Selecting Energy Efficiency Measures Beyond 2012 IECC for Utility Programs, Stretch Codes and Base Codes

Jim Edelson and Mark Frankel, New Buildings Institute

ABSTRACT

This paper describes methodologies to inventory and select measures from a wide range of sources for developing codes and programs at higher energy savings levels. The methods used for development of base codes and stretch codes are based on the experience of New Buildings Institute (NBI) in multiple states. For utility-based programs, a parallel approach was used in the *Advanced Buildings: New Construction Guide* that taps deeper efficiencies from prescriptive strategies, begins to incorporate previously under-regulated loads such as plug loads, and leverages a collection of highly effective design strategy pathways. In allowing a project to select one or more pathways, program flexibility is increased for buildings that seek to achieve higher levels of savings. To support quantitative evaluation of these code and utility efforts, NBI conducted extensive prototype analysis for measuring energy savings beyond 2012 IECC.

Introduction

Increasingly stringent energy codes since the first 'Energy Crisis' in the 1970s have significantly decreased energy consumption levels in commercial buildings as represented by simulations of building energy use. Jurisdictions with consistent energy code enforcement, such as California and Washington, have been able to demonstrate progressive improvement in their building stock. This matches the policy objectives of the U.S. Department of Energy and several states, including California. As shown in Figure 1 below, the ASHRAE 90.1-2010 standard (and the equally efficient 2012 IECC) shows a reduction of 40% of code-regulated energy use compared with the standards in place in 1975. With these increases in prescriptive code stringency, it is becoming increasingly challenging to prescribe a universal set of measures that can achieve additional energy savings across the full range of building types, climate zones, and operating conditions.

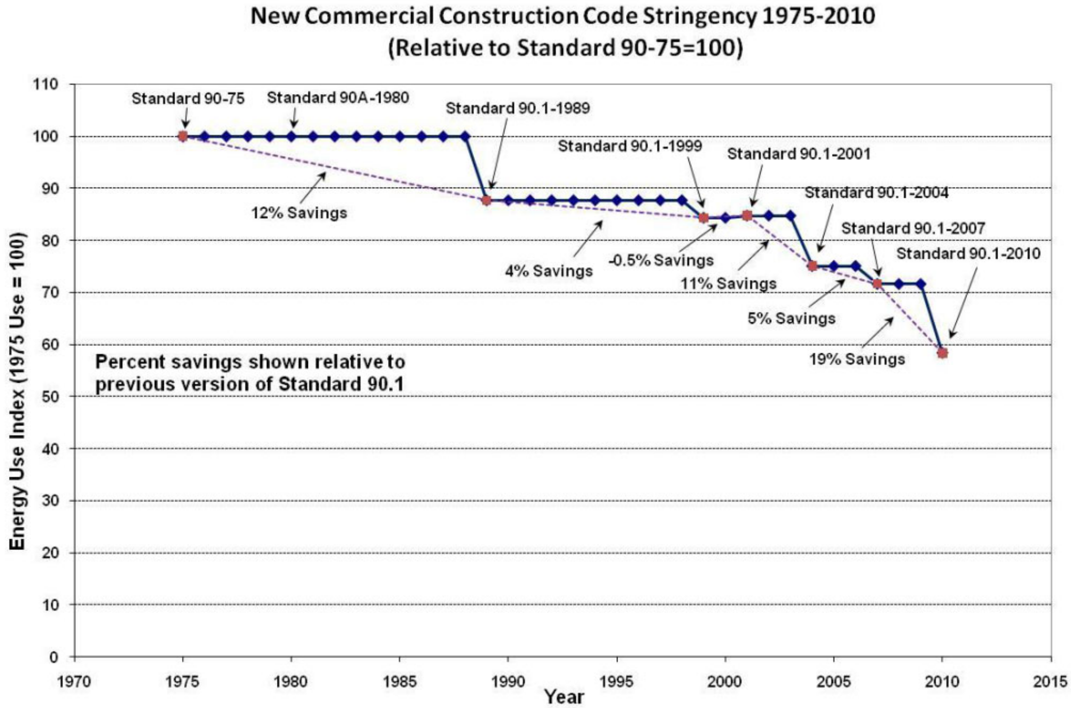

Figure 1. New commercial construction code stringency 1975-2010 relative to 1975 energy use of '100'.
Source: Pacific Northwest National Labs, 2011

Sourcing New Measures for Energy Codes and Utility Programs

Although a steady progression in code improvement is depicted in Figure 1, these improvements do not incorporate improvements in the energy performance of appliances and equipment that are typically installed after the building begins operation, sometimes referred to as 'plug loads.' In addition, these reductions do not take into account the way the building is operated or maintained. Taken together, these two factors comprise an increasing fraction of total building energy use as the energy use of the 'regulated' systems decreases. This paper will examine how measures were selected beyond standards and code levels adopted in code cycles that culminated in 2012, and will include measures to address those increasingly important 'unregulated' loads.

This paper uses the examples of the 2014 Vermont Stretch Code, the City of Boulder Energy Code, and the *Advanced Buildings: New Construction Guide*, a utility program of NBI, to illustrate the interconnected nature of the measure development process. In the development of the current *New Construction Guide* (release date April, 2014), once again there was a virtuous cycle in play as the *Guide* was directly related to current and pending code applications. Taken together, the *Guide* and the two examples of codes described here have successfully sourced a wide range of measures for a new cycle of codes and programs.

Shown in Figure 2 below is the interplay in the cycles of codes that lead from utility programs, such as the ones based on the *New Construction Guide*, that were the source of many significant revisions of the 2009 IECC that led to the 2012 IECC.

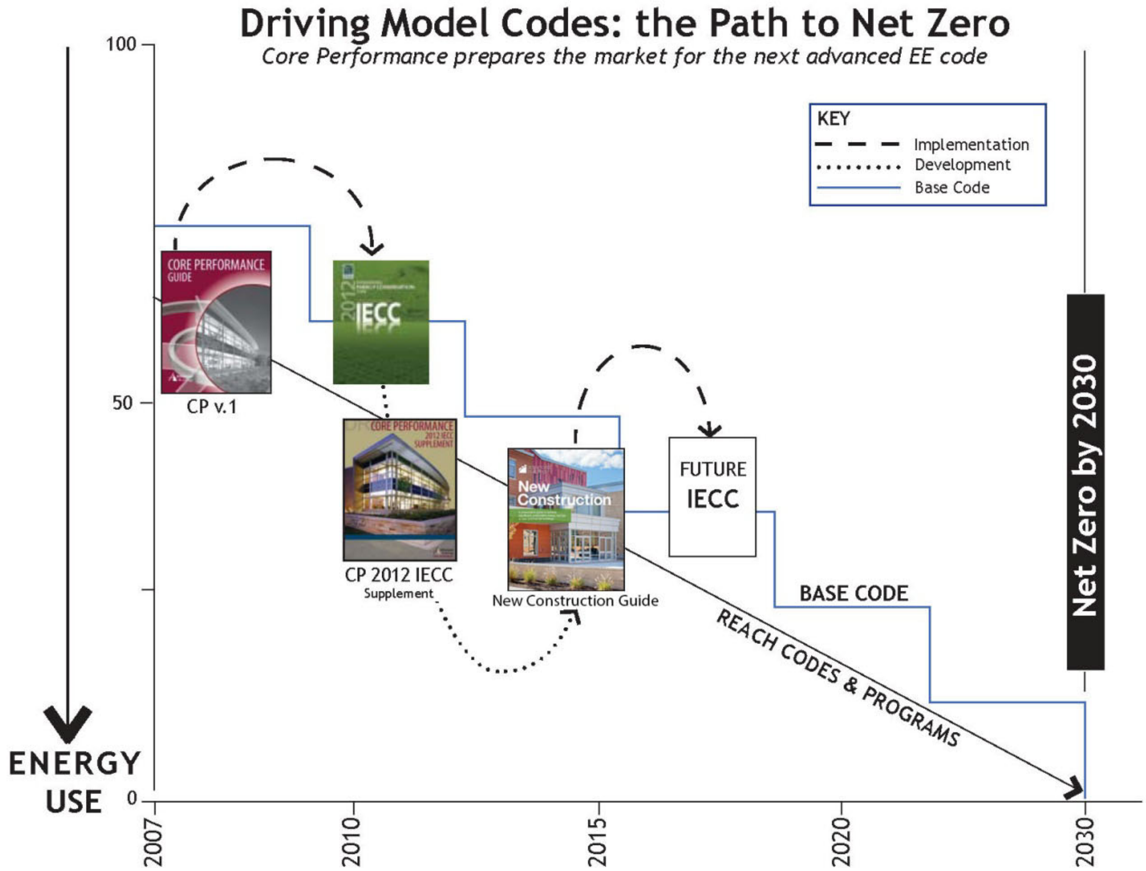

Figure 2. Relationship of new construction programs to reach codes and base codes. *Source:* NBI, 2013.

First, we will examine the objectives of the *New Construction Guide*, how efficiency measures were sourced to create the *Guide*, and how modeling supported evaluation of the level of savings achieved. Second, we will look at how the State of Vermont, and its partner the Vermont Energy Investment Corporation, used some of the measures in the *Guide* and added other sources, such as the next version of the 2015 IEEC, to create a stretch code framework for Vermont. Finally, we will look at how the City of Boulder largely depended on the *Guide* to develop a new prescriptive path to a revised energy code per an ordinance that took effect January 31, 2014.

Advanced Buildings New Construction Guide

During the update cycle for the 2012 *International Energy Conservation Code,* significant technical content from the *Advanced Buildings: Core Performance Guide* was submitted as a comprehensive code update proposal. Through the code process, much of that content was nationally vetted, revised and ultimately adopted as part of the 2012 IECC, resulting in an increase in code stringency of approximately 25% from the 2006 IECC. Previously, the *Core Performance Guide* had been the basis for commercial whole-building utility incentive programs; with the success of the "Core to Code" proposal process, first implemented in the

Massachusetts stretch code, *Core Performance* would not be able to deliver the same level of savings above the new 2012 code baseline. In response, New Buildings Institute began development of a new commercial whole-building prescriptive guide to succeed *Core Performance.* While some states and jurisdictions would be moving to the 'modern' model codes like the 2012 IECC or the roughly equivalent ASHRAE/ANSI/IESNA Standard 90.1-2010, many states and jurisdictions were maintaining 'legacy' versions of those model codes with stringencies at least 25% lower, such as 2006 IECC. So, any prescriptive guide that could deliver significant savings over the modern code baselines would likely be more stringent than markets with legacy code baselines could bear. The successor to the *Core Performance Guide* would have to be structured in a way to respond to this diverse code ecology.

The *New Construction Guide* is structured in a series of increasingly stringent Tiers capable of delivering savings over code baselines with different levels of stringency, or delivering different levels of savings over any single code baseline. Tiers 1 and 2 each contain a comprehensive set of Criteria addressing a full array of building features, from the thermal envelope to lighting efficiency and control to HVAC components. Tier 1 is equivalent to the 2012 IECC and is based on the technical content of the *Core Performance Guide*, as revised by the 2012 code update process. Tier 1 of the program therefore offers a savings strategy over the 'legacy' code baselines still in force in many jurisdictions. Beyond that, the set of prescriptive measures in Tier 2 deliver significant savings above the 'modern' code baselines such as the 2012 IECC and 2010 ASHRAE-90.1. Tier 3 is the next level of savings, but does not contain a comprehensive set of measures as in Tiers 1 and 2. Instead, Tier 3 contains a set of "performance pathways;" energy savings measures that can save significant energy but may not be appropriate for all building types or all individual designs due to the impact on the building design. Although many of these performance pathways can be used together, designers would generally select only one or two of the performance pathways since each can have significant design impacts.

To address savings opportunities represented by unregulated plug loads and building operational practices, the *New Construction Guide* also incorporates a series of measures to address ongoing operational energy. These measures include basic acceptance testing (commissioning) requirements, the implementation of building metering and feedback strategies, and requirements for hard-wired plug load controls and efficient appliances. In general these measures represent a new focus area for both utility incentive programs and building energy codes, since these strategies tend to address aspects of the building that are not in place at the end of the construction phase. Since these unregulated loads represent a significant and growing opportunity for energy savings in both new and existing buildings, with each code cycle it becomes more clear that long-term performance goals for the building stock must include effective strategies to address ongoing building operational energy.

Sourcing and Compiling the Measures for the New Construction Guide

NBI took a multi-faceted approach to develop the content of the *New Construction Guide.* The different performance levels of the three Tiers each call for a different developmental approach.

Tier 1 is based on the *Core Performance Guide* and 2012 IECC. Where the content of *Core Performance* was used a source to revise the IECC, it was not used verbatim. A national vetting process revised, updated and added to the requirements of *Core Performance* before they were adopted in the IECC. This process was then used to revise the *Core Performance Guide* and to create a supplement to *Core Performance* that fully aligned the requirements of C*ore Performance* with the finalized requirements of IECC-2012. This "2012 Supplement" was the basis for Tier 1 of the *New Construction Guide* (see Figure 1).

Tier 2 required the development of a whole new set of requirements. A wide net, both within and beyond NBI, was used to identify potential requirements. NBI looked at existing codes such as California's Title 24, and ASHRAE's Standards 189.1 and 90.1-2013, as well as existing above-code programs such as the Collaborative for High Performance Schools, USGBC's LEED program and the ASHRAE *Advanced Building Design Guides.* NBI also leveraged its involvement in the development of next-generation codes such as the *International Green Construction Code (IgCC),* the 2015 edition of the IECC, and the 2013 edition of ASHRAE's Standard 90.1 and work on the Massachusetts stretch code.

NBI combined this external sourcing with significant internal development work. NBI's Office of the Future, Daylighting Pattern Guide, Advanced Lighting Guidelines and the Plug Load Best Practices Guide were referenced in addition to general building performance research and HVAC research conducted in-house. The combination and refinements of these sources were used to define the requirements of Tier 2. In addition to the 'traditional' requirements specifying insulation levels, window performance and LPD requirements, Tier 2 also includes new requirements such as the verification of air barrier performance, exterior lighting sensor controls, fan power limits and daylighting controls.

As much of the technical content of the *Core Performance Guide* was migrated into the 2012 IECC, it became evident that achieving significant savings over modern code baselines with a universal prescriptive standard[1] would become challenging and, in some instances, begin to approach technical limits. Improvements in technologies and cost-effectiveness allowed Tier 2 to attain higher levels of performance than had been expected a couple of years earlier during the IECC-2012 development. However, since some of the concepts for Tier 2 came from the development of pending editions of the IECC and ASHRAE 90.1, and some of the concepts developed for Tier 2 were going into that development process, the performance premium of Tier 2 over those national model codes will soon be eroded as states and cities adopt those changes.

In order to respond to the continued upward trend of the code baselines and to offer even greater performance levels, it became clear that an alternative to the universal requirements approach would be necessary in Tier 3. Research into building performance conducted by NBI showed there were approaches to efficiency that could deliver significant savings, but the realities of different buildings types, different climates and even different designs meant these approaches were neither universally appropriate nor consistently effective. This meant they could not be required in the "universal requirements" model. Additionally, although the code is neutral as to HVAC system type, different HVAC system types can deliver significantly different performance levels in the same building design – and offer ranges of energy savings not achieved by increasing equipment standards alone.

NBI had introduced the concept of "Additional Efficiency Package Options" into the IECC-2012, where projects are required to select one of three "Efficiency Packages" in order to demonstrate code compliance. The approach was developed as a way to generate additional savings in the energy code while also crediting HVAC efficiency beyond the federal HVAC

[1] A universal prescriptive standard is the traditional prescriptive standard where every building is required to meet essentially every requirement of the standard. There may be some building type-specific requirements, but there is essentially only one path through the prescriptive standard.

efficiency requirements,[2] but was readily adapted for use in Tier 3. Tier 3 is composed of seven performance pathways. Each performance pathway defines an approach to efficiency that generates significant savings, but may not be appropriate for every building. The performance pathways include the following:

- "Advanced Envelope" defines a super-insulated shell with limited window area and infiltration.
- "Advanced Daylighting" defines a set of requirements that result in a building design that is essentially fully lit by daylight with integrated electric lighting controls.
- "Advanced Office Lighting Design" defines a high performance lighting design for offices based on highly efficient equipment, special design, sophisticated lighting design of a task-ambient system and a high degree of occupancy control.
- Three advanced HVAC system pathways including Ground Source Heat Pumps, Variable Capacity Heat Pumps and Radiant systems, typically paired with Dedicated Outdoor Air Systems.
- Plug Load Controls addressing plug equipment efficiencies, control strategies, and off-hour use management.

Modeling the Measures in the Advanced Buildings: New Construction Guide

An extensive energy modeling protocol has been implemented to support development of the *Advanced Buildings: New Construction Guide*.

The protocol uses a batch modeling tool developed by NBI and Madison Engineering over the past seven years to analyze large numbers of variations of measure combinations, building and system prototypes, climate characteristics, and code baselines in support of the development of the *Advanced Buildings: New Construction Guide*. The tool is capable of analyzing the energy impact of various combinations of the above factors in batches of tens of thousands of modeling runs in a single application. In all, several hundred thousand individual energy modeling analyses have been conducted in support of the development of the program.

The tool uses the eQUEST energy modeling software as the basic calculation engine. A custom front-end developed by Madison Engineering is used to set up the batch analysis, and the results are sorted into a very large Excel spreadsheet that incorporates a series of customized macros, functions, and formatting protocols to display the results in a form that can be easily reviewed and evaluated. This tool not only allows the comparison of a wide range of program variables, but also the generation of an effective comparison of different code baselines with respect to their relative stringency. This capability allows the comparison of information about the relative stringency of a range of code baselines to each other.

To develop this analysis, five building prototypes were identified to represent a portion of the building stock. The prototypes included a medium-size office building, a school, a retail building, a warehouse, and a midrise multifamily residential building. The prototypes were drawn from other nationally significant analyses, including the NREL existing building prototypes, the California DEER analysis, and NBI's prior analysis for the *Core Performance*

[2] HVAC efficiency is regulated at the federal level. These requirements both set a minimum efficiency standard, but also a maximum efficiency level that energy codes can require. Mandatory energy codes, in general, cannot require HVAC equipment that is more efficient than the federal standards.

Guide. For each prototype, three to five HVAC system types were defined. Each of these prototypes and variants was evaluated across ASHRAE climate zones.

The analysis was set up to establish savings for the successive bundled measures (Tier 1 and Tier 2) against a series of code baselines. Within each bundle, individual measure savings were also evaluated to verify savings and assess interactive effects of the measure bundles. The savings of Tier 3 pathways were evaluated individually.

The results of this analysis demonstrated that the new whole-building measure package developed for Tier 2 represented significant savings over the 2012 generation energy codes and could be used as a basis for utility incentives in jurisdictions with advanced codes in place. At the same time the Tier 1 bundle of measures could continue to serve as the basis of whole-building incentives in jurisdictions that had not yet adopted the newest national model energy codes. The evaluation of additional savings from Tier 3 pathways became a critical component of the aggressive code performance goals adopted by the City of Boulder, as discussed below.

State of Vermont Stretch Code

The State of Vermont, with the passage of Act 089 in 2013, created a new objective for a stretch code for energy efficiency in Vermont homes and buildings (Vermont, 2013). Vermont's stretch code joined a growing presence in the United States for many jurisdictions wanting to publish two levels of energy codes simultaneously. The more advanced levels of energy efficiency found in stretch codes allow implementing jurisdictions to acquire higher levels of energy savings for policy purposes, such as Zero Net Energy building directives, energy affordability, and carbon reduction goals.

In 2013, the Vermont Energy Investment Corporation contracted with NBI to develop a preliminary list of measures that would be made available to the Vermont Department of Public Services for the developmental foundation of Vermont's first stretch code. Using a format first developed in conjunction with Mathis Consulting Co. for revisions to the Massachusetts stretch code, NBI compiled additional measures from the newest versions and drafts of 90.1-2013 and 2015 IECC. In addition, measures were investigated from new versions of other state codes, such as California Title 24-2014, the 2011 Oregon reach code, and from material collected for the Massachusetts stretch code itself. Of course, this was also compared to the incumbent Vermont code, the 2011 Commercial Building Energy Standard (CBES).

From the review of this material, a final matrix was developed that would be useful for the Vermont Department of Public Service (Department) to take to public proceedings. This comprehensive code development matrix now embodies the work of many measure development venues, and as a result has proved useful as a foundation for formulating the first stretch code in Vermont. An extract of the matrix is found in Figure 3. The Department has taken these recommendations to the next phase of the CBES development process to prepare for rulemaking and final implementation.

2011 CBES	2012 IECC	Draft 2014 Mass. Stretch or NBI N/C Guide Tier 2	2015 IECC	Recommendation and Comments
HVAC Energy Recovery				
C503.2.6 Mandatory for systems with airflow >5000cfm.	Required for some systems	Required for ventilation systems with high airflow rates (>1000 CFM)	**CE214: Approved as Modified** – expand range of exhaust energy recovery down to 10% of outdoor air rate.	**2015 IECC as BASE; 1000 cfm as STRETCH**
Economizers				
C403.3.1 Performance verification economizer requirement C503.2.10.2.1	Required for some systems	Removed several exceptions to expand the use of economizers in key areas.	**CE209; CE247; CE249: Approved** Fault Detection and Diagnostic Requirements (CE209). Low-leakage damper rating and labeling required (CE247) and waterside(CE249)economizer for non- fan cooling systems	2015 IECC as BASE and STRETCH
Duct Leakage				
C503.2.7.1.1	N/A	Maximum leakage lowered from 6 to 4.No more than 5% of ductwork can be located outside of thermal envelope.	**CE223: Approved** – Duct sealing for low pressure systems and pressure classification on construction documents.	2015 IECC as BASE; lower leakage and outside duct limit as STRETCH

Figure 3. Commercial options for the Vermont stretch code. *Source:* NBI and Britt/Makela Group, 2014.

City of Boulder Energy Code

The Boulder Energy Code is a critical component for the City to meet its Climate Commitment goals. In 2013, the City passed a resolution to reduce greenhouse gas emissions 80% by 2050. Since buildings contribute up to 75% of greenhouse gas emissions, reducing emissions by improving building energy efficiencies is important to attaining Boulder's Climate Commitment goals. Recent updates of the program add measurement and verification mechanisms for retrofits and additions so that these types of existing buildings projects will also enhance program contributions to citywide goals.

Under Boulder's Energy Conservation Code, commercial buildings must achieve significant energy performance over national code baselines such as ASHRAE/IENSA Standard 90.1 or the International Energy Conservation Code. Based on actions taken by the City Council in October 2013, permit applications for commercial buildings larger than 20,000 square feet. must utilize predictive computer modeling to demonstrate energy performance that is at least 30% better than ASHRAE/IENSA Standard 90.1-2010. (City of Boulder, 2013) Permit applications for commercial buildings smaller than 20,000 square feet have the option to demonstrate energy code compliance by predictive modeling, but are also allowed to utilize 'approved' prescriptive standards that achieve energy performance of at least 30% better than the 2012 IECC. NBI was contracted to develop a *Boulder Application Guide* to describe prescriptive path compliance options for commercial buildings under 20,000 square feet. Prescriptive options are provided for new construction, additions, and retrofits.

NBI used the resources in *Advanced Buildings: New Construction Guide* to assemble measure-based packages that would meet the "30% beyond 2012 IECC" goal set forth in the ordinance. Four energy efficiency packages, plus one largely based on onsite-renewable energy, were developed for Boulder and subsequently modeled in eQUEST to represent the 30% savings. Each of the packages contains expanded plug load control measures and commissioning or functional testing of an expanded range of building systems. The packages shown in Figure 4 were written into a document entitled *Boulder Application Guide.* This approach was deemed by the City to meet the 30% goal for new construction and for buildings undergoing system and/or building retrofits. The savings for retrofit measures in existing buildings were measured against system-by-system savings, rather than the whole building savings modeled for new construction.

ALL Criteria this Column	**PLUS ONE** Package from this Column
Criteria 2.1: IECC 2012 Compliance Criteria 2.2: Air Barrier Performance Criteria 2.5: Daylighting Criteria 2.6: Lighting Controls Criteria 2.8: Exterior Lighting Efficiency Criteria 2.10: Economizer Criteria 2.11: Duct Construction Criteria 2.12: Fan Power Reduction Criteria 2.13: HVAC Controls Criteria 2.14: Fault Detection and Diagnostics Criteria 2.15: Water Heating Criteria 2.16: Acceptance Testing (Cx) Criteria 2.20: Lighting Power Density Criteria 2.22: Energy Recovery Ventilation Criteria 2.23: Demand Control Ventilation Criteria 3.8: Plug Loads	**Package A: Advanced Envelope:** Criteria 3.2: Advanced Envelope
	Package B: Advanced Daylighting: Criteria 2.18: Opaque Walls Criteria 2.19: Fenestration Criteria 3.3: Advanced Daylighting
	Package C: Advanced Office Lighting: Criteria 3.4: Advanced Office Lighting Criteria 2.18: Opaque Walls Criteria 2.19: Fenestration
	Package D: Advanced HVAC: Criteria 2.18: Opaque Walls Criteria 2.19: Fenestration **-AND EITHER-** Criteria 2.9: Efficient Equipment **-OR-** Criteria 3.6: VRF **-OR-** Criteria 3.7: Radiant Heating and Cooling
	Package E: Renewable Energy: Criteria 2.18: Opaque Walls Criteria 2.19: Fenestration **-AND-** An installed Renewable Energy System with a minimum system rating of 0.2 W/sf of conditioned area.

Figure 4. New construction compliance packages. *Source: Boulder Application Guide,* NBI, 2014.

As illustrated is Figure 4, in order to meet the goals of the ordinance setting forth Boulder's new Energy Conservation Code it was necessary to use a pathway approach. A pathway approach means that each building can choose the compliance path most suited to their project. The deeper energy savings pathways approach used in Boulder is one method for prescriptive codes to achieve greater energy savings objectives of new energy and climate policies. However, this need to go to a more 'customized' prescriptive path in the Boulder code development project reinforces the fact that there is limited headroom remaining in the traditional prescriptive energy code approach, and presents a continuing challenge for codes to find additional savings from plug loads, buildings operations, and occupant behavior.

Conclusion

With the examples of the *Advanced Buildings: New Construction Guide*, the proposed Vermont Stretch Code, and the 2014 City of Boulder Energy Code, it is demonstrated that there are measures and pathways that can produce significant energy savings beyond ASHRAE 90.1-2010 and 2012 IECC. Many state and local jurisdictions are seeking greater levels of energy use reduction in the building sector to meet climate and energy policy goals, and they now have the regulatory mechanisms available to begin meeting those goals. To make these regulations more effective, links have been formed between voluntary utility programs, stretch codes and base codes. The efforts described in this paper demonstrate, however, that only initial progress has been made in tackling the growing impacts, as a percentage of total building energy use, of plug load energy use and operational/tenant behavior. As energy programs and codes move along the path to net zero energy, developing advanced strategies to tackle these impacts is becoming the paramount challenge for both codes and programs in achieving energy use reductions in the building sector.

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