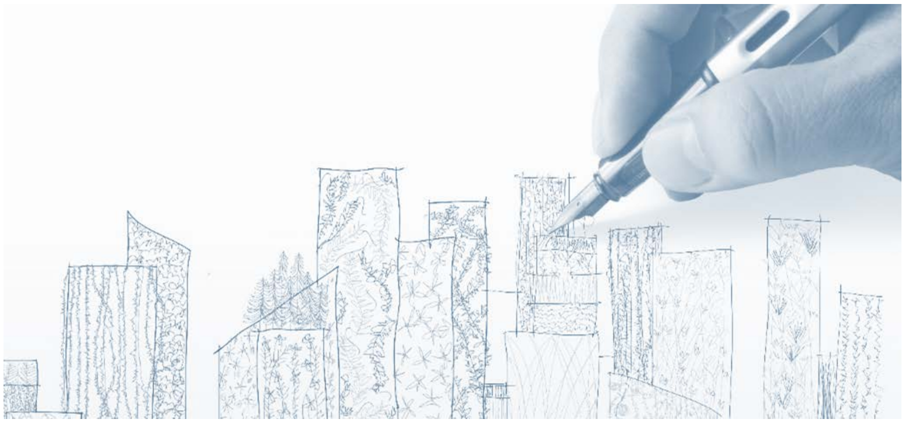
Tackling Energy Codes with Energy Modeling

Preparing Design Professionals to Face Building Performance Demands



Prepared by the Building Codes Assistance Project for the Energy Foundation

About the Building Codes Assistance Project

With over two decades years of experience, BCAP has established itself as a trusted, non-partisan U.S. leader for energy code advocacy, research and analysis, technical support, training, and code status tracking. From its national platform, BCAP facilitates increased communication and collaboration between allies, identifies and navigates past policy and structural pitfalls, and helps state and local decision-makers design strategies to improve building energy efficiency.

About the Energy Foundation

The mission of the Energy Foundation is to promote the transition to a sustainable energy future by advancing energy efficiency and renewable energy.

Over the past two decades, the Energy Foundation has supported and coordinated sophisticated and effective networks of grantees and allies who share our vision of a prosperous and healthy future powered by clean, reliable, and secure sources of energy. Making progress in the largest and fastest-growing energy markets in the world.

The Energy Foundation is pragmatic and nonpartisan, dedicated to finding practical solutions that work in the real world. A primary role is as a grantmaker, supporting groups to build the new energy economy. Programs focus on making the buildings, power, and transportation sectors more efficient, and on advancing effective policies that open big markets for clean energy technology. Grantees include health, labor, environmental, faith, property-rights, clean-energy, and consumer groups, as well as think tanks, universities, and military organizations.

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Executive Summary

Design professionals, especially architects, are increasingly being asked to incorporate another consideration into their buildings: energy efficiency. This idea of doing more while consuming less has gained a solid foothold in the minds of clients, policymakers, and other stakeholders. Model energy codes, such as ASHRAE Standard 90.1 and the International Energy Conservation Code (IECC), have been integral in reducing building-related energy use over the past few decades. As codes become more rigorous, however, it is clear that a shift must take place within the design industry. Prescriptive energy codes, essentially checklists of components meeting certain efficiency requirements, have been taken nearly as far as they can go. It is now time to shift to performance-based codes, where a building is considered as a single system rather than as a collection of discrete parts.

The performance path requires that the design team use energy modeling to demonstrate compliance, a process that generally takes place right before construction begins. Some newer modeling software specializes in early iterative modeling, i.e. before code compliance considerations, when design changes can have the largest impact on the eventual energy efficiency of the finished product with the lowest cost. But to create buildings that take advantage of advances in energy modeling software, architects and other professionals will need to integrate energy predictions through every phase of design.

The majority of design teams nationwide are not currently using energy modeling to show code compliance, but even fewer are using this valuable tool to make decisions during the earliest phases of projects. To reach the full potential of building energy usage reductions – towards AIA's 2030 goals and for the sake of mitigating climate change and lowering operating costs over the lifetime of the building – we need a workforce of architects who understand how to leverage building energy modeling during each phase of early design and why this is such a key tactic.

This paper intends to map the existing landscape of building energy codes and modeling software, highlighting current best practices and identifying steps for removing barriers.

In addition to explaining the challenges and opportunities that face designers, this paper also contains the results of a survey conducted by BCAP during the spring of 2015. In brief, this survey asked design professionals about their demographics, their current usage of energy modeling with regard to code compliance, and how they thought it would be best to move forward.

Other highlights:

- In a 2011 American Institute of Architects Codes and Standards member survey, 74% of respondents agreed with the statement that "licensed professionals should prepare to practice under enhanced codes".
- Numerous finding point to the importance of integrating energy modeling throughout the design process, from initial concept through occupancy.
- There are two major types of fragmentation that threaten to the widespread use of energy modeling: that among design professionals and that among software platforms
- One of the keys to improving workflow is the adoption of a common file format to enable information transfer between specialized software programs.

Glossary of acronyms and terminology

AEE .... Association of Energy Engineers
AIA .... American Institute of Architects
ASHRAE .... American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BCAP .... Building Codes Assistance Project
BECP .... Building Energy Codes Program
BEM .... Building energy model
BIM .... Building information model
DOE .... Department of Energy
BTO .... Building Technologies Office
EIA .... Energy Information Agency
ECB .... Energy Cost Budget
ERI .... Energy rating index
EUI .... Energy use intensity
GUI .... Graphical user interface
HERS .... Home energy rating system
ICC .... International Code Council
IECC .... International Energy Conservation Code
IESNA .... Illuminating Engineering Society of North America
IgCC .... International Green Construction Code
IPD .... Integrated project delivery
LEED .... Leadership in Energy and Environmental Design
Low-e .... Low thermal emissivity *(relating to energy efficient windows)*
NCARB .... National Council of Architectural Registration Boards
NZE .... Net zero energy
PNNL .... Pacific Northwest National Laboratory
PRM .... Performance Rating Method
RESNET .... Residential Energy Services Network
RMI .... Rocky Mountain Institute
SHGC .... Solar heat gain coefficient
SRD .... Standard reference design
USGBC .... United States Green Building Council
WBES .... Whole building energy simulation

Introduction

Today's design professionals are witnessing an unprecedented confluence: rising mandates for building energy efficiency and the development of technology that enables quicker energy simulations than ever before. National model energy codes – those that govern the allowable efficiencies of numerous building parameters, including building envelopes, systems, and equipment – are becoming more rigorous. New updates to these documents are released every three years, each requiring more conservative use of energy than the last. These codes are subsequently adopted on the state and/or jurisdictional level along with other non-energy building codes.

National model codes and standards save states the time and resources of developing their own individual requirements; they also provide a certain level of standardization, though many states will modify the model codes with region-specific amendments.[1] Each model code has resulted in a marked decrease in the energy use intensity (EUI) of commercial and residential buildings. EUI is a measurement of energy demand per unit area per unit time, often seen as kBtu/ft^2/year. It enables fair comparisons between buildings of different sizes and allows stakeholders to set specific numeric efficiency goals.[2]

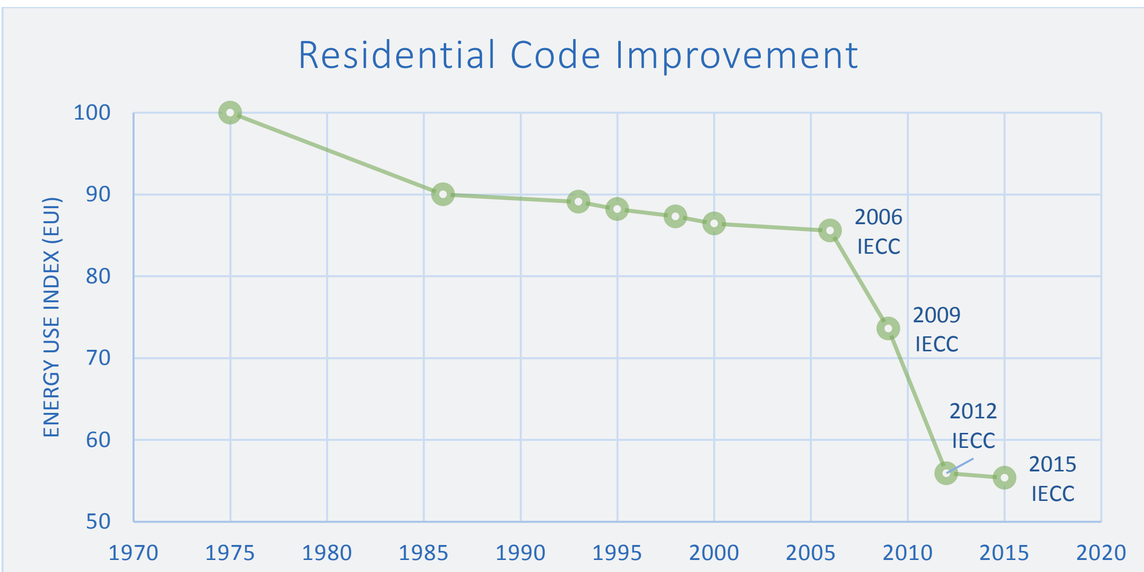

Figure 1: Residential energy code efficiency improvements over time, adapted from DOE graph

[1] http://www.nist.gov/standardsgov/omba119.cfm#3
[2] http://sustainabilityworkshop.autodesk.com/buildings/measuring-building-energy-use

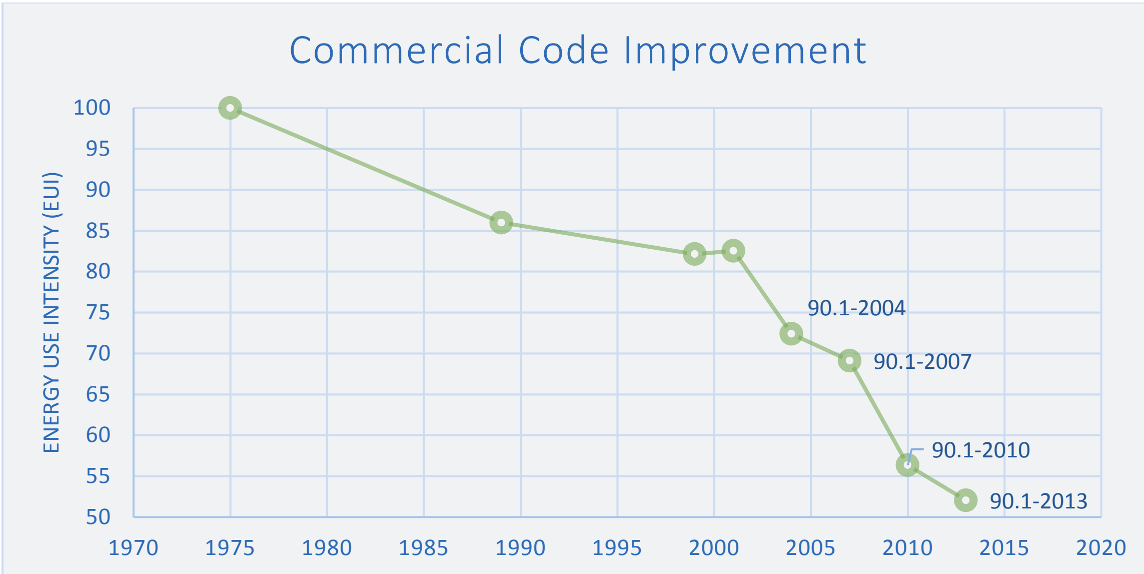

Figure 2: Commercial energy code efficiency improvements over time, adopted from DOE graph

The responsibility of designing the better buildings of tomorrow falls on the shoulders of every individual who contributes to the process, from building owners to architects and engineers, project managers and contractors. In fact, numerous findings point to the importance of integrating energy modeling throughout the entire design process, from concept to occupancy. All decisions will, of course, have some impact on the overall efficiency of an operational building, but careful consideration of big-picture performance factors during the early design phases can make the subsequent workflow much more streamlined.

"Performance analysis is transitioning away from being an afterthought, and is becoming more integrated into projects from the beginning. Now we're starting to think of it as an intrinsic part of the design process." – Christine Reinders, CannonDesign[3]

The past decade or so has seen an argument for the advantages of the Integrated Project Delivery (IPD) model of collaboration, which allows teams to work through design challenges earlier and more efficiently. Early stage energy modeling provides a similar advantage, and in fact is often a key part of IPD. A modified version of the MacLeamy Curve, normally used to visualize the potential of IPD, is shown below for energy modeling (see Figure 3). This curve describes the cost and effort required to execute design alterations at different stages when using early energy modeling and when using the "business as usual" process without early energy modeling.

[3] https://www.greenbiz.com/article/startup-bakes-performance-analysis-green-building-design-process

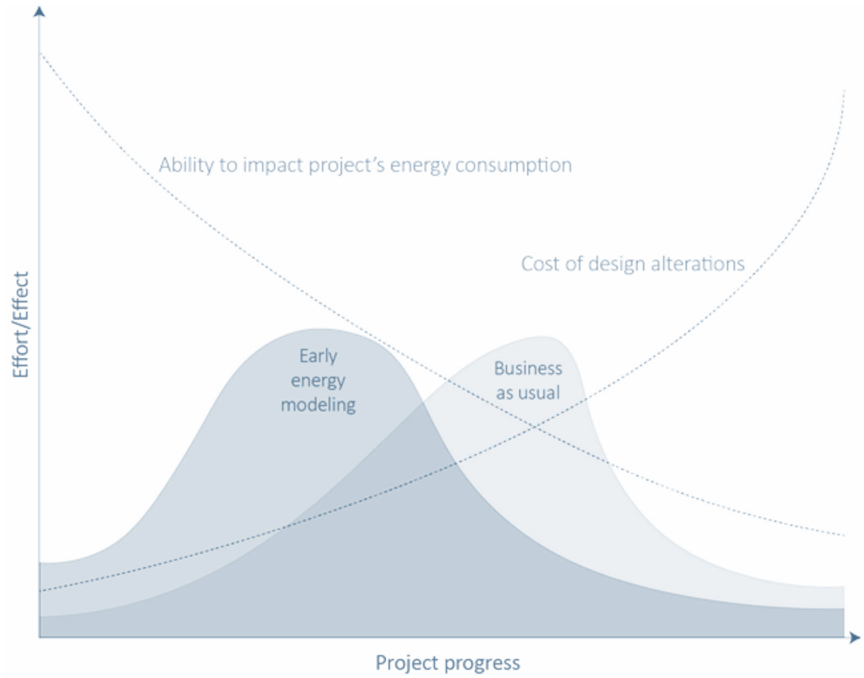

Figure 3: A prototypical MacLeamy curve as applied to energy modeling

At the Rocky Mountain Institute (RMI) Building Energy Modeling Innovation Summit in 2011, one main issue raised was the lack of support for the architectural community to learn new energy modeling tools.[4] Many also find the requirements of building energy codes overly complicated. One of the goals of this paper is to provide a clear road map for design professionals to engage in the new building energy paradigm through early and continuous modeling.

Newer energy modeling software applications, especially those that integrate cloud-based technology, allow users to receive quick feedback on their work and then leverage that information to improve the next iteration of their energy model. Until recently, the United States Department of Energy (DOE)'s Building Technologies Office (BTO) maintained a database of over 400 software tools that could evaluate nearly every imaginable variable of building energy efficiency. The responsibility of maintaining tis list has since been transferred to the Building Energy Software Tools (BEST) Directory[5]. Modern energy modeling is used for several performance demands, including energy code compliance. But for either of these trends – high-tech modeling capabilities or progressive codes – to have significant real-world effects, design professionals need to be prepared for the challenges of creating high-performance buildings.

[4] http://www.rmi.org/Content/Files/BEM_Report_FINAL.pdf
[5] http://www.buildingenergysoftwaretools.com/

Where are we now?

- A BCAP survey (see Appendix A: BCAP Survey of Design Professionals) found that respondents viewed flexibility in their design strategies as the largest motivating factor for using the performance path (see Figure 4 and Figure 5 for details compliance path options). They found many other uses for modeling software besides code compliance, including green building rating systems and utility incentive programs.
- In 2014, 41% of all national energy consumption could be attributed to residential and commercial buildings, representing about 40 quadrillion British thermal units (BTUs).[6] The International Energy Agency (IEA) has identified the building sector as one of the most cost-effective targets for reducing overall global CO_2 emissions.[7]
- In 2010, the U.S. building sector alone accounted for 7% of global primary energy consumption.[8] This despite the national population representing only about 5% of the world's population.[9]
- In 2013, the U.S. (all sectors) was responsible for 16% of global CO_2 emissions.[10]
- Many organizations and numerous design and construction firms have signed onto the 2030 Challenge, which aims to make all new buildings carbon neutral (i.e. not reliant on fossil fuels that contribute to GHG emissions) by the year 2030.[11] The efforts of this project and other national efforts have caused the Energy Information Agency's (EIA) energy consumption predictions to the year 2030 to decline every year for the past decade. This is taking into account the new construction that will be added to the building stock.[12]
- As of January 2015, more than 3.6 billion square feet of space are LEED-certified in the United States.[13] In 2014, the ten countries with the most LEED-certified space (after the U.S.) were Canada, China, India, South Korea, Taiwan, Germany, Brazil, Singapore, United Arab Emirates, and Finland. Collectively, these countries have 61 million gross square meters.[14]
- Within the group of 99 architecture firms surveyed by AIA in 2013, 66% of projects (by gross square footage) included energy modeling in the design process.[15] However, a 2014 AIA Firm Survey Report, with a significantly larger and more diverse sample size, found that only 12% of all firms were using energy modeling software for their billable projects, with another 6% of firms saying that they had obtained the software but had not yet implemented it into their process. The majority of firms did not use energy modeling software *and* did not plan to change that in the near future.[16] Within this same large group in 2012, 49% of firms reported that they offered some sustainable/green design specialty services, suggesting that there is a substantial group that would be willing to incorporate energy modeling into their design process if its contributions to broader sustainability goals were adequately demonstrated.

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[6] http://www.eia.gov/tools/faqs/faq.cfm?id=86&t=1
[7] http://www.iea.org/topics/energyefficiency/subtopics/sustainablebuildings/
[8] https://catalog.data.gov/dataset/buildings-energy-data-book
[9] http://data.worldbank.org/indicator/SP.POP.TOTL
[10] http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2015.pdf
[11] http://architecture2030.org/2030_challenges/2030-challenge/design_faq/#baseline
[12] http://architecture2030.org/files/roadmap_web.pdf
[13] http://www.usgbc.org/articles/green-building-facts
[14] http://www.usgbc.org/articles/us-green-building-council-releases-ranking-top-10-countries-leed-outside-us
[15] http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab104793.pdf
[16] http://www.aia.org/press/AIAB104656

I. Energy Code Compliance Approaches

There are multiple ways to demonstrate that a commercial or residential project meets the requirements of the energy code that a state or jurisdiction has adopted (see diagram on next page). Design teams can choose from two broad compliance path categories: **prescriptive** or **performance**[17]. Each has its own set of benefits and drawbacks. In addition to providing information about both, this section will seek to demonstrate that the performance path is the preferable option for a growing proportion of projects in terms of minimizing energy costs and carbon emissions.

There are two main organizations that direct the development of building standards (including but not limited to energy standards): the International Code Council (ICC) and ASHRAE (formerly the American Society of Heating, Refrigerating and Air-Conditioning Engineers). ICC develops the **International Energy Conservation Code (IECC)** along with the International Green Conservation Code (IgCC), a more progressive model code for sustainability. ASHRAE contributes to the development of **ANSI/ASHRAE/IES Standard 90.1**, which will be referred to in this paper simply as 90.1. Both of these building energy standards are updated on a three-year cycle which includes input from the public. ASHRAE also publishes Standard 189.1, which relates to standards for the design of high-performance green buildings (except low-rise residential buildings).

Please note that any references to sections or chapters of model codes will refer to the most recent editions, the 2015 IECC and ASHRAE 90.1-2013. The organization and content of previous editions may vary, and will be explained where noteworthy.

High-rise multifamily residential buildings must comply with the commercial code provisions.[18]

What code has my state or jurisdiction adopted?

Determining what code applies to your area and type of project can be complicated. For the most up-to-date information about what energy code your state or jurisdiction is using (and when the code will next change), please refer to BCAP's Code Status Maps[19], which are updated every month. Other resources for identifying an applicable building energy code include the ICC and the DOE's Building Energy Codes Program (BECP).

[17] Outcome-based codes, which measure actual building performance, will be discussed further in the Future Endeavors section.
[18] Syed, Asif. *Advanced Building Technologies for Sustainability*, 2012.
[19] http://bcapcodes.org/code-status/

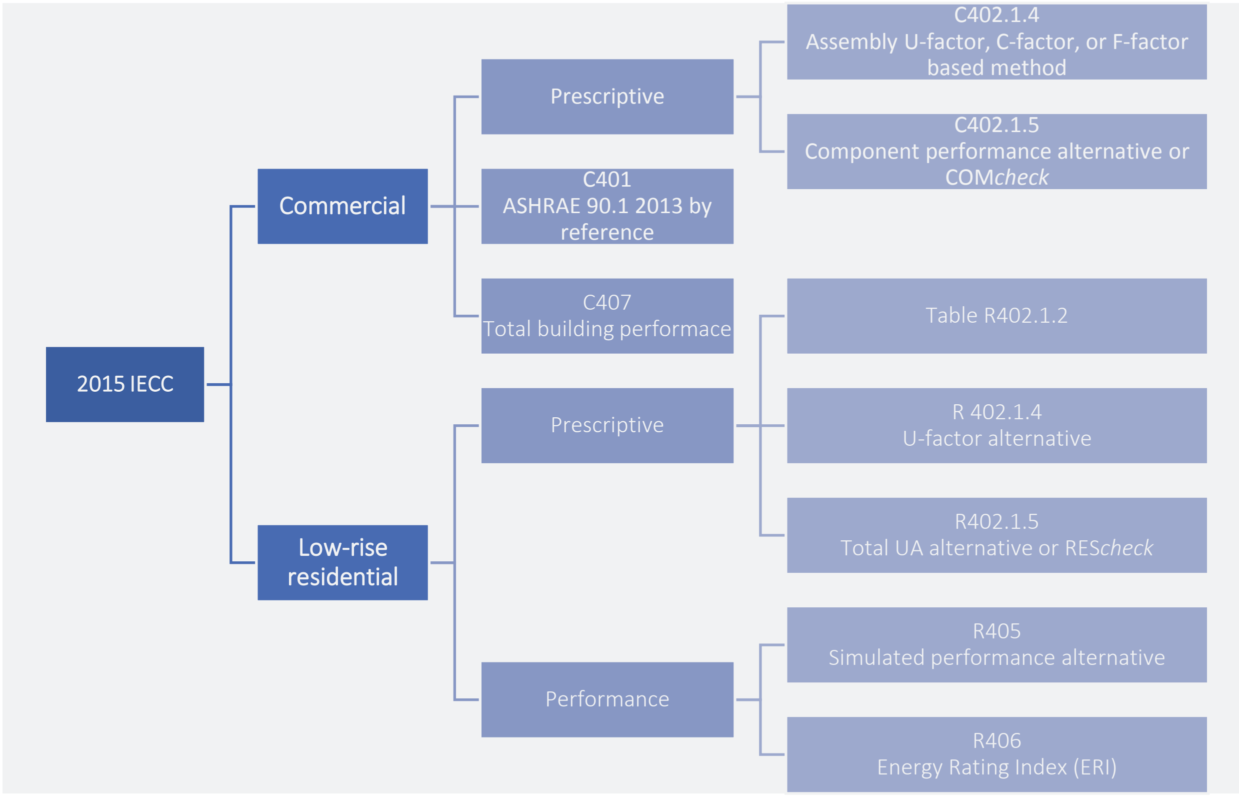

Figure 4: Compliance paths of the 2015 IECC

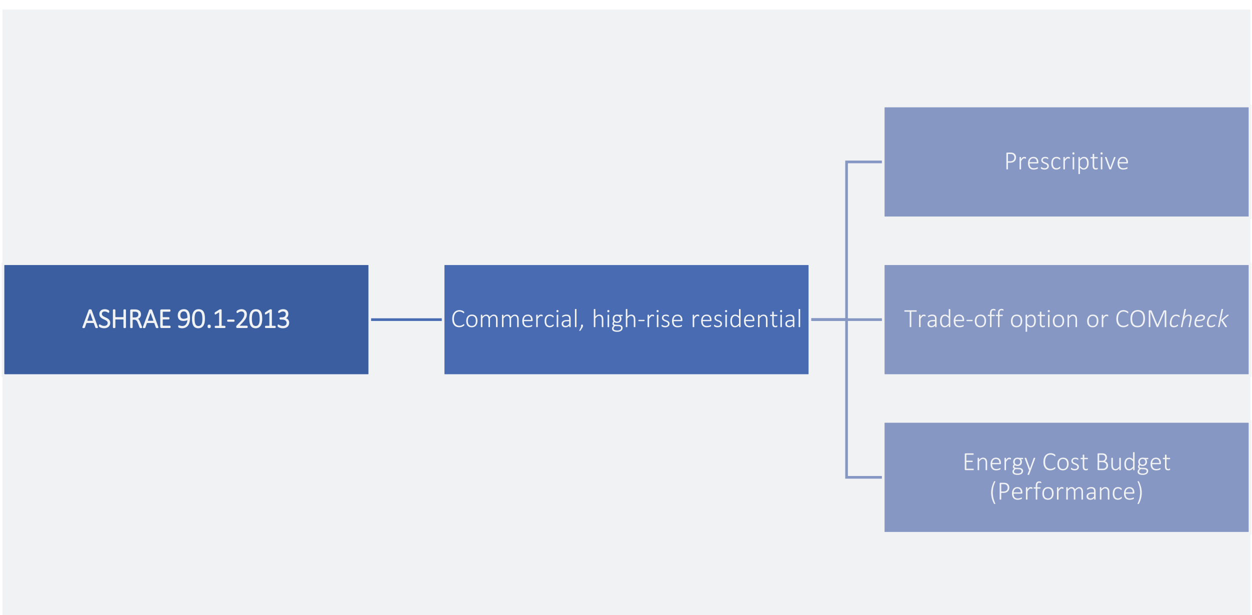

Figure 5: Compliance paths of ASHRAE Standard 90.1-2013

Prescriptive Path

The prescriptive path is a comprehensive checklist of the building components whose characteristics can affect energy consumption. For example, insulation must have certain minimal thermal properties depending on the climate zone of the proposed building site. Prescriptive paths are typically straightforward but inflexible. Each separate component's properties must meet or exceed a specific energy standard. This method covers the building envelope as well as equipment and system operations.

Over the course of history, prescriptive energy codes have proven effective at reducing the amount of energy that code compliant buildings consume. This path can be a reasonable option for projects with a small scale, a basic layout, or those where creativity and innovation are not primary objectives. Some residential and small-scale commercial projects still benefit more from the simplicity of the prescriptive path.[20] An efficient and code compliant final product is possible here without needing to create an energy model. With the current state of technology, designers who choose this path can expect to allocate less time to documenting code compliance. The "check-box" organization of this path also makes it easier for code officials to enforce.

Prescriptive Compliance Paths for Commercial Construction

Chapter C1-C6 of the **2015 IECC** pertains to energy efficiency for commercial buildings. Commercial buildings must comply with one of the following:

- ASHRAE 90.1-2013 requirements
- 2015 IECC prescriptive requirements for building envelope, building mechanical systems, service water heating, and electrical power and lighting systems (Sections C402 through C405), mandatory requirements, and additional efficiency package options (C406; specific requirements are different for tenant spaces)

ASHRAE Standard 90.1-2013, which addresses efficiency requirements for the building envelope, mechanical systems, and lighting, provides two prescriptive compliance options for commercial buildings:

- Mandatory provisions of Section 5.4, consisting of insulation, fenestration, doors, and air barriers, along with prescriptive requirements of Section 5.5
- Mandatory provisions of Section 5.4 along with trade-off requirements of Section 5.6

Prescriptive Compliance Paths Options for Residential Construction

Compliance requirements for low-rise residential construction can be found within Chapters R1-R6 of the 2015 IECC.

The chief shortcoming of the prescriptive path is that is cannot evaluate a building as a whole, or the properties of a relationship between two components. Any project using the prescriptive path is measured as a sum of its parts. As a result, this method overlooks many factors that can affect operational performance, such as building system interactions or external conditions, e.g. a particularly sunny or shady site. Meanwhile, for those who develop new versions of the national model codes, it is

[20] http://www.archlighting.com/industry/reports/the-atlantic-divide-on-energy-codes_o

becoming increasingly difficult to identify cost-effective efficiency improvements for individual components.[21]

The prescriptive path is also slow to incorporate emergent technology. Choosing the prescriptive path may result in a design that complies with the code but fails to capitalize on the more nuanced ways of minimizing a building's energy footprint. This is especially true for buildings with more unconventional forms or geometries. Shying away from energy considerations after the design is well-developed risks wasting significant amount of energy. A sophisticated mechanical system and efficient components can compensate for an inefficient design strategy, but these can both place strain on time or budget constraints.

Further, the prescriptive path cannot evaluate the degree to which an efficient building exceeds a given minimum code.[22] This is a drawback for stakeholders who might want to use a project's energy efficiency to demonstrate added value.

[21] http://newbuildings.org/sites/default/files/Performance_Outcomes_Summit_Report_5-15.pdf
[22] https://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf

Performance Path

The performance path uses energy modeling software to calculate annual energy consumption and costs. Instead of setting minimum standards for individual building components, the goal of the performance path is a building with an EUI equivalent to (or better than) one built to the prescriptive code. Say for example that an office building shows compliance with the applicable energy code using the prescriptive path and is found to have an EUI of 82. A design team using the performance path would then aim for a building with an EUI or 82 or less – but the allocation of resources to reach this target would be at their discretion. The theoretical base case building is known as the **standard reference design**; its performance-based doppelganger is called the **proposed design**. Energy codes can inform design strategies as much as the constraints imposed by other requirements – aesthetic, programmatic, economic, or others – can influence how the team works towards code compliance. This freedom makes the performance path especially appealing for firms that work with unique or unusual building forms. In BCAP's survey of design professionals, 47% of respondents chose flexibility in design strategies as the most compelling reason for selecting the performance path (see Figure 23).

The performance path conceptualizes the building as a single complex organism rather than as a kit of parts. In the same way, the performance-based design process is transformed from a series of discrete points to a tightly interwoven system. Just as the quality of windows might have ramifications on solar heat gain – and therefore on the sizing of HVAC equipment – the caliber of effort given to early energy considerations will impact a number of other design stages, from mechanical engineering to actual construction.

For large and complicated commercial buildings, as well as those with innovative energy efficiency features, the performance path is without question the better option. It is nearly impossible to make an informed choice about design strategies based only on rules of thumb. (One architect and participant in the AIA 2030 commitment goes so far as to compare working without an energy model to driving a car while blindfolded.[23]) Embedding energy modeling into every phase of design empowers professionals to become invested in long-term energy management, beginning with code compliance. Energy therefore takes its crucial place among the other numerous factors that determine the final form and functionality of a building. We can think of the performance path as promoting energy-conscious early design.

The performance path for code compliance in ASHRAE 90.1-2013:

11.1.1 Energy Cost Budget Method Scope. The Energy Cost Budget (ECB) Method is an alternative to the prescriptive provisions of the 90.1 standard. It may be employed for evaluating the compliance of all proposed designs except designs with no mechanical system.

The ECB Method is used for demonstrating minimum code compliance for buildings that do not meet the 90.1 prescriptive requirements. Projects designed to meet this code should be comparable in cost to projects built to comply with the minimum prescriptive path checklist.[24]

90.1 has a list of approved software programs, including DOE-2, EnergyPlus, and eQUEST, but notes that the list is not exhaustive. Details on the ECB Method can be found in 90.1 Section 11.

[23] http://www.aia.org/practicing/2030Commitment/

[24] ANSI/ASHRAE/IES Standard 90.1-2013 Chapter 11 and Appendix G.

Simulation programs for code compliance need to include calculation methodologies for all of the building components being modeled. For example, 90.1 mentions DOE-2 and BLAST, but notes that designers are not limited to only using these programs.

Summary of Performance Path Advantages

- Allows design professionals to prioritize energy-saving measures based on which strategies will be the most cost-effective
- Facilitates compliance with increasingly stringent building energy codes
- Frees creativity and innovation from the limitations of prescriptive component requirements
- Gives clients and stakeholders an estimate of a building's operational costs
- Familiarizes design professionals with a workflow that can also be used for beyond-code targets (e.g. LEED certification, utility incentives) and the eventual goal of net zero energy (NZE) buildings

Exploring the Compliance Path Decision

According to an August 2014 webinar by the Institute for Market Transformation (IMT), the building owner (in consultation with the authority having jurisdiction and the design and construction teams) makes the final decision about which compliance path to use[25]. BCAP's survey of design professionals found that engineers most commonly make this decision (see Figure 24), although this answer may be a result of the disproportionately high percentage of survey respondents who use energy modeling for code compliance. Regardless, it is the ethical imperative of all design professionals to inform their clients about opportunities for greater building energy efficiencies.

Beyond Code Best Practices

For a comprehensive list of national Beyond Code programs, including LEED and ENERGY STAR, please visit BCAP's Beyond Code Portal.[26]

ASHRAE 90.1-2013 Performance Rating Method (PRM)

This modification of the ECB Method in Section 11 is intended for quantifying the energy efficiency and performance of building designs that exceed minimum code requirements. It was written for LEED, EPAct tax incentives, utility programs, ASHRAE Standard 189.1, and the International Green Construction Code (IgCC). It measures the percentage improvement of a proposed building over its given baseline. <u>This appendix does NOT offer an alternative compliance path for minimum standard compliance; that is the intent of Section 11, Energy Cost Budget Method.</u> The PRM is explained in 90.1 Appendix G.

A High Baseline: California's Title 24

Effective July 1, 2014, the mandatory energy code in California for commercial and residential buildings is the 2013 Building Energy Efficiency Standard, part of Title 24.[27] It includes performance and prescriptive compliance paths, both of which include several mandatory measures such as minimum insulation, HVAC, and water heating efficiencies. The structure of the performance approach is very

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[25] "Realizing Energy Efficiency Goals through an Outcome-Based Pathway." Institute for Market Transformation (IMT) webinar, August 27, 2014.
[26] http://bcapcodes.org/beyond-code-portal/
[27] http://www.energy.ca.gov/title24/2013standards/

similar to the ECB Method in 90.1. A report by the California Energy Commission found that the new non-residential construction energy savings expected from the 2013 Building Energy Efficiency Standards exceeded those of ASHRAE 90.1-2010.[28] On the residential side, California minimum requirements also surpass those in chapter 4 of both the 2009 IECC and the 2012 IECC.[29] California is currently working on the 2016 version of Title 24, which is expected to at least meet if not exceed the efficiency of ASHRAE 90.1-2013 and the 2015 IECC.[30]

Massachusetts Stretch Energy Code

This optional appendix to the state energy code increases efficiency requirements for jurisdictions that choose to adopt it. For new residential construction, the MA stretch code is largely based on the performance path; for new commercial construction and residential renovations, builders may still use the prescriptive path.[31] The stretch code does not have provisions for commercial renovations or small commercial buildings. Although the base code in Massachusetts is based on the 2012 IECC and has been available since July 1, 2014, the Stretch Energy Code has not been updated as of this writing and is still based on the 2009 IECC and ASHRAE 90.1 2007.[32] As of June 28, 2016, 176 municipalities representing over half of the state population have adopted the stretch code.[33]

Besides the cost and environmental benefits of energy savings, advanced statewide codes also encourage design professionals to take advantage of educational opportunities.

2. Energy Modeling: From Concept to Code Compliance

Building energy modeling (BEM) is a kind of simulation that predicts of energy usage by looking at building geometry, envelope, orientation, materials, site, climate, occupant activity, lighting, HVAC, and other parameters. Although calculations using prescriptive methodologies are useful, they often fail to account for interactions between building systems.

Information gleaned from energy models can be used as a step towards code compliance, green certifications, other energy efficiency targets, and operational cost predictions. Whatever the purpose, modeling efficacy depends on asking the right questions at the right times during the design process. Energy efficiency could become a primary driving force from the inception of any architectural project. But first, designers need to know what type of energy model is appropriate for their purposes. A model's results are only as good as its inputs, so the importance of choosing software suited to the stage of the project and the modeler's level of training cannot be overstated.

We need to make a distinction between the user-friendly front-end applications such as Autodesk's Green Building Studio or SketchUp's OpenStudio and the back-end energy simulation tools that tend to be the foundational calculation engines for the former. However, no strict divide exists: DOE's EnergyPlus can run simulations within itself, but it is also integrated into the workings of programs such

[28] http://www.energy.ca.gov/2013publications/CEC-400-2013-007/CEC-400-2013-007.pdf
[29] http://www.energy.ca.gov/2013publications/CEC-400-2013-009/CEC-400-2013-009.pdf
[30] https://www.nrdc.org/experts/meg-waltner/energy-savings-way-new-construction-and-major-renovations-california-new
[31] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/stretch-code-qa-feb10-2011.pdf
[32] http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/csl/stretch-energy-code-information.html
[33] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/stretch-code-towns-adoption-by-community-map-and-list.pdf

as OpenStudio and DesignBuilder. Front-end programs are known as graphical user interfaces, or GUIs. GUIs are developed both as open source freeware and as proprietary products. Most GUIs use government-developed simulation engines, such as DOE-2 or EnergyPlus (see first column of Figure 6), but some have their own privately developed back-end engines (see last column of Figure 6).

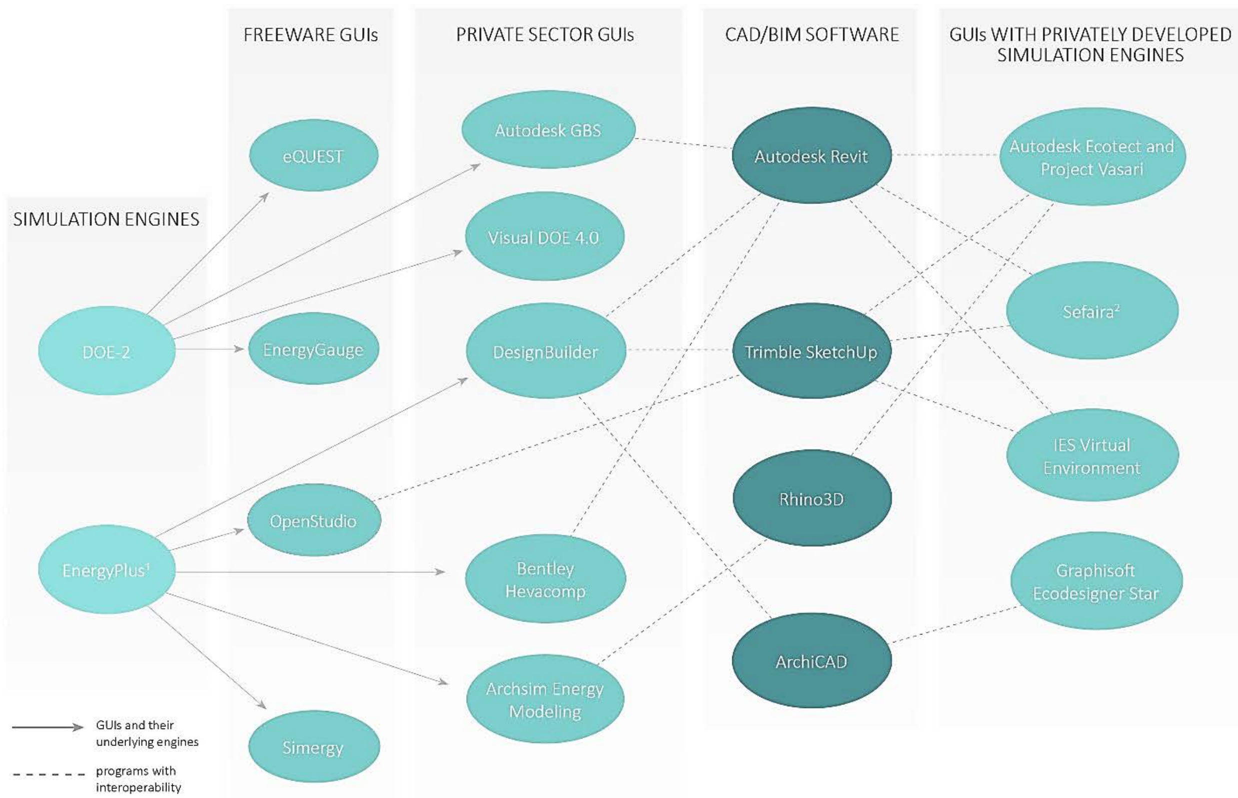
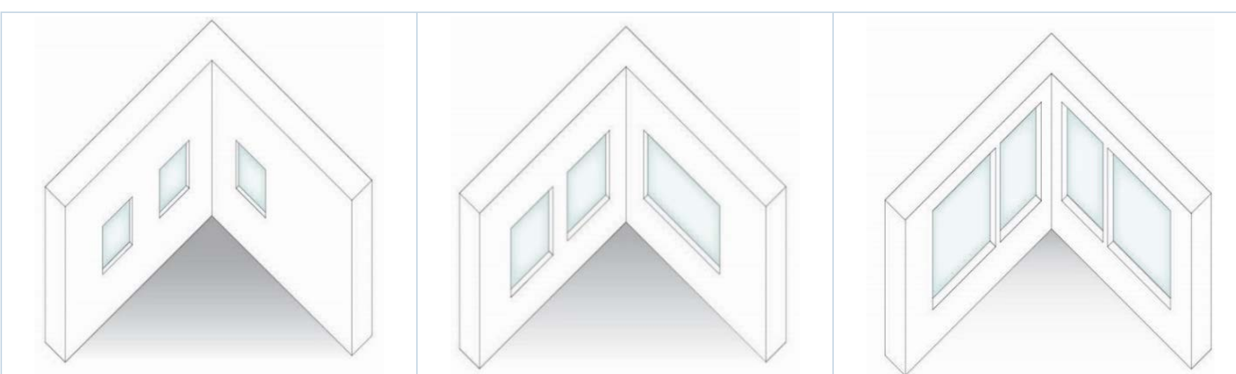


Figure 6: Relationships between some of the many different pieces of energy modeling software

In terms of ideal application, front-end modeling software falls into two categories. The first type enables a detailed **Whole Building Energy Simulation (WBES),** a lengthy process requiring exact inputs and technical building science knowledge. These results are can be used to size mechanical systems, estimate costs, and demonstrate code compliance. Although very useful, the cost and effort of repeating a WBES make this kind of software ill-suited for the iterative early design process.



72 degrees, highest lighting cost	***78 degrees***	***84 degrees, highest cooling cost***

Figure 7: Balancing energy costs using modeled simulations

The second type of software provides designers with a rough idea of how one concept might perform relative to another and, more importantly, shows the pros and cons of alternatives. Models generated by this software would include information about the overall building envelope. This kind of work is called **Design Performance Modeling (DPM),** which "stay to the left of the decimal point".[34] It helps designers to evaluate options; for example, a project team trying a balance adequate daylighting (lower peak electrical demand for lighting) with moderate solar heat gain (lower peak cooling load) might construct several models showing glazing options (see Figure 7). Tools that analyze building performance can help designers compromise in scenarios with conflicting outcomes.[35] Many DPM tools are suitable for those with architectural training and experience with Building Information Model (BIM) models.

Time invested into optimizing design choices greatly reduces the time and money required later to make the building code compliant and eligible for LEED points and other incentives. DPM should be done early and often.

The most common use of energy modeling in current practice is for code compliance and verification in advanced stages of design, with only a minority of modeling being used for early and iterative performance evaluation.[36] BCAP's survey found that many design professionals are using software such as eQUEST and IES VE (see). When asked an open-ended question about what other pieces of software they used, many respondents named Trane TRACE 700, Carrier Hourly Analysis Program (HAP), TRNSYS, EnergyPlus, and DOE 2.1. In other words, most of the software used in current practice is not ideal for the creation of quick conceptual models. However, a market is emerging for fast software suited for DPM, a stage when comparing schemes is far more useful than pinning down absolute values.[37]

There are also software tools that focus on modeling one parameter. For example, the program COMFEN is used for fenestration on commercial buildings. Another specific subset of modeling focuses on daylighting, since the intensity and duration of sunlight can have both positive and negative effects. RADIANCE is the most commonly used suite of tools for daylighting and electric lighting simulation. Knowledge of natural lighting and heat gain is especially important when considering the feasibility of passive solar design solutions. Other considerations include airflow and occupant comfort.

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[34] http://www.aia.org/practicing/AIAB095959

[35] Kensek, Karen and Douglas Noble. *Building Information Modeling: BIM in Current and Future Practice*, 2014.

[36] http://newbuildings.org/sites/default/files/Performance_Outcomes_Summit_Report_5-15.pdf

[37] http://web.stanford.edu/group/peec/cgi-bin/docs/people/profiles/The%20Impact%20of%20the%20Building%20Occupant%20On%20Energy%20Modeling%20Simulations.pdf

[38] http://newbuildings.org/sites/default/files/Performance_Outcomes_Summit_Report_5-15.pdf

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A variety of free and proprietary software for late-stage energy estimates already exists, including DOE's COM*check* (and the equivalent RES*check* for residential construction). Many firms that use energy modeling throughout the design process will still ultimately use COM*check* to show code compliance to the applicable jurisdiction.

[39] http://web.stanford.edu/group/peec/cgi-bin/docs/people/profiles/The%20Impact%20of%20the%20Building%20Occupant%20On%20Energy%20Modeling%20Simulations.pdf

Reimagining the Design Process

The two purposes of energy modeling are decision-making and demonstrating that a building is reaching certain targets, such as code compliance or qualifications for green building certification. ***Applying energy models to the entire sequence of design processes comes at a non-zero marginal cost, but using this technology allows cost- and energy-saving strategies to be identified early, when they are the least expensive to implement.*** Once the design process progresses from comparing conceptual strategies to finalizing a single strategy, energy modeling can only be used to confirm expectations or raise red flags. If issues or missed opportunities are discovered, later design modifications tend to be purely corrective and have limited effects.[40][41]

> *"… when modeling is only used late in design—after the massing, orientation, envelope and glazing design, and mechanical systems in a building are already specified, and hundreds of hours of work have already been put into those designs—the modeling might have little value beyond keeping score." From https://www2.buildinggreen.com/article/energy-modeling-early-and-often*

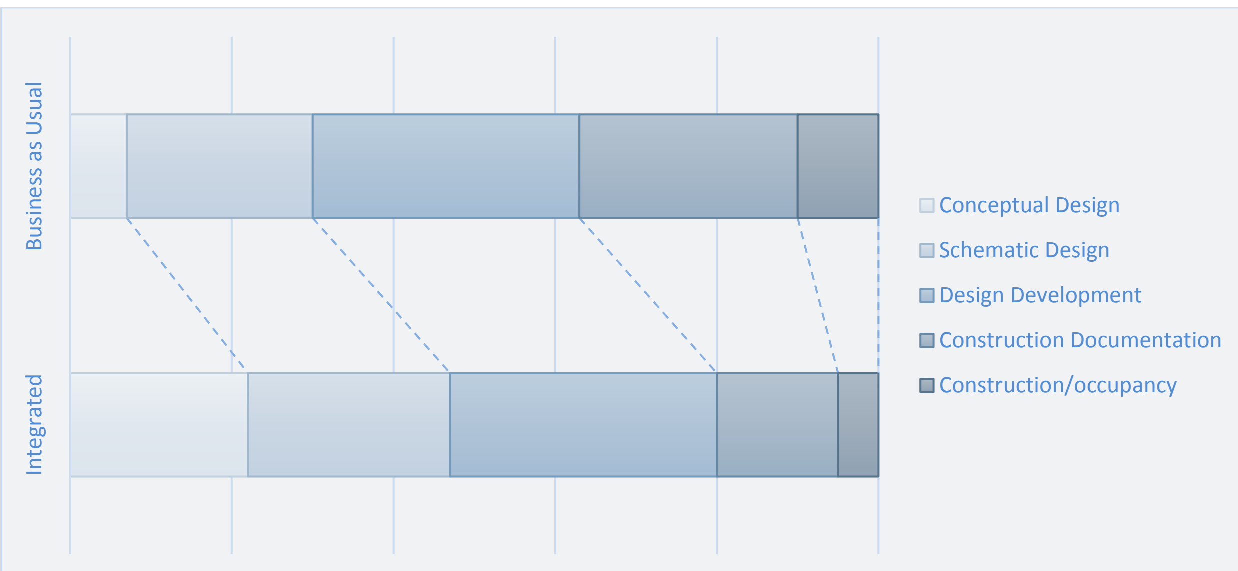

Figure 8: Reimagined timeline for more early-stage energy modeling

[40] Edwards, Brian W. and Emanuele Naboni. *Green Buildings Pay: Design, Productivity and Ecology.* 2013
[41] http://www.rmi.org/Knowledge-Center/Library/2010-27_EnergyModelingDesignPhase

Conceptual design

- Design teams reach a consensus on high-level energy efficiency goals and energy performance metrics, e.g. annual energy costs or EUI.
- Energy models at this stage should consider climate, massing, site conditions, building orientation, building type, and occupancy schedules.

Schematic design

- Previous findings are integrated with information on interior geometries, building envelope properies, and more detailed occupancy schedules.
- The largest energy uses are identified and the most inefficiency design strategies are eliminated from consideration through a series of iterative analyses.

Design development

- Once a single scheme is chosen based on an educated, collaborative decision, designers work to fine-tune that scheme without comparing it to alternatives.
- Specific products may be modeled to test their effect on the overall building envelope.

Construction documentation

- Now that enough information is to size HVAC systems and choose materials, design teams can develop a model for estimating energy costs and documenting code compliance.

Construction & occupancy

- If necessary, energy modeling is used to inform decisions about change orders.
- Predictions to should be compared to actual energy usage to identify any weaknesses in modeling software or simulation methodologies.

Figure 9: Outline of tasks during each design phase

3. Barriers and Opportunities

Misunderstandings about energy codes

Within the family of building codes, energy codes can be seen as less important or urgent than those pertaining to human health, safety, and welfare (HSW). But energy codes protect us from the long term environmental risks of an unsustainable human existence; they are a noteworthy energy efficiency policy with proven efficacy. They also make our homes and buildings more comfortable and less expensive to heat and cool.

Design professionals sometimes find the dense material of code books unclear and difficult to parse. As a result, energy codes can be perceived as just another hindrance to getting a project approved for construction. Because of this opinion, design and code compliance have not been optimally integrated thus far. But code compliance is aligned with other energy efficiency goals, such as LEED accreditation and lower costs of operation. A building that meets code is not just a better building – it is a building that is well on its way to meeting criteria for a number of voluntary incentives.

Uncertainty of goals and purposes

All design professionals need greater clarity about the applications of building performance simulation tools in the early design stages. It is impossible to fully exploit a piece of modeling software without knowing what its exact capabilities are. It is also difficult for advocates to demonstrate the value of this software when many designers are unfamiliar with it. A series of questionnaires about how to better inform architects about energy simulation found that many were skeptical about the potential of software to provide decision-making support.[42]

The selection of appropriate technology and team expertise should happen on a project-by-project basis, and assistance from consultants or others with greater modeling experience should be considered if and when it is feasible. The key here is to eliminate the misconception that energy simulations are mostly beneficial for load calculations and showing code compliance, and also the idea that a large amount of information about mechanical systems is needed to perform an initial analysis.[43] One solution for these issues is the publication of case studies that show best practices in early energy modeling.[44]

There is a limited amount of educational information available for design professionals without a background in building science. In a National Council of Architectural Registration Boards (NCARB) 2012 report on continuing education, 34% of licensed architects reported that they wanted to expand their knowledge of the effects of the thermal envelope on the design of building systems. Almost 36% of surveyed architects wanted more information about energy codes that could impact construction.[45]

However, the emerging consensus on the importance of energy-related early design decisions is encouraging the production of more educational materials suitable for architects and similar professionals.

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[42] http://www.ibpsa.org/proceedings/BS2009/BS09_1306_1313.pdf
[43] http://www.ibpsa.org/proceedings/BS2009/BS09_1306_1313.pdf
[44]http://www.perkinswill.com/sites/default/files/ID%203_PWRJ_Vol0501_02_Building%20Simulations%20and%20High-Performance%20Buildings%20Research.pdf
[45] http://www.ncarb.org/About-NCARB/~/media/Files/PDF/Special-Paper/2013PA_ContinuingEducation_Report.ashx

Fragmented workflow

Engaging more members of design teams in the energy modeling process means that a lack of efficient communication is a huge barrier to success. When workflow is compartmentalized and designers are only concerned with the completion of their own specialized tasks, the project suffers. Many architects still believe that only engineers and consultants should work on energy modeling, not those without building science expertise. This is a view shared by some non-architects, who feel that a superficial understanding of energy modeling results in users who do not have enough experience. On the other hand, non-experts are often among the first team members to work on a project, and can also offer valuable input on how energy considerations might affect non-energy considerations. More user-friendly software, such as the web-based program Sefaira, can help to remove technical barriers between architects, engineers, and consultants. Firms who have implemented this software report that it has helped them make more early design decisions based on data rather than intuition.[46]

The majority of large architecture firms are now using BIM software for some parts of their design process. In 2012, firms reporting BIM usage were most likely to use the software for design visualization (91%), coordinated construction documents (74%), and sharing models with consultants (55%). But only 24% reported using BIM for any sort of energy or performance analysis.[47] On a more positive note, almost 60% of AEC degree programs in the United States now include BIM as part of their standard curricula.[48] This means that a large portion of new professionals entering the workforce will already have the foundational skills necessary for energy-related demands.

An energy efficient building requires project delivery models that use a collaborative approach, such as Design-Build (DB) or IPD. As of 2012, these two methods each accounted for 2% of project value.[49] Most firms still use the traditional design-bid-build arrangement, which results in the compartmentalization of design teams. However, there has been a slow but steady upward trend of design professionals using collaborative business models. As of 2011, 22% of architectural firms offered design/build services, up from 21% in 2008 and 20% in 2005.[50]

Interoperability is "the possibility for information to flow from one computer application to the next throughout the lifecycle of a project"[51]. Improved interoperability between software applications has been identified as a priority not just for energy modeling, but for the entire AEC community.[52]

According to some estimates, the time required to recreate the geometry and information from a BIM file for the purposes of energy analysis can take up to half of the overall time allocated for energy modeling.[53] The silver lining here is that once interoperability improves, the time commitment for performing rudimentary energy analyses will be cut dramatically.

There are two kinds of fragmentation that threaten the widespread use of energy modeling. One of them is among design professionals. The other is among software platforms. A lack of interoperability

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46 http://www.greenbiz.com/article/startup-bakes-performance-analysis-green-building-design-process
47 http://www.aia.org/practicing/aiab095764
48 http://www.mdpi.com/2227-7102/2/3/136
49 Athienitis, Andreas and William O'Brien. *Modeling, Design, and Optimization of Net-Zero Energy Buildings.* 2015.
50 http://www.aia.org/practicing/aiab095764
51 http://www.mdpi.com/2075-5309/3/2/380
52 http://bim.construction.com/research/pdfs/2009_Bim_SmartMarket_Report.pdf
53 http://ascelibrary.org/doi/abs/10.1061/(ASCE)CP.1943-5487.0000215

among building performance analysis software means that there is a tenuous connection between energy modeling and code compliance. Tools that are suitable for making critical early design decisions are too slow to be useful in later phases; tools capable of validating code compliance have learning curves that are too steep for many design professionals. Too often, models from one phase cannot be easily packaged up from one program and imported into another.

One of the biggest barriers to widely practiced early energy modeling is transferring CAD and BIM information to BEMs. Too many variables affect the amount and quality of information that can be carried over. These include the caliber of the design model, the pre-transfer preparation, the ability of the software to recognize imported components and assign them the correct attributes, and the expertise of whoever is working on the project. If model inputs are garbled in translation, it takes a certain amount of experience to recognize this and correct it instead of misinterpreting it. Clearly, we need a better bridge between these programs, both to widen the population that modeling software is accessible to and to streamline workflow for all users.[54] In recent years, more architectural software with capability to automatically generate multi-zone thermal models has become available. Earlier examples of this type of tools include Autodesk Ecotect Analysis (which is now being integrated into Revit®) and Diva for Rhino3D.[55,56] Difficulties in translation discourage design professionals from using existing CAD and BIM models. The elimination of this manual data duplication could result in a huge increase in productivity. Up to 50% of the time spent on a simulation is devoted to gathering and validating building performance data.[57] This is obviously a hindrance to workflow during all stages of the process, but it is especially detrimental during the early conceptual and schematic phases, where being able to quickly receive results for use in the next iterative model is crucial. Modeling errors in early design could mean decisions are made on the basis of misinformation. Design professionals at all stages of their careers are realizing the importance of integration. A 2011 survey of architectural students at the University of Liverpool found that 92% thought the integration of thermal analysis software with conventional 3D modeling software would streamline the design process.[58]

It is readily apparent what spatial information needs to be rebuilt within the BEM interface. As it stands, users need to visually check for accuracy and make manual corrections when moving from standard design software to energy modeling software. This means opportunities for human error, compounded by the lack of communication. The onus is on the energy modeler to find the best software and the best way of transferring information. As better integration of energy analysis tools is developed, designers and modelers will be able to focus on problem solving instead of diligent data extraction and software workarounds.

The fundamental reason behind the fragmentation of software is that the aims of the two kinds of models are different. BIM software contains building geometry and spatial relationships but also can hold information about building location and the characteristics of building components. Even though they are working towards the unified goal of a functional, comfortable, efficient building, architects, energy modelers, and engineers have different representational paradigms. An architectural model that

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[54] http://www.gsa.gov/portal/mediaId/227111/fileName/GSA_BIM_Guide_Series
[55] http://usa.autodesk.com/ecotect-analysis/
[56] http://diva4rhino.com/
[57] http://web.mit.edu/SustainableDesignLab/publications/TemplateEditor_SimBuild2014.pdf
[58] http://www.sciencedirect.com/science/article/pii/S1877042813004448

is constructed for the sake of visualizing a purely aesthetic aspect might not be usable for energy simulations. Energy modeling means shifting away from "faithful physical representation" to visualizing performance properties.[59] For example, the architectural idea of a room is not the same as a thermal zone. To calculate heating and cooling loads in energy models, we have to think of a room as an enclosed volume of relatively homogeneous air.

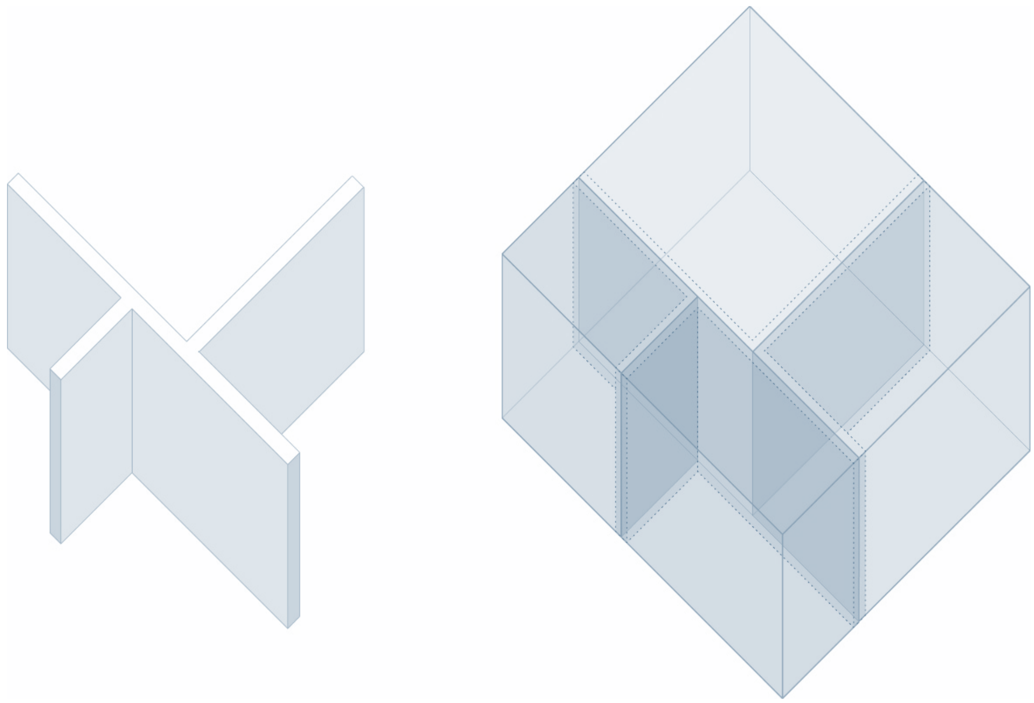

Figure 10: Model of architectural partitions (left) versus model of thermal zones (right)

Walls and ceilings, which in architectural models will have some given thickness, become simple surfaces that are given properties relating to rates of heat transfer. Without careful attention paid to the correct boundaries between zones, an energy model based on an architectural model can generate erroneous analysis numbers.[60] Even when the transfer from BIM to BEM goes smoothly, design changes in the BIM file require a corresponding change in the energy model that often has to be performed manually. Common file formats such as gbXML and IFC have the potential to reduce these and other issues, but their uptake is limited in part by the threat they pose to the market share and profitability of privately developed software.

Building industry stakeholders have a professional responsibility to comply with the energy code, so it would be irresponsible not to collaborate to produce the optimal building. Working together more closely will encourage design professionals to trust the results of others and build upon what has already been done instead of starting from scratch. As of 2014, only 48% of consultants and designers reported that they would feel comfortable using data that had been generated by other professionals due to

[59] https://espace.library.uq.edu.au/view/UQ:236886/biminterop.pdf
[60] http://www.sciencedirect.com/science/article/pii/S1877042813004448

concerns regarding liability and data quality. Only 7% reported that they started their own work with inputs or models assembled by a colleague.[61]

One of the keys to improving workflow is the uptake of a common file format for communication between specialized programs. For example, a concept model used for daylighting should not have to be rebuilt from scratch so that another team can test strategies for airflow. By establishing standards, common file formats can improve project delivery times and overall productivity.[62]

gbXML

The Open Green Building Extensive Markup Language (gbXML) Schema is a non-proprietary file type that can transfer information back and forth between BIM models and BEM. It has become the industry standard, used by Autodesk and many others. This file type helps prevent energy modelers from having to recreate a 3D model from a 2D drawing file of a building plan. This minimizes human errors that occur in translation. Examples of software that are compatible with the .gbXML file format include Autodesk Green Building Studio, Bentley Hevacomp, DesignBuilder, OpenStudio, and Sefaira.

IFC

The Industry Foundation Classes (IFC) file type is available free to all software vendors. Along with three dimensional geometry, .ifc files can hold information about project elements, such as materials, functions, and even properties like color and fire rating. However, it is only widely used during the earlier phases of design. Examples of software that are compatible with the .ifc file format include Autodesk Ecotect, Simergy, and AECOsim Building Designer.[63]

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[61] http://web.mit.edu/SustainableDesignLab/publications/TemplateEditor_SimBuild2014.pdf
[62] http://knowledge.autodesk.com/support/revit-lt/learn-explore/caas/CloudHelp/cloudhelp/2015/ENU/RevitLT-DocumentPresent/files/GUID-0D546BEA-6F88-4D4E-BDC1-26274C4E98AC-htm.html
[63] http://www.buildingsmart-tech.org/implementation/implementations

Expertise gaps

The building industry involves "a number of uncoordinated private and public actors" who have varying degrees of building science expertise.[64] The results of a model are only as good as its inputs, which in turn depend on the knowledge of the person or persons creating the inputs. In other words, the maxim of "garbage in, garbage out" holds true here. Architects are the group of design professionals poised to effect the greatest change on building performance, but are also the group with the least amount of applicable training.

One speaker at a building energy modeling summit noted that new graduates at his firm excelled at understanding software interfaces but struggled with the underlying logic of the variables that they were modeling.[65] 3D visualizations make it possible to perform energy analysis without understanding all of the underlying mathematical and thermodynamic calculations, but architects still need to find a middle ground of technical proficiency in building science and performance.[66] Otherwise, they will be unable to catch errors and troubleshoot if problems arise. They will also lack the ability to fully interpret simulation feedback and apply it to future design iterations.[67]

There is at least some recognition within the community that this expertise gap must be remedied. In a 2012 NCARB survey, the vast majority of licensed architects reported that they would need skills related to energy codes and energy modeling.

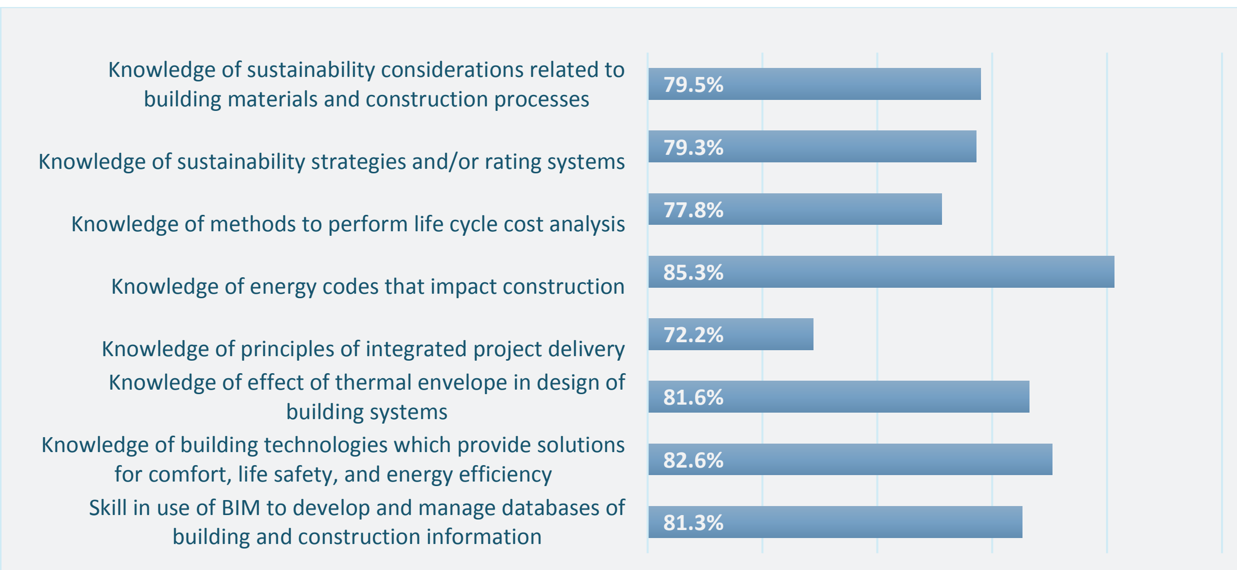

Figure 11: NCARB Continuing Education Report, percentage of licensed architects who reported needing a skill

[64] http://www.iea.org/publications/freepublications/publication/policy-pathways-modernising-building-energy-codes.html
[65] http://www.rmi.org/Content/Files/BEM_Report_FINAL.pdf
[66] http://www.asee.org/public/conferences/8/papers/5045/view
[67] http://www.ibpsa.org/proceedings/BS2013/p_980.pdf

Upfront investment

Not all clients are willing or able to pay for a team of consultants to conduct performance simulations. In BCAP's survey, many respondents revealed that one of the barriers to using the performance path was their clients, who either did not have the expertise to understand the value of changing compliance paths or were unwilling to pay for it.

Many smaller architecture and engineering firms cannot afford the up-front cost of having energy modeling specialists in-house. In our survey, almost 89% of respondents who used energy modeling reported that they had in-house staff meeting those needs. Another financial barrier is the proprietary nature of many pieces of modeling software. Because of economic limitations, a number of important design decisions at some firms are still being made based on prior experiences or rules of thumb.[68]

An important clarification to make is that energy modeling is not necessarily more time consuming overall; it simply shifts some of the decision-making to the front end of the project. Technological advances have and will continue to bring down cost marginal costs, especially as the growing number of design professionals with building performance expertise allow smaller firms to conduct energy modeling tasks in-house. Due to the popularity of sustainable building, more and more design teams are bringing energy modeling specialists on board and using consultants. This is driving down the price of these services as multiple entities compete for design work.[69]

A noteworthy best practice that can offset the upfront investment is utility design assistance program management. Xcel Energy, an electric power and natural gas supplier for eight states, has successfully leveraged modeling software innovations for its Energy Design Assistance (EDA) program since 2006. This service provides energy design consulting and predictive energy modeling for new commercial construction. Since retooling their process in recent years, Xcel Energy has used a web-based tool for project management. Their engineers and consultants use a combination of DOE's EnergyPlus simulation engine and the OpenStudio visual interface.[70]

Ultimately, demonstrating the value of high-performance buildings as an investment in energy efficiency will reduce reluctance among both clients and designers. In some markets, commercial tenants are already willing to pay a premium to know that they are occupying a green space and showing their commitment to sustainability, whether the building has been certified by LEED, ENERGY STAR, or another third party program.[71] Although design performance modeling may increase initial costs of construction, it will reduce life cycle costs of building operation, creating competitive advantage in the marketplace.

The question of existing buildings

In places like the United States and Western Europe, where the replacement rate of new construction typically hovers in the single digits, retrofitting older buildings to meet higher efficiency standards will be part of any comprehensive approach to building energy emission reductions.[72] A building's initial construction is the most cost-effective time to ensure that it uses as little energy as possible. But even in

[68] http://www.ibpsa.org/proceedings/BS2009/BS09_1306_1313.pdf
[69] http://www.gsa.gov/portal/mediaId/227111/fileName/GSA_BIM_Guide_Series
[70] http://aceee.org/files/proceedings/2014/data/papers/5-603.pdf
[71] http://www.appraisalinstitute.org/assets/1/7/Green-Building-and-Property-Value.pdf
[72] http://www.academia.edu/11557969/Building_energy_consumption_in_US_EU_and_BRIC_countries

the best-case scenario where all new construction is built to comply with the most recent model code, the United States would still fall short of many national goals for energy efficiency and building emission reductions. In BCAP's survey of design professionals, 88.6% of respondents said that their work at least sometimes involved renovations or remodeling. In most developed nations, at least half of the building stock projected to be in use in 2050 has already been built today.[73] In countries within the continental northern hemisphere, this number can be as high as **90%**.[74] Of the building stock built since 1949 in the United States, a significant portion has never undergone any renovation (see Figure 12).

Due to several factors including lower energy prices and a lack of awareness about building science, older buildings were frequently designed with minimal consideration for the energy code if any. They tend to use far more energy and resources than comparable modern buildings.[75] Retrofitting existing envelopes and mechanical systems therefore represents an enormous opportunity to reduce emissions and save money. Although most people think of new construction when they think of energy modeling, the technology is also very useful for energy-code-related upgrades on existing spaces, where it can again be used to capture potential savings by looking at interactions between building systems. The 5.6 million existing commercial buildings in this country collectively contain around 87 billion square feet of interior space. Five billion square feet of existing buildings are renovated every year.[76]

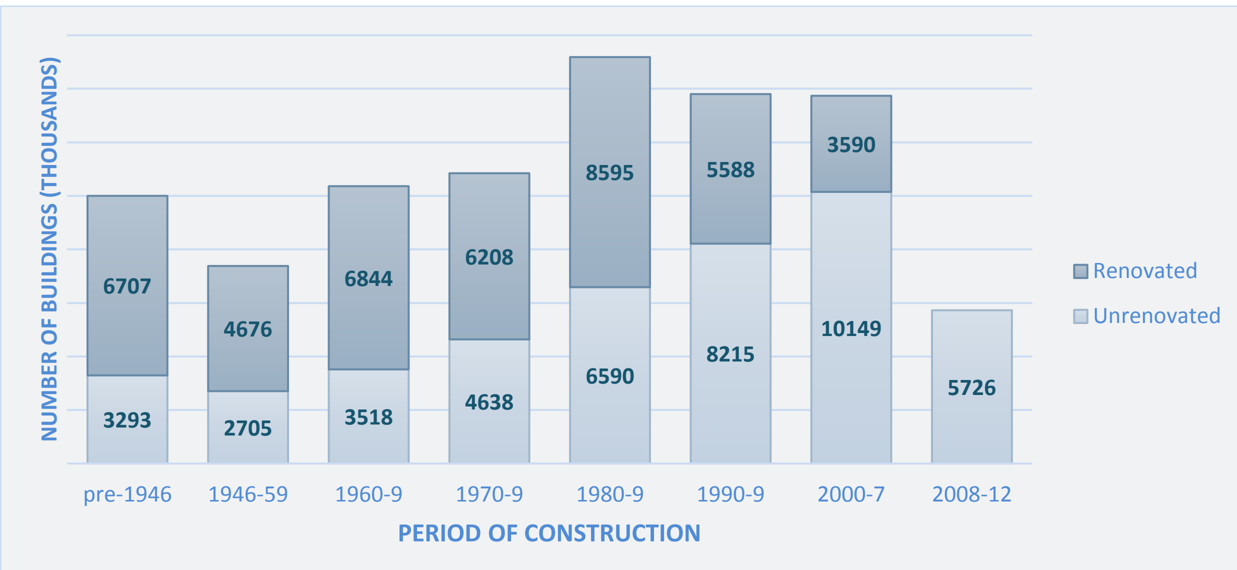

Figure 12: Renovated and un-renovated existing building stock, data from 2012 EIA CBECS survey data

Assessing existing buildings on a massive scale is one of the primary challenges that stakeholders and design professionals face. Which buildings have the greatest potential for energy savings or ROI? And within the selected buildings, which components should be switched out for those of higher efficiency? This is where the advancement of energy modeling software is very useful. A relatively new framework for existing building, called rapid energy modeling, condenses the building evaluation process into three essential elements: capture, model, and analyze. Building professionals can use existing Google Earth

[73] http://www.institutebe.com/Existing-Building-Retrofits/Why-Focus-On-Existing-Buildings.aspx
[74] https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvelopes.pdf
[75] http://www.epa.gov/greeningepa/projects/guidingprinciples.htm
[76] http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099241.pdf

imagery or digital photographs as inputs to generate a simplified 3D wireframe using BIM software (such as Revit Architecture or Revit MEP, although some open source BIM for this purpose may also be available). The quantity of inputs is minimized while the quality of outputs is maximized. Rapid energy modeling it also eliminates the need for specialized energy personnel and greatly reduces the time and associated costs. It is cheaper and faster than whole building energy analyses or energy audits, yet more useful than utility bills, energy benchmarking, or carbon calculators.[77]

Researchers at Lawrence Berkeley National Laboratory (LBNL) and their partners have started developing a way to make rapid energy modeling even faster. The portable Rapid Building Energy Modeler (RAPMOD) is a 3D mapping system that translates information from 3D scanners and digital cameras into an energy model. A person carries this technology in a specialized backpack and captures the necessary data over the course of single building walk-through. RAPMOD is still in development but has been successfully tested in one building in Berkeley, California.[78]

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[77] http://images.autodesk.com/adsk/files/rem_white_paper_2011.pdf

[78] http://www.ibpsa.org/proceedings/BS2015/p2409.pdf

4. The Role of Architects in Supporting the Energy Code

Architects bear tremendous responsibility in the development of our built environment. They are tasked with delivering safe, functional, and aesthetically pleasing buildings. Over the past ten years, increased awareness of the environmental impact of buildings has broadened the scope of architects' responsibilities. AIA's 2030 Commitment – which calls for all buildings to be carbon-neutral by 2030 – reinforces the professional's dedication to energy efficiency and sustainable design. One of the commitment's strengths is that it highlights energy codes as a path to meeting goals; however, the current model energy codes will not meet the pace set by 2030 Commitment milestones.

To meet AIA targets, architects need to become more active in supporting effective energy codes through code development and compliance efforts. These would represent a chance to have a collective impact on the built environment and expand the profession's influence as market demands shift to greener buildings. In an increasingly competitive environment where energy service companies (ESCOs) and energy performance benchmarking could pose a threat to architecture firms, support for the energy code could boost designers' competitiveness. **More so than other codes, the energy code allows architects to associate value with their design strategies and connect the dots between the code compliance, high-performance buildings, and sustainability commitments.** This in turn can validate and demonstrate the value of design decisions as they are presented to clients.

To date, the majority of architects have shown little interest in participating in the building code development process. However, the language of these codes, energy-related and otherwise, is an issue that greatly affects their business operations. It is imperative that architects become more engaged in code development and also in its later implementation. By having a more comprehensive understanding of the challenges that the energy code may present, architects can shift their focus to the environmental and financial benefits that come with embracing building energy performance.

5. Meeting Demands of the Profession

In 2013, AIA identified four priority issues that would help architects strengthen their leadership role in the future. One of them was energy – specifically, the use of energy efficiency and renewable sources to meet AIA 2030 goals.[79] (The same report also named buildings performance metrics performance-based codes as major sustainability trends.) Understanding the role of energy in buildings is key for architects as well as for engineers and others.

Sustainability credentials

Every year, more and more design professionals are choosing to obtain green building credentials. These programs are designed to meet the growing industry need for individuals who have a comprehensive understanding of new demands on top of more traditional goals.

Leadership in Energy and Environmental Design (LEED)

The US Green Building Council (USGBC) offers many LEED credentials depending on a person's career specialty and the amount of time they can reasonably dedicate to continuing education hours.

Building Energy Modeling Professional (BEMP) Certification

385 HVAC&R professionals have been certified through ASHRAE's BEMP program, which was developed to be beneficial for certified professionals, building owners, and employers alike.[80]

Certified Building Energy Simulation Analyst (BESA) Certification

The Association of Energy Engineers (AEE) program is aimed at those who have special expertise with simulation software and its applications in assessing a building's energy performance. There are currently 49 professionals with the AEE BESA certification.[81]

[79] http://www.aiacc.org/wp-content/uploads/2013/05/sus_ldr_scan.pdf
[80] http://report.ashrae.org/Certification/list?type=BEMP
[81] http://www.aeecenter.org/custom/cpdirectory/index.cfm

6. Future Endeavors

Integrated and cloud-based workflow

The integration of energy code compliance and BIM with BEM is an absolute prerequisite for achieving higher performing buildings. Eventually, energy analysis and code compliance should both be part of standard operations. This will help to reframe code compliance not as red tape but as a way to guarantee a minimally efficient building - a way to quantify, especially for stakeholders, a building's energy demands and how they compare to those of similar buildings.

On a small scale, this is already happening: programs like Sefaira, which allows real-time energy analysis within BIM environments, let designers stop seeing energy as an extra hurdle and start seeing it as simply another criterion to test ideas against. Cloud-based software like this also enable faster results because they are less dependent on a user's own desktop computer. In early 2016, Trimble announced its acquisition of Sefaira, bringing SketchUp and Sefaira under the same roof and indicating that the business case for integration is well understood.[82]

Measuring the amount of energy consumed by a particular building will soon be no more complicated than measuring room dimensions. A 2009 survey of architects found that respondents' top priority for items to be integrated into the knowledge base of architectural software was "guidelines for building codes and rating systems compliance"[83]. Using this kind of workflow will also potentially make performance path compliance easier for code officials to verify, meaning that construction can proceed with fewer hindrances. To this end, we need to encourage the development of software that meets the specifications of model code performance paths.

Public-private collaborations

In October of 2014, Autodesk and BTO finished their efforts to update the EnergyPlus software. Version 8.2.0 was written in a more modern computer language, could process more architectural details, and could run certain models up to 20% faster.[84] Since then, DOE has updated EnergyPlus to version 8.5.0; one major focus of this release was to make more improvements on simulation runtimes.[85] Project EnergyPlus Cloud, another promising venture developed by Autodesk with DOE, went beyond beta testing and became available to the public for a brief period during the spring of 2015.[86] The next step of April 2016 is to graduate the technology to a production version.[87]

Another building energy modeling project still under development is a BEM calibration methodology called Autotune. Its developers at the Oak Ridge National Laboratory (ORNL) hope that the automated calculations done by this software will reduce both the time and the level of expertise necessary for the production of quality models.[88]

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82 https://www.trimble.com/news/release.aspx?id=020816a
83 http://www.ibpsa.org/proceedings/bs2009/bs09_0204_211.pdf
84 http://energy.gov/eere/buildings/articles/energyplus-overcomes-computer-language-barrier
85 http://apps1.eere.energy.gov/buildings/energyplus/energyplus_features.cfm
86 http://autodesk.typepad.com/bpa/2015/05/energyplus-cloud-labs-project-opens-access-to-all-users.html
87 https://beta.autodesk.com/callout/invalid.html?callid=%7b5366FFEA-6FCC-4F6A-94E1-9B78A62698A2%7d&err=expired
88 http://rsc.ornl.gov/autotune/?q=content/autotune

Robust resources

Information on codes and modeling should be compiled somewhere that is both available to the public and easy to navigate. Codes are necessarily complex in order to cover the many possible design permutations, but a companion guide to code books could bridge the gap between dense technical writing and practice application.[89] Organizations such as the New York State Energy Research and Development Authority (NYSERDA) are currently developing materials for design professionals.

Secondly, design professionals would benefit from an up-to-date online database on climate and other site-specific variables.[90] New construction will have to address climate change, so accurate model inputs for weather are more important now than ever. When modelers use older data, they risk underestimating peak loads and therefore requirements for system sizing.[91] About 87% of professionals contacted for a survey by the International Building Performance Simulation Association (IBPSA) said that they would use a public standard dataset if it were properly referenced and validated.[92] If modelers spent less time searching for data, they could shift towards design optimization.

Selected Resources:

- Standard Energy Efficiency Data (SEED) Platform[93]
- Design Data Exchange (DDx)[94]
- Building Component Library (BCL)[95]
- Building Energy Software Tools (BEST) Directory[96]
- Simulation Research: Building Technology and Urban Systems Division[97]

Simulating innovations

New material technologies for building energy efficiency are less useful if design professionals are not given the tools to understand how these might interact with other components. New software entering the marketplace should allow users to simulate nascent technologies and methods. This will encourage the application of building innovations by reducing uncertainties about performance. Many survey respondents said that their inability to analyze the energy impacts of new technologies was a barrier to them using energy modeling (see Figure 25).

For example, architects often use complex façade geometries to maximize access to natural light for occupants while minimizing cooling loads. A building's solar heat gain depends on, among other things, the angle at which sunlight strikes glazing, so there needs to be a reliable way of modeling the relationship between energy needs and window orientation.[98]

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89 http://bcapcodes.org/wp-content/uploads/2015/12/One-Pager_Implementation.pdf
90 http://www.rmi.org/Content/Files/BEM_Report_FINAL.pdf
91 http://www.csemag.com/single-article/energy-modeling-and-climate-change/607bb4e8cb81e1af348a6b9a689cd30b.html
92 http://web.mit.edu/SustainableDesignLab/publications/TemplateEditor_SimBuild2014.pdf
93 http://energy.gov/eere/buildings/standard-energy-efficiency-data-platform
94 http://www.aia.org/press/releases/AIAB106511
95 https://bcl.nrel.gov/
96 http://www.buildingenergysoftwaretools.com/
97 http://simulationresearch.lbl.gov/
98 http://www.techstreet.com/products/1883960

Outcome-based codes and post-occupancy

Widespread usage of the performance path would be a marked improvement over the predominance of the prescriptive path. Still, it is necessary to remember that even the best simulation is not a substitute for actual energy usage data. Evaluating a building as it functions in real time is the only way to ensure that energy efficiency efforts are paying off as predicted. Comparing actual energy consumptions and costs with model estimates is also crucial for recalibrating software to produce more accurate simulation results in future projects.

Discrepancies between models and reality can also occur when buildings are not used as intended. During the modeling process, it is difficult to guess how much occupants might affect energy demands, since this is largely based on individual preference.

Occupants also respond mal-adaptively to maximize comfort levels when these needs are not met by the design.[99] This might mean using a personal space heater in an overly air-conditioned office, opening a window on a cold day, or using extra task lighting. Future efforts should include better methods for modeling human behavior, especially as the proportion of building energy usage associated with occupants (i.e. plug loads) continues to rise.[100]

The consideration of actual building performance relative to predictions has found its way into the model codes. The 2015 International Green Construction Code (IgCC) includes an outcome-based compliance path that sets energy-use targets based on building type and climate zone. Progressive outcome-based codes rely on commercial building energy disclosure mandates to be effective, but many major cities – such as New York, Philadelphia, Austin, Seattle, and DC – already have these policies in place.[101]

The ultimate goal of net zero

As of April 2016, the New Buildings Institute (NBI) has identified only 57 commercial buildings that have achieved – or are actively working towards – net zero.[102] The generally accepted definition of a net zero building – or a campus, or a community – is the ability to produce at least as much energy as it consumes, using a combination of energy efficiency and renewable energy sources, such as solar panels. Other definitions of net zero include the use of fossil fuels as long as the energy consumed is offset by on-site renewable energy generation.[103]

The current model energy codes – the 2015 IECC and 90.1-2013 – stipulate that buildings achieve a certain level of efficiency, either through setting minimum standards for building components or requiring than a building have comparable energy performance to one meeting the these component standards. These codes are understood to be a certain percentage better than their previous iterations, e.g. ASHRAE 90.1-2013 captures an additional 8.7% of energy costs savings over the 2010 version[104]. But the most progressive sectors of the building industry are shifting the conversation from hitting minimum

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[99] http://www.ibpsa.org/proceedings/asim2012/0050.pdf
[100] http://newbuildings.org/sites/default/files/Plug%20Loads_Sabo.pdf
[101] http://www.neep.org/model-progressive-building-energy-codes-policy-2012-updates
[102] http://newbuildings.org/resource/getting-to-zero-database/
[103] Maclay, Bill. *The New Net Zero: Leading Edge Design and Construction of Homes and Buildings for a Renewable Energy Future*. 2014.
[104] https://www.energycodes.gov/sites/default/files/documents/901-2013_finalCommercialDeterminationQuantitativeAnalysis_TSD.pdf

efficiency targets to the inevitable end goal: a net-zero built environment. The Residential Energy Services Network's (RESNET) HERS index, a popular way of quantifying the efficient attributes of homes, encourages homeowners and building professionals to consider projects relative to net zero instead of to the latest version of the IECC.

Through performance-based codes, design professionals can acclimate themselves to the type of workflow required to meet minimum standards as they become more stringent; they can also use this framework to pursue even loftier goals. Some beyond-code programs are already using these best practices: in 2014, updates to the Passive House Planning Package (PHPP) enabled users of the NZE residential software to use a 3D model interface to input building geometry, including information from Google SketchUp. The Passive House Institute is the only internationally recognized performance-based energy standard in construction.

The potential for building energy efficiency in a nation using collaborative, performance-based methods to achieve code compliance is huge. The potential when design professionals look further ahead to net zero is even bigger.

Further reading

- *Advanced Building Technologies for Sustainability*, Asif Syed (2012)
- An Architect's Guide to Integrating Energy Modeling into the Design Process, American Institute of Architects (2012)
- *Building Codes Illustrated*, Francis D. K. Ching (2015)
  Modeling, Design, and Optimization of Net-Zero Energy Buildings, Andreas Athienitis & William O'Brien (2015)
- *Building Information Modeling: BIM in Current and Future Practice*, Karen Kensek & Douglas Noble (2014)
- *Building Performance Simulation for Design and Operation*, edited by Jan L. M. Hensen and Roberto Lamberts (2011)
- *Data-Driven Design and Construction: 25 Strategies for Capturing, Analyzing and Applying Building Data,* Randy Deutsch (2015)
- *Designing Energy Simulation for Architects,* Kjell Anderson (2014)
- Energy Modeling: A Guide for the Building Professionals, Colorado Governor's Energy Office (2011)
- *Green Building Illustrated*, Francis D.K. Ching (2014)

Appendix A: BCAP Survey of Design Professionals

To collect information on current usage of energy modeling software, BCAP conducted a survey of design professionals. The main goal was to determine how energy modeling is utilized in relation to energy code compliance. While modeling at any stage will provide valuable predictions on building energy consumption, energy modeling during the early conceptual stage has the unique ability to influence design decisions and promote energy conservation strategies that can be implemented without increasing construction costs. This in turn can reduce the time and expense of achieving compliance with the energy code when using the performance path. BCAP hopes that the results of this survey will help to identify and remove barriers to more design professionals using building energy modeling software at every stage of workflow.

Quantitative Data Analysis

In total, there were 291 respondents to the survey; 245 (84%) were from the United States. Within the United States, the top states in terms of respondents were New York (22), Illinois (19), California (18), Texas (18), Tennessee (12), Washington (12), Ohio (11), Virginia (11), and Wisconsin (11).

Figure 13: Geographic distribution of survey responses

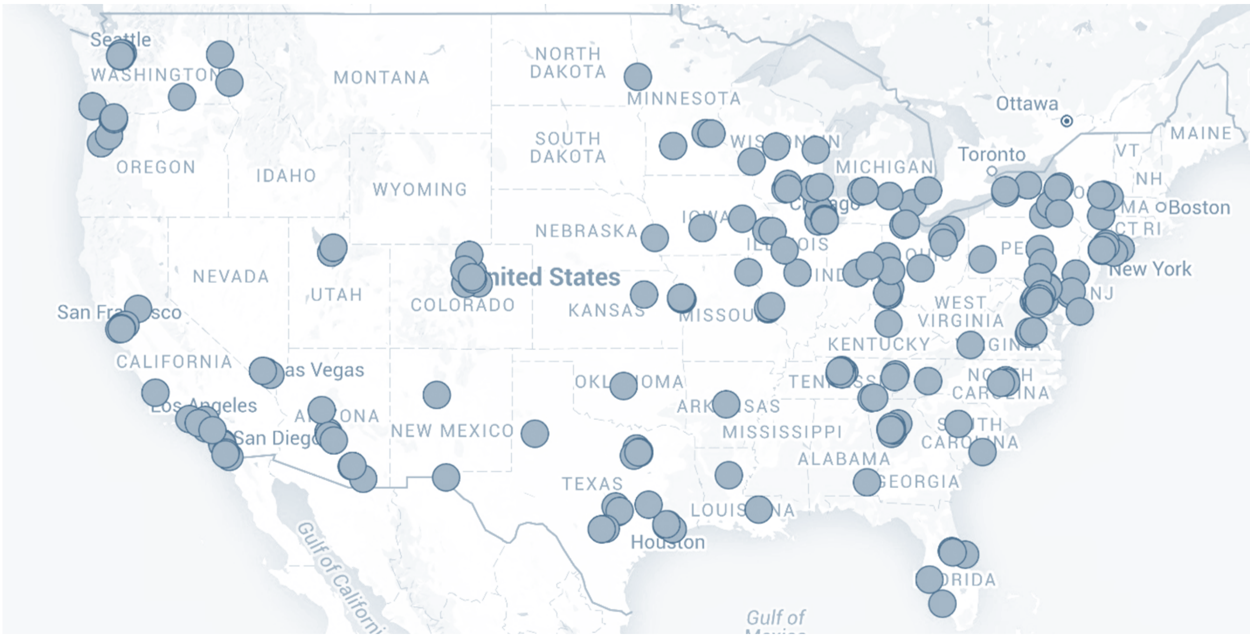

Figure 14: Map of respondents within continental United States, map data © 2016 Google, INEGI

Nearly half of respondents (46.1%) described themselves as licensed engineers. About 15% reported that they were professional architects. <u>Among the 38.6% who selected other, many specified that they were energy modelers, consultants, analysts, or building officials</u>. Others were in the process of becoming professional engineers or architects, but had not yet obtained their license. Several noted that they had specific qualifications relating to building energy efficiency, including ASHRAE BEMP, Certified Energy Manager (CEM), HERS Rater, and ENERGY STAR.

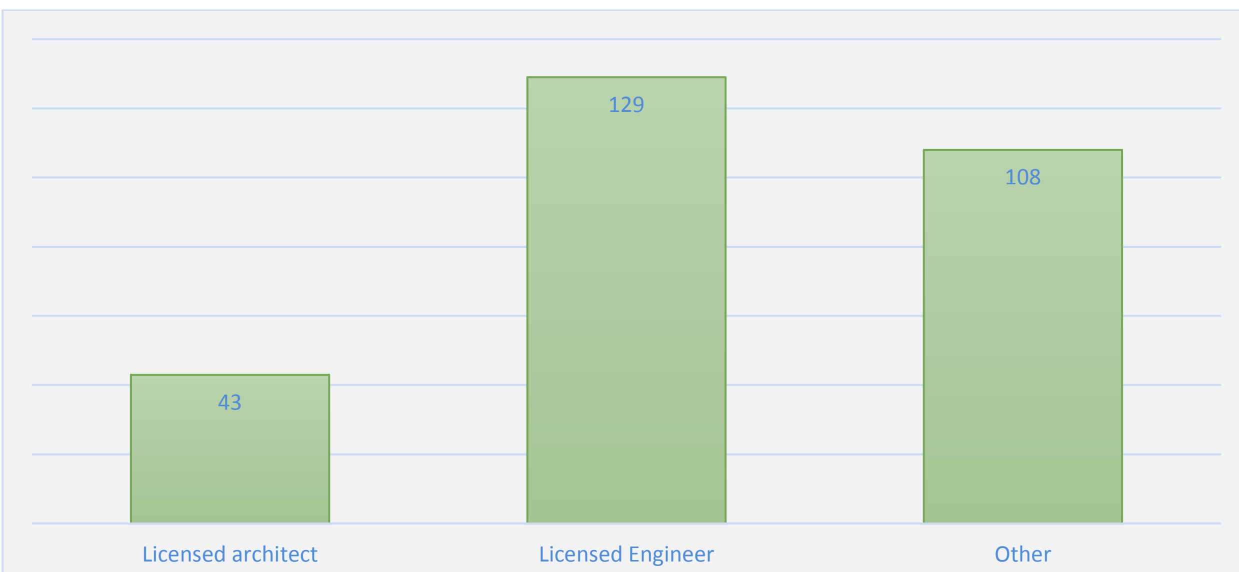

Figure 15: Which of the following best describes your profession?

Other respondents indicated that they were unlicensed professionals, project managers, energy modelers, consultants, energy specialists, and designers.

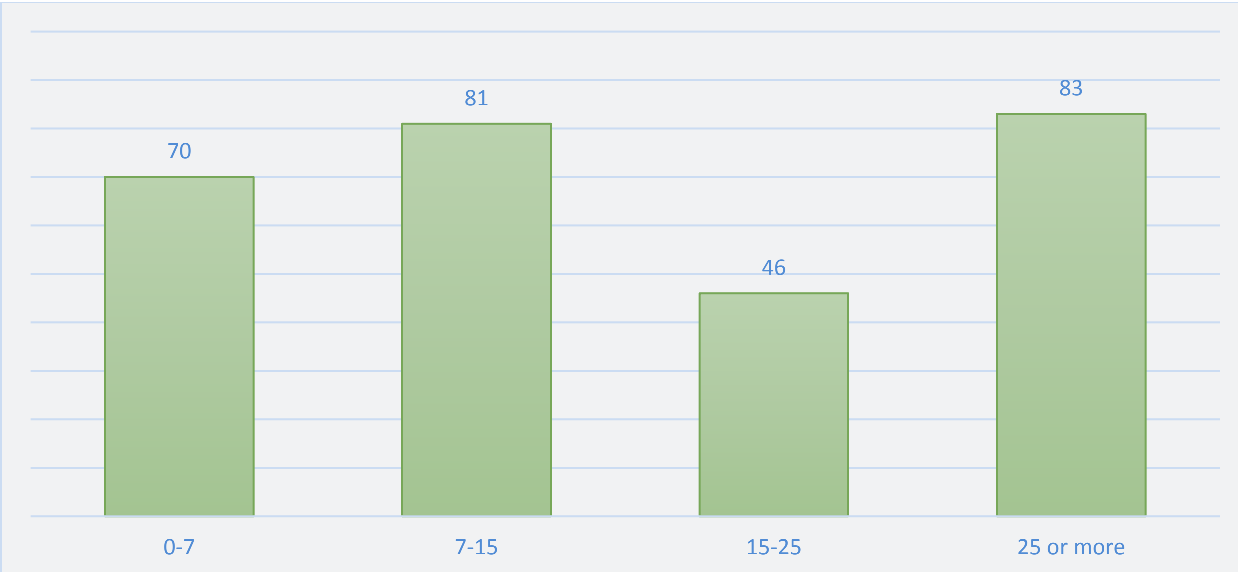

Figure 16: How many years have you worked in your field?

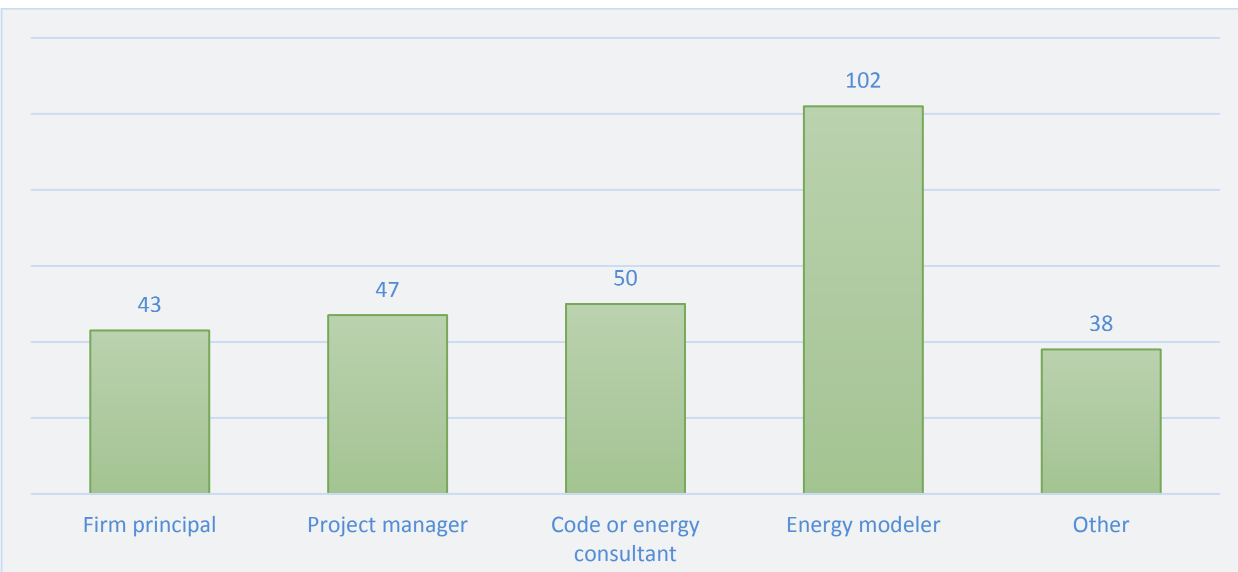

Figure 17: Please define your role in the energy code compliance of your projects.

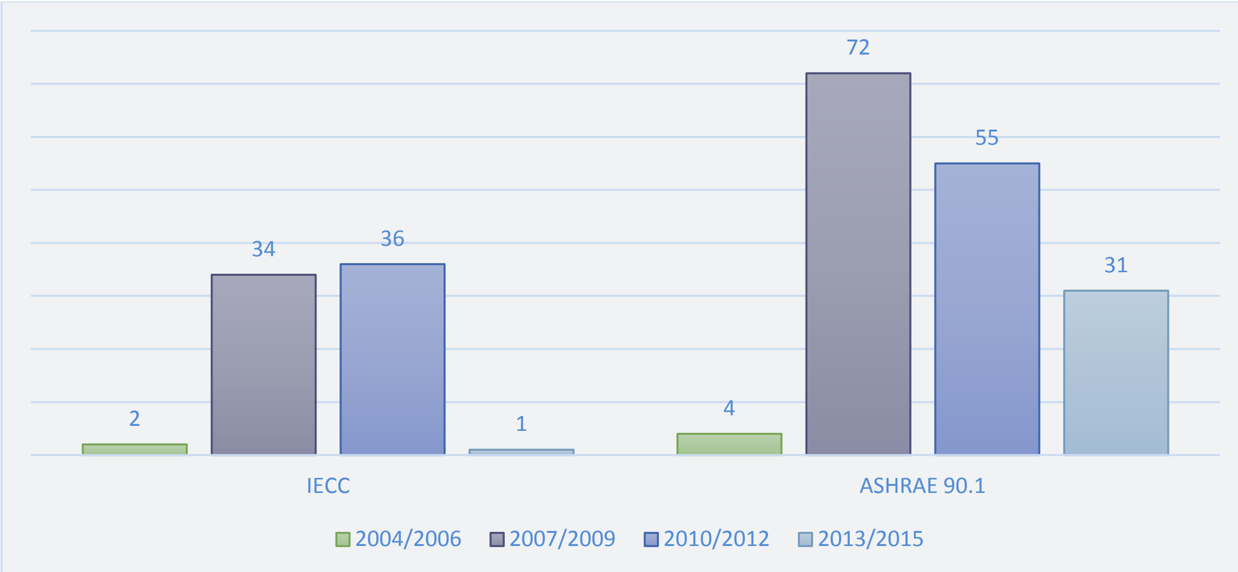

Figure 18: Which national model energy code do you use the most frequently?

The five most frequently used energy codes were ASHRAE 90.1 2007 (25.7% of respondents), ASHRAE 90.1 2010 (19.6%), the 2012 IECC (12.9%), the 2009 IECC (12.1%), and ASHRAE 90.1 2013 (11.1%).

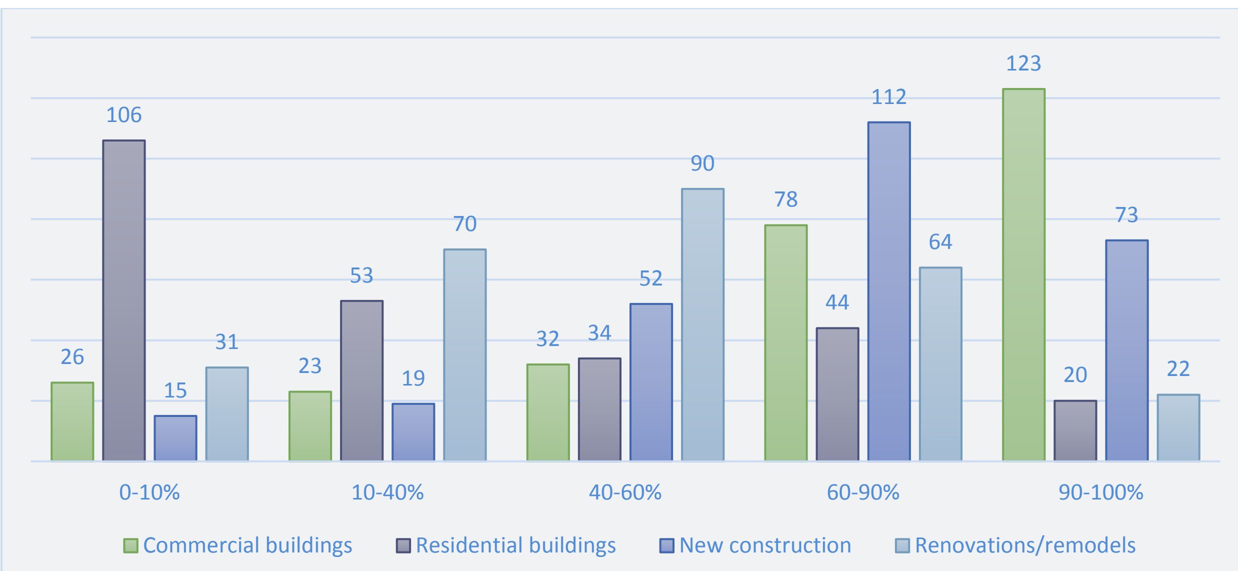

Figure 19: Please indicate how often your work involves each of the following building types.

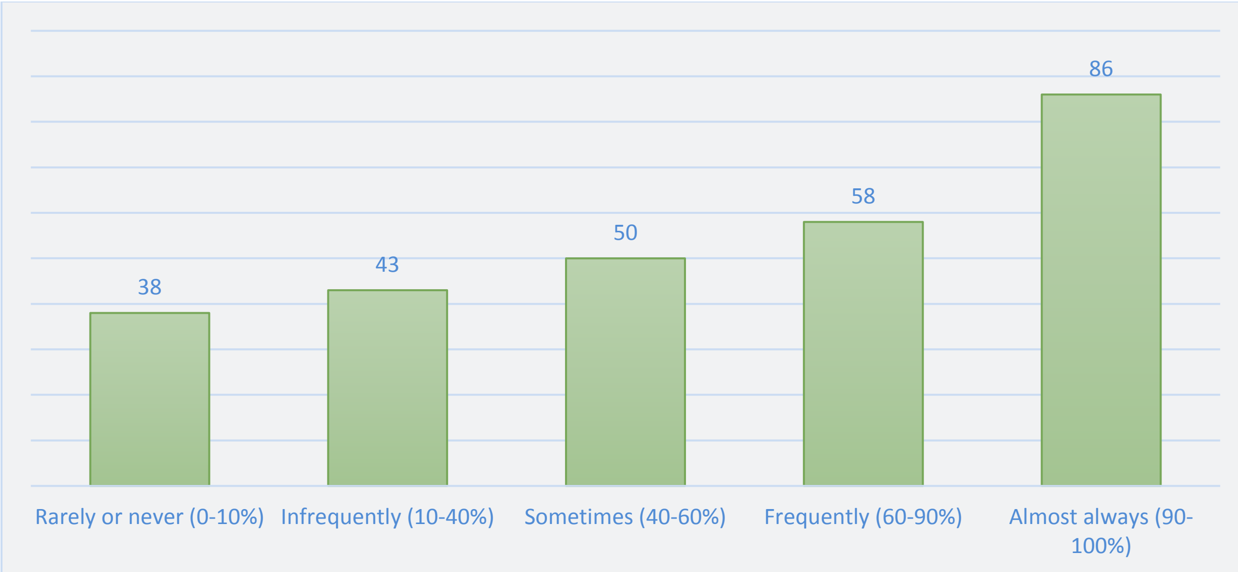

Figure 20: How often is the performance path used in your designs for energy code compliance?

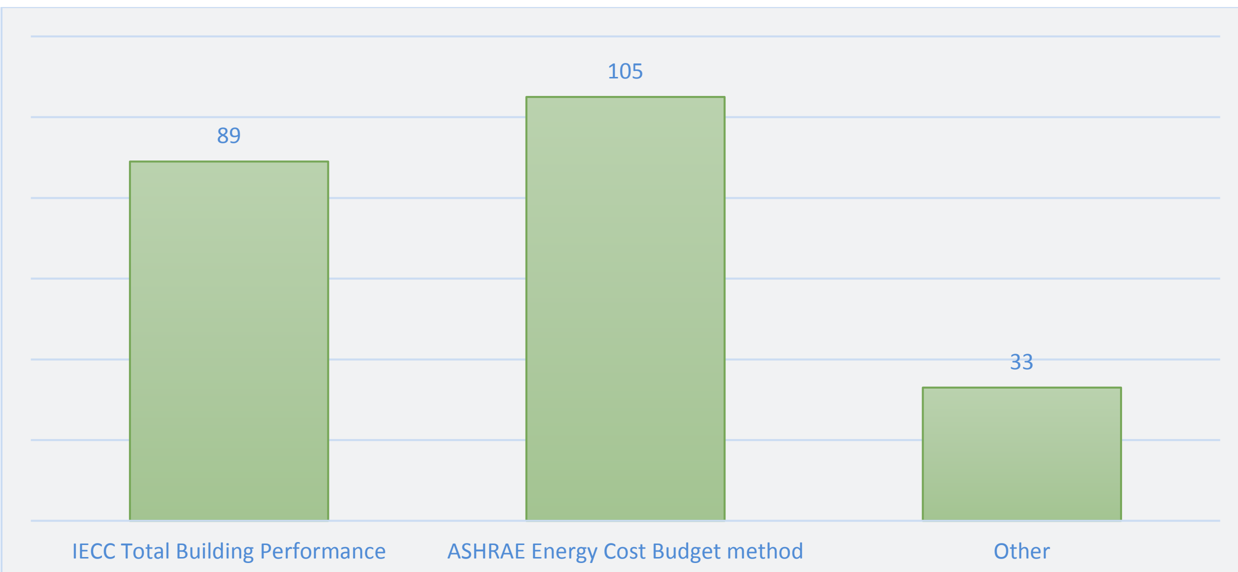

Figure 21: Which of the following is more likely to be used for performance path code compliance?

Other respondents indicated that they used state-specific codes, HERS scores, or the Performance Rating Method (PRM), although the PRM is typically used as an above-code measure.

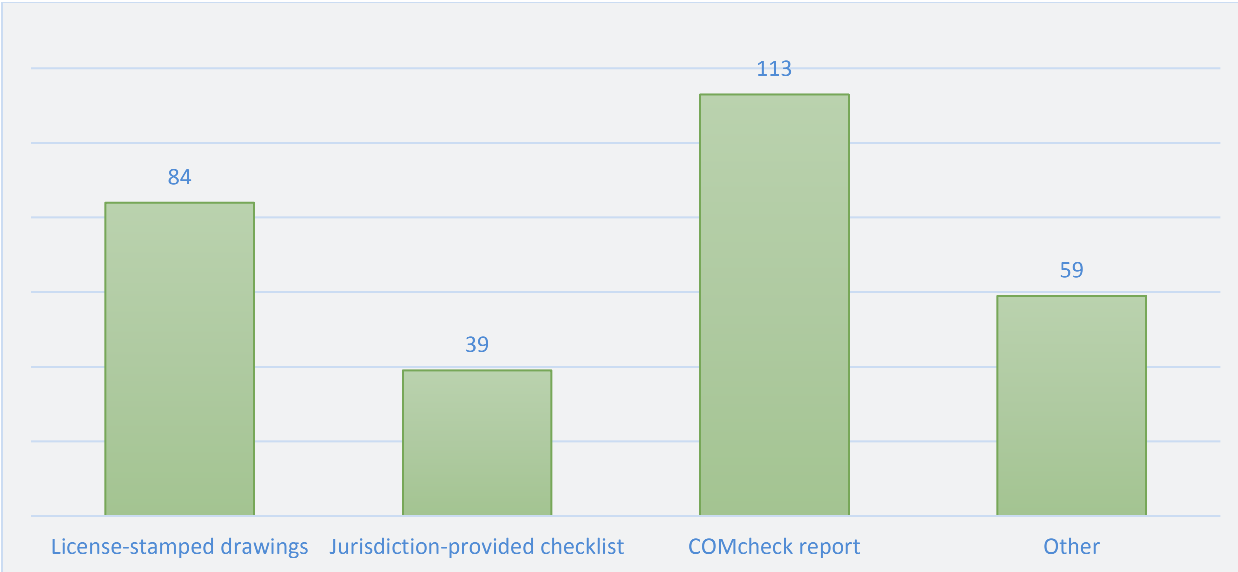

Figure 22: When using the performance path, how do you show compliance to the local jurisdiction?

Other responses included the ASHRAE ECB forms, REScheck, state-specific materials, and compliance reports generated from energy modeling software.

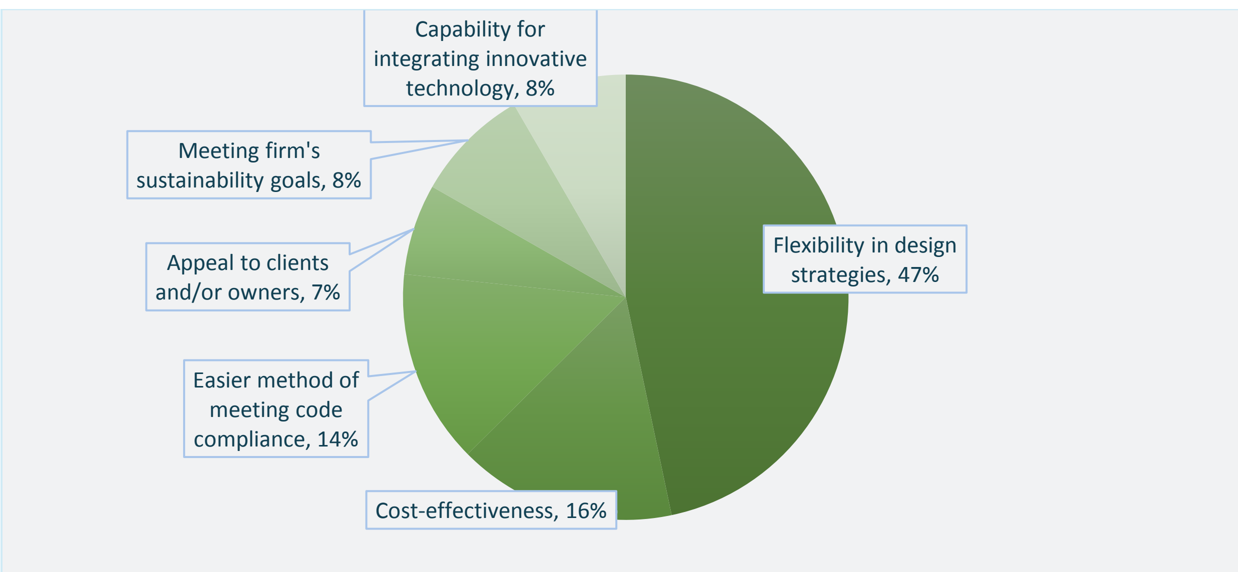

Figure 23: What is the biggest factor in choosing the performance path over the prescriptive path?

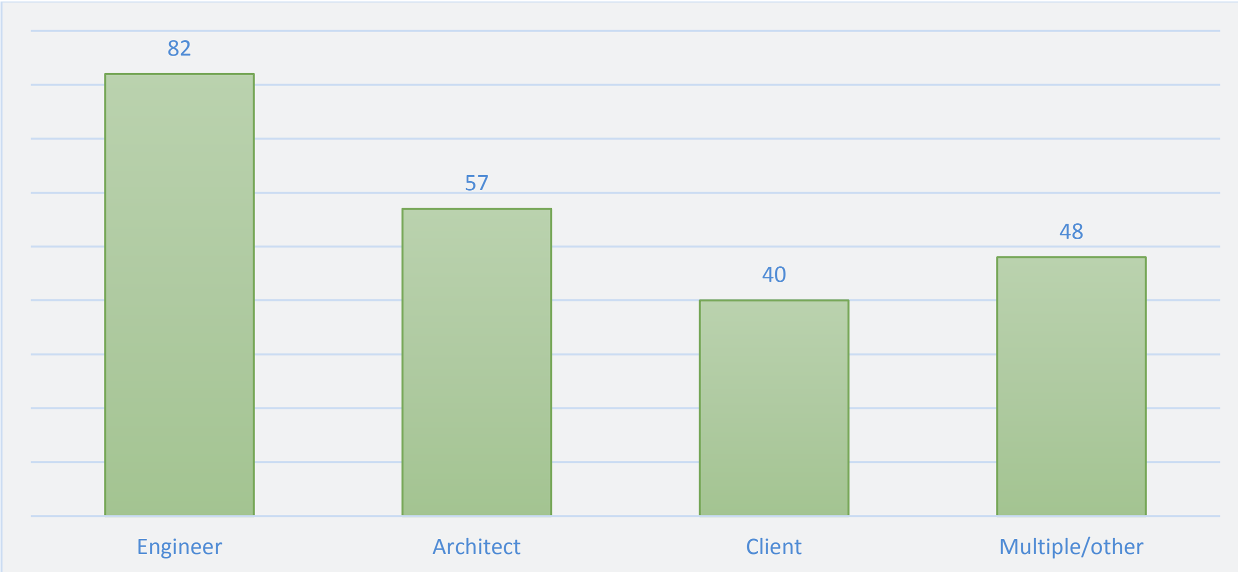

Figure 24: Who ultimately chooses which compliance path to pursue?

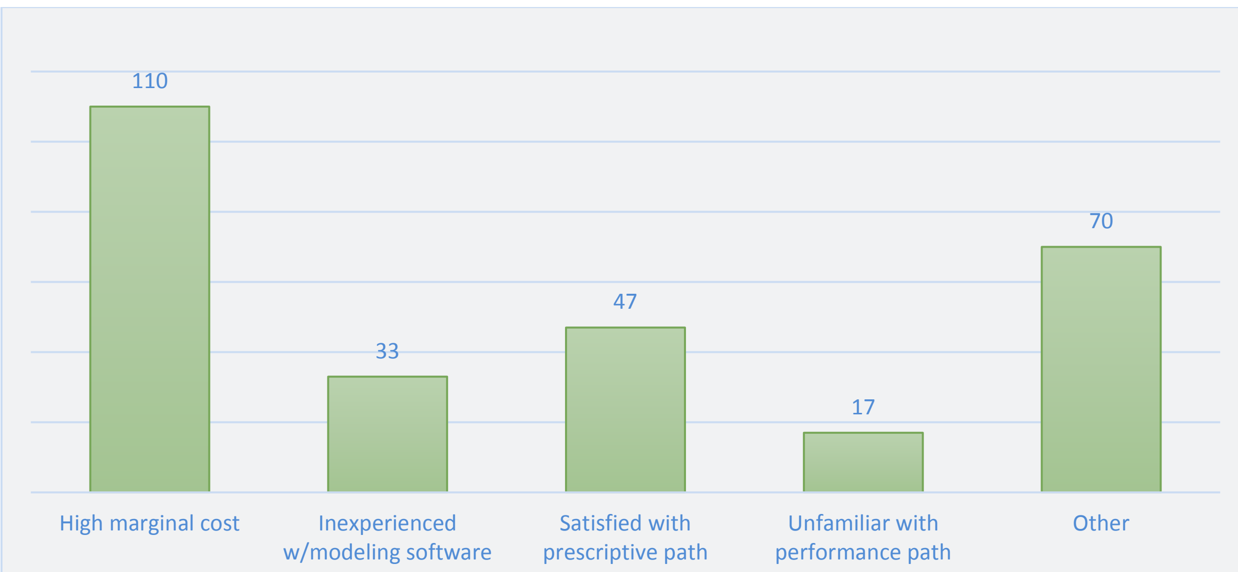

Figure 25: What have you found to be the biggest factors limiting your use of the performance path?

Selected open/"other" responses: What have you found to be the biggest factors limiting your use of the performance path?

- *Not as accurate as would be ideal, too complicated*
- *Lack of client understanding, difficulty selling owner on long term benefits of extra design phase*
- *Lack of code enforcement; code officials are unfamiliar with how to review it*
- *Design professionals' preferences*
- *Energy code stringency has effectively removed performance path flexibility*
- *Lack of experience of other team members, especially the architect*
- *Easier for the client to use prescriptive*
- *Time and cost to perform energy modeling*
- *Client education and/or lack of willingness to pay*
- *Not required by client*
- *Time vs. time to use COMcheck*
- *Models do not accurately reflect energy use in existing buildings*
- *Tough to get architects to pay extra and make time in the design schedule for modeling*
- *No option for building type in the code being referenced*
- *Energy modeling is generally used for design assistance and predicting future building performance. The prescriptive path is generally adequate to show code compliance.*
- *System designs that do not lend itself to using performance path.*
- *No options for shell versus tenant buildout versus partial tenant buildout. Limited number of building types to choose from*
- *Permitting authority does not understand method*
- *Multitude of modeling software, none is the "silver bullet"*

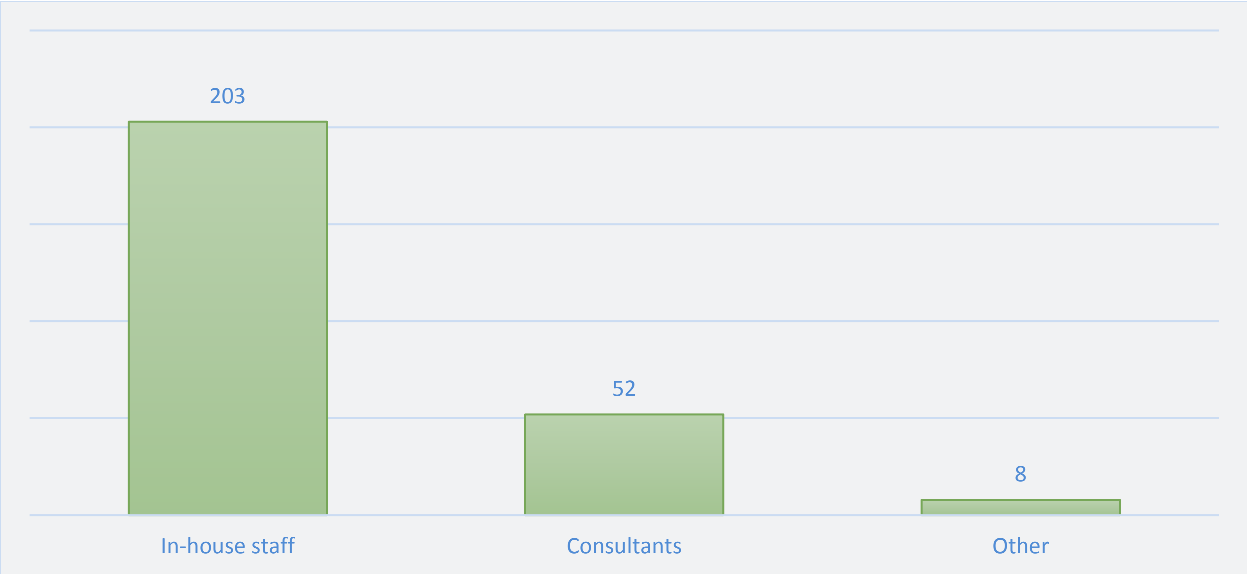

Figure 26: What kinds of energy modeling personnel does your firm use?

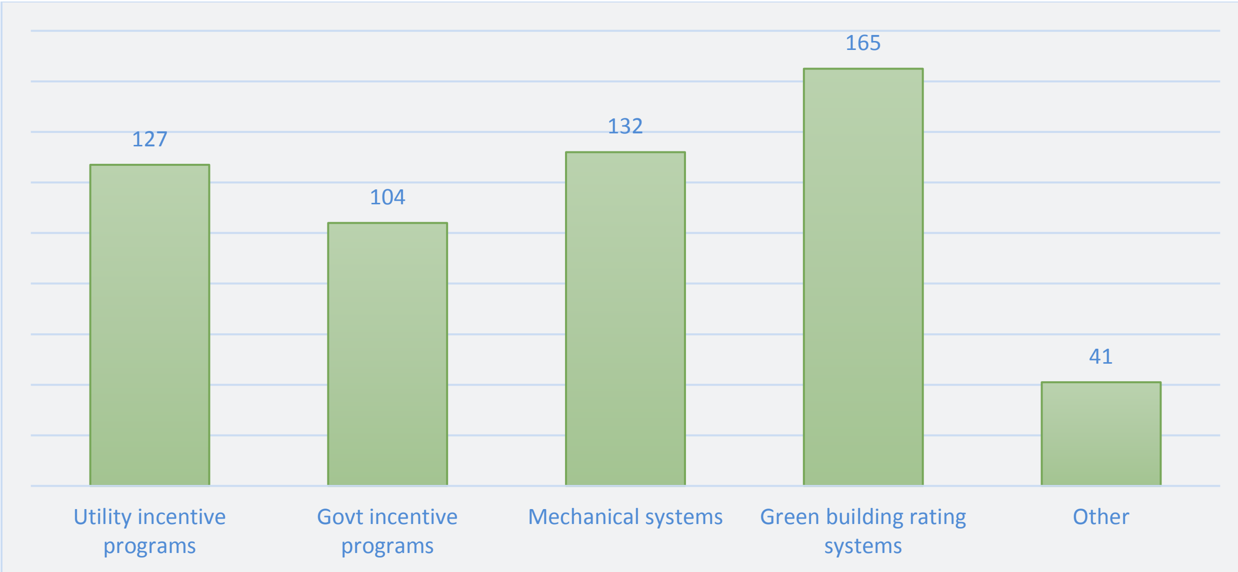

Figure 27: Other than code compliance, what uses has your firm found for energy modeling software?

Other responses included Life Cycle Cost Analysis (LCCA), new system development, and performance contracting.

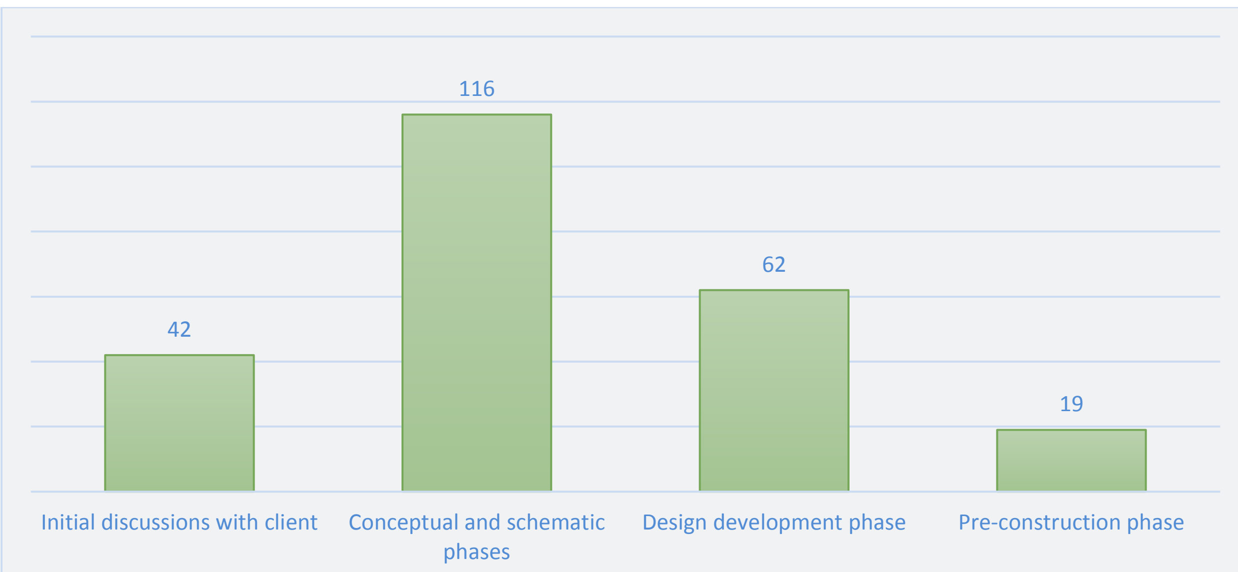

Figure 28: Where in the timeframe of a project do you start to apply energy modeling?

Respondents were also asked to rank 11 different qualities of energy modeling software in order of importance. The table below shows these qualities in order of average rating. Ease of use was by far the most popular, with 98 people considering that most important.

Answer Options	← most important									least important →	Rating Average
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	***11***	
Easy to use	98	33	20	15	13	20	11	15	5	5	4	3.37
Flexible use/navigation	25	30	30	32	19	38	23	23	7	9	3	4.84
Affordable	45	41	22	14	14	19	18	14	17	17	18	4.99
Quick analysis for iterative modeling	14	26	25	23	23	33	19	40	16	18	2	5.63
Can compare several designs	12	27	28	33	22	22	16	18	43	14	4	5.65
Graphic representation of inputs	2	16	28	32	26	31	21	20	23	22	18	6.25
Graphic representation of outputs	6	15	17	23	40	19	28	27	23	28	13	6.42
CAD/BIM compatible	18	24	30	12	19	12	16	22	22	20	44	6.45
Shows effect of one component on whole building	11	11	24	13	26	20	24	22	20	59	9	6.78
Climate database	4	4	6	18	24	13	52	21	38	23	36	7.53
Default assumptions made available as placeholders	4	12	9	24	13	12	11	17	25	24	88	8.09

Figure 29: Please rank these qualities of energy modeling software from most to least important.

Selected open responses: What missing features would make building performance analysis easier for you?

- *Trials of modeling software to see if it is worth the cost of software and training staff*
- *Logical, modern and intuitive layout of input screens, including mobile (phone/tablet) applications*
- *Option for manual climate data input*
- *Integration with drawings to reduce hands on entry, output into ACCA Manual J, REScheck, COMcheck*
- *Better R or U value defaults for detailed assemblies*
- *Code official recognized CAD energy modeling*
- *Utility rates for specific project area - either STATE DOE rates or actual utility rates; alignment with local utility rebate programs; comparison with actual building utility data*
- *Output features that clearly show when minor changes make the total design trade-offs work, suggestions for reaching code compliance*
- *Ranges of assumptions (i.e. R-value from 0.1 to 100)*
- *More tutorials, including specific examples of how to model different system types*
- *Availability of more built-in HVAC systems and components; performance data from manufacturers; built-in renewable energy systems; built-in multiple units selection*
- *Material and equipment libraries with reliable material and performance properties*
- *Improved, affordable CAD/BIM integration; ability to cleanly import BIM data and MEP schedules; one single platform and/or model for better coordination*
- *Easier to navigate report formats; custom report options*
- *Database of performance of similar structures and use*
- *Accurate inputs/outputs for ASHRAE 62.1, daylighting analysis, thermal comfort analysis*
- *Help screen features for simple explanations of software components; training disks; sample exercises*
- *Better handling of common HVAC types*
- *More detailed modeling options for varied HVAC air-side and water-side systems*
- *Transparent documentation of calculation methodology and assumptions, including margin of error; integration of techniques to assess confidence in results*
- *More system options and types, better confidence in newer system types*
- *More preconfigured HVAC system types, better default schedules for defined building types and performance curves, certification lists and options preconfigured*
- *Sensitivity analysis of multiple parameters*
- *More flexibility to create custom functions/modules*
- *Integration of innovative/cutting-edge HVAC and LED*
- *Education about energy losses resulting from poor design/construction, maintenance and operations*
- *Merging of load calculation software with energy modeling software*
- *Integration with equipment/system costs for material and installation to allow financial analysis*
- *Improved graphical representation of model (for visual verification) and outputs*
- *Increased adoption of low-cost software supported as an ASHRAE maintenance standard*
- *Automated creation of the reference model, whether that is a code reference or a specified baseline*
- *Improved accuracy for passive solar gains and thermal mass, air source heat pump efficiency, domestic hot water, passive solar heating, passive cooling*
- *Necessary outputs for code compliance and green building standard compliance*
- *Life cycle cost, integration with cost analysis program*
- *Ability to efficiently update energy model geometry based on architectural model*
- *Ability to link BMS data to energy modeling to facilitate post-occupancy analysis comparison*
- *Input interface that aligns with a decision-making protocol*

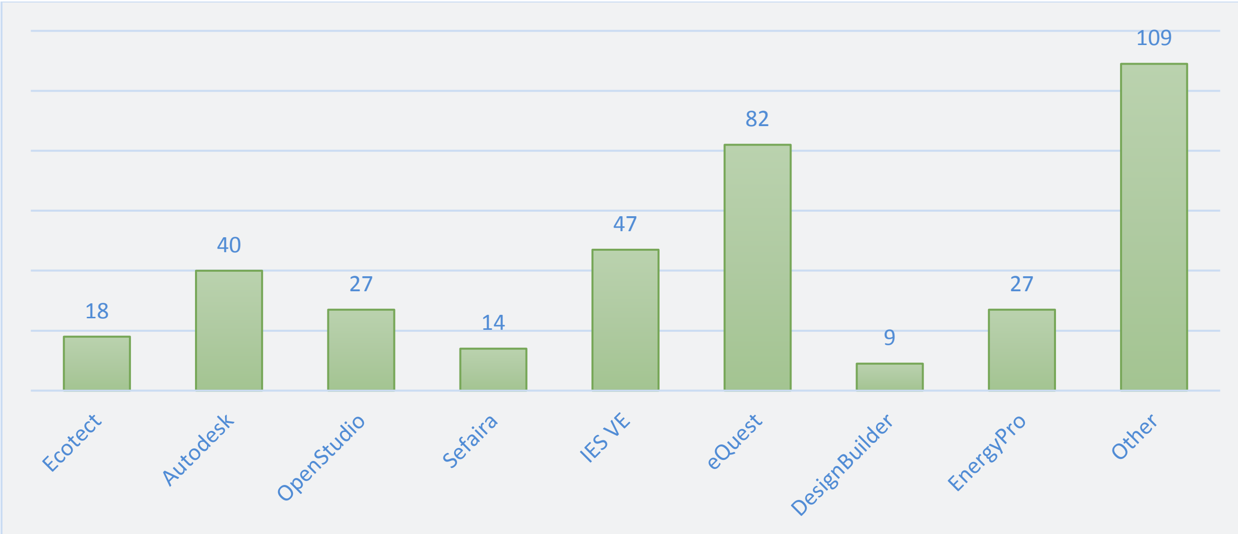

Figure 30: What software have you used the most?

Software mentioned most often in the **Other** category included Trane Trace 700 (40 responses), Carrier HAP (18), EnergyPlus (10), COM*check* (7), and RES*check* (7).

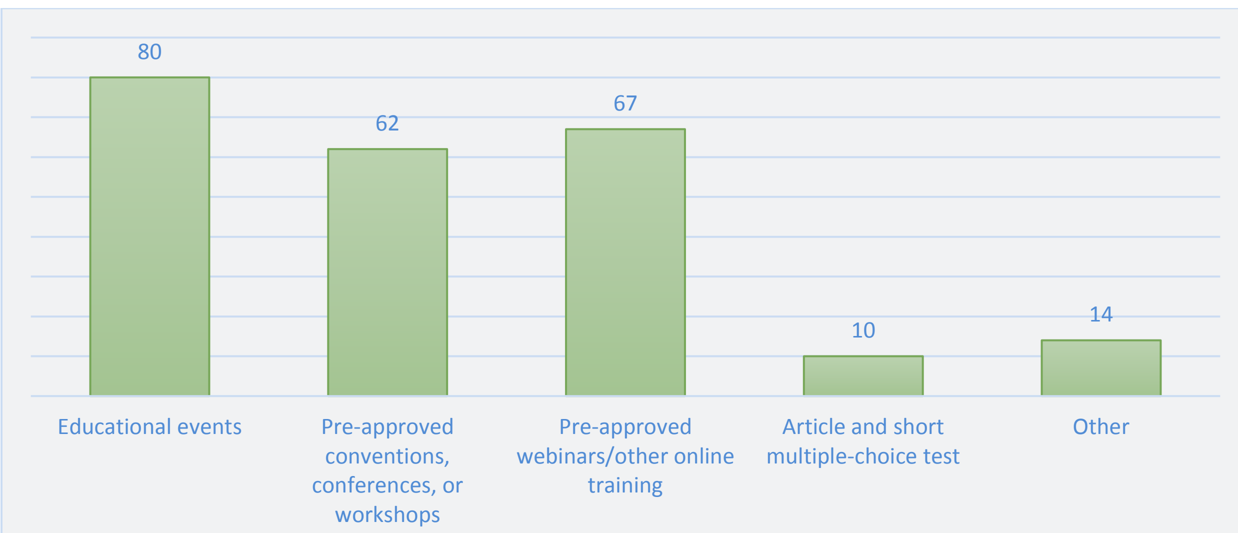

Figure 31: How do you earn most of your required continuing education units (CEUs)?

Answer Options	1	2	3	4	5	Rating Average
Educational events	95	55	61	19	3	*2.06*
Pre-approved webinars or other online training	54	70	95	12	2	*2.30*
Pre-approved conventions, conferences, or workshops	55	84	45	41	8	*2.41*
Article followed by a short multiple-choice test	17	22	25	148	21	*3.58*
Other	12	2	7	13	199	*4.65*

Figure 32: Please rank your order of preference for earning your CEUs.

Selected open responses: How do you earn most of your required continuing education units (CEUs)?

- *All of the above*
- *Teaching workshops/delivering training to other professionals*
- *LEED project experience*
- *Lunch and learns*
- *In-house seminars*
- *Web-based learning such as webinars*
- *ASHRAE meetings*

Selected open responses: If you have another preferred method for earning CEUs, please describe it briefly.

- *Vendor sponsored workshops for training on using their products*
- *Attending ICC Code Hearings*
- *Well-developed courses on subscription sites that are available at will*
- *Attending local chapter meetings (ASHRAE, IBPSA, etc.)*
- *In-house seminars at work that summarize a very specific topic and provides CEU documentation*
- *Professional society seminars/meetings*
- *Writing an article, giving a webinar, or presenting at a local USGBC/ASHRAE/AIA event*
- *Teaching (multiple responses)*
- *Lunch and learns (multiple responses)*