Roadmap Toward a Predictive Performance-based Commercial Energy Code

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ABSTRACT

Energy codes have provided significant increases in building efficiency over the last 38 years, since the first national energy code was published in late 1975.[1] The most commonly used path in energy codes, the prescriptive path, appears to be reaching a point of diminishing returns. The current focus on prescriptive codes has limitations including significant variation in actual energy performance depending on which prescriptive options are chosen, a lack of flexibility for designers and developers, and the inability to handle control optimization that is specific to building type and use. It is likely that an approach that considers the building as an integrated system will be necessary to achieve the next real gains in building efficiency. This paper provides a high level review of different formats for commercial building energy codes and explores a next generation commercial energy code approach that places a greater emphasis on performance-based criteria. A vision is outlined for future commercial code development being led by a specific approach to predictive energy performance combined with building-specific prescriptive packages, designed to be both cost-effective and to achieve a desired level of performance. Compliance with this new approach can be achieved by either meeting the performance target as demonstrated by whole building energy modeling, or by choosing one of the prescriptive packages.

Introduction

Energy codes that impact the design and construction of commercial buildings offer one of the best opportunities for reducing energy use over the life of a building. While other factors impact energy use in buildings, including operation, maintenance and the level of services provided, without an energy efficient infrastructure, a building will never achieve its full energy efficiency potential. Initial construction is the time to impact building energy efficiency; otherwise there is a lost opportunity, as it is rarely as cost-effective to retrofit a building later.

This paper briefly reviews a number of possible energy code formats and looks at issues with the current prescriptive focused approach. It then reviews several options and suggests a path forward for the next generation of commercial building energy codes. Options discussed include predictive performance with EUI[2] targets, predictive performance with a stable and independent baseline, prescriptive packages, and outcome based codes. This paper presents a direction for future commercial energy code development that, if realized, can achieve a significant improvement in building energy performance. It goes a step further than previous work in this area, in that it lays out a framework of actionable changes that can serve as a test bed for developing such a code. While compliance and enforcement are extremely important to achieve the goals of an energy code, they are only briefly addressed in this paper to the extent that they are impacted by the proposed code approach.

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[1] The term "energy code" is used within this paper as a generic term that includes ASHRAE 90.1 (a standard), the IECC (a code), and other forms of building energy standards, guidelines, laws, rules, etc.

[2] The target metric could be energy use index (EUI) or energy cost index (ECI).

Background

The intent of energy codes is to minimize the use of energy in buildings. Current energy codes attempt to achieve this goal by focusing on providing minimum requirements for energy efficient design and construction of buildings, where the most cost effective opportunities exist. While the value of preventing lost opportunities with energy codes is well recognized, leading to greater emphasis on code improvement over the last several code development cycles, there has also been growing sentiment that energy codes in their current form are getting too complex, change too often, limit design flexibility, don't achieve their desired outcomes, have reached a point of diminishing returns, and do not consider the building as an integrated system.

The first national building energy code, ASHRAE Standard 90, was published in 1975. Since its inception, the standard has been upgraded eight times resulting in significant increases in building energy efficiency. Figure 1 shows the relative improvement in commercial energy efficiency for each version of ASHRAE Standard 90/90.1 through 2013. Component improvement based on changes in efficiency requirements is also shown for prescriptive type requirements.[3] A projection is shown with dotted lines based on maintaining the same rate of improvement that occurred from 2004 to 2013. A conclusion that can be drawn from this data is that maintaining the same trend in component efficiency improvement (a lofty goal itself), will not result in net zero energy new construction, which has been a stated goal of many stakeholders in the buildings industry (Architecture 2030 2011).

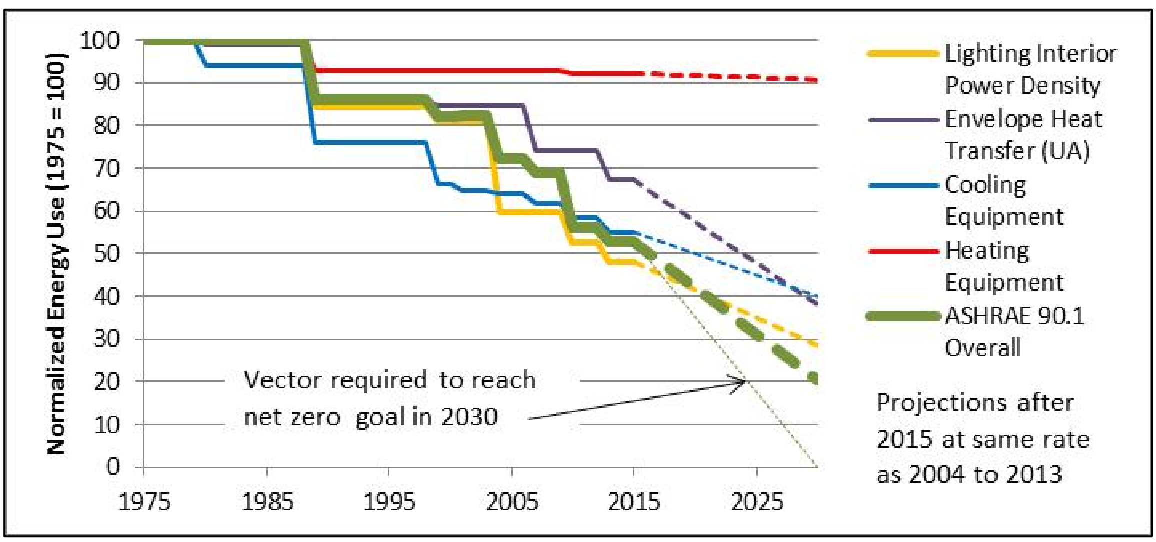

Figure 1. Improvement in ASHRAE Standard 90/90.1 (1975-2013) with projections to 2030.

Code Formats

There are multiple building energy code formats in use today or contemplated for future codes. While other publications have provided more exhaustive descriptions of code formats, they are summarized here for reference (Conover et al. 2013; Hogan 2013). In general, most

[3] Heating and cooling use index based on weighted equipment efficiency requirement changes; Envelope based on typical medium office steel frame wall and window areas with U-factor changes; Lighting power based on building area allowances weighted for U.S. building floor area; Overall Standard 90.1 progress based on PNNL's analysis.

codes have mandatory[4] requirements that must always be met and prescriptive requirements that must be met as prescribed or that can be adjusted in a trade off or predictive performance approach. Other approaches are based on energy use or capacity limits. These main formats or paths are described below and shown in Figure 2. Characteristics of the formats are shown in Table 1.

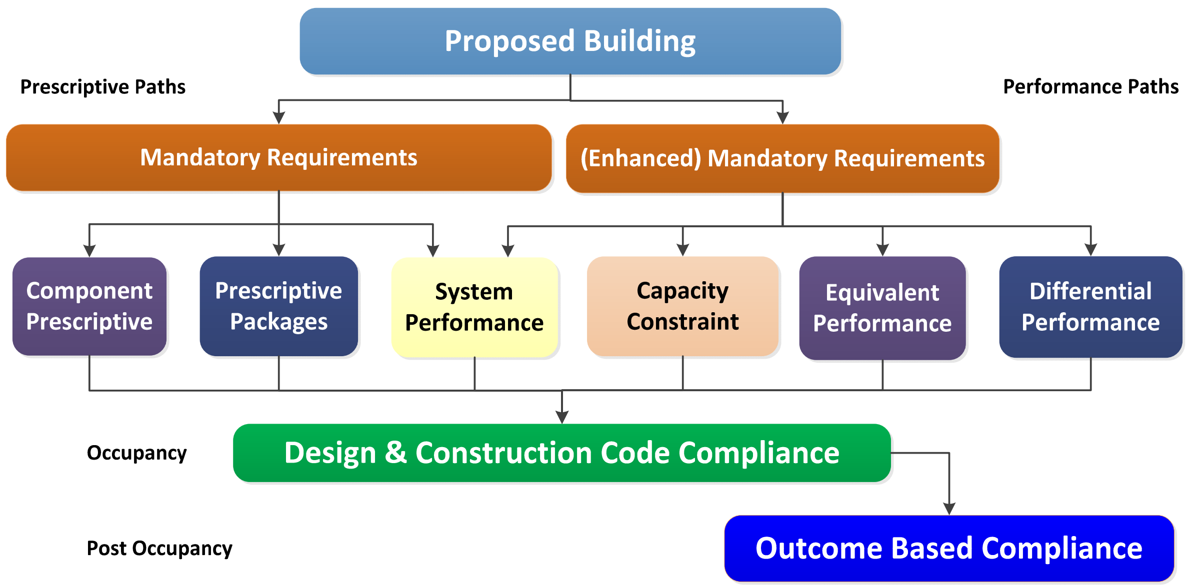

Figure 2. Code compliance paths.

Component prescriptive and system performance. Strictly speaking, a prescriptive code requires a particular defined component quality, such as insulation R-value (stamped on the product) in a wall of a particular framing type. More generally, the prescriptive section of the code also contains component performance items like a required U-factor for wall assemblies. There may also be trade-off approaches based on system or partial system performance such as envelope trade-off that allows more insulation in one area to be traded off for less in another (Hogan 2013). Generally, if all the mandatory and relevant prescriptive requirements are met, a building is considered to comply with the code.

Prescriptive packages. A prescriptive Package approach puts together packages of items that are intended to reach a desired minimum level of performance. An example might be a higher efficiency heating system in conjunction with either larger window areas or cathedral ceilings with less insulation. Prescriptive packages are discussed in more detail later.

Capacity constraint. Capacity constraint refers to a code or standard that expresses its requirements as a limit on one or more service capacities (e.g., maximum capacity of the electric service panel). The capacity limit can be applied to equipment, like total heating or cooling capacity. An example is a maximum lighting power density for each building type or space use.

Predictive performance. A whole building performance path allows some items to be less efficient in exchange for other items being more efficient than the prescriptive approach. It also provides additional flexibility as the designer can use a variety of materials or approaches that

[4] For performance paths, enhanced mandatory requirements are discussed under Other Considerations.

may not meet prescriptive requirements. The typical goal of a performance approach is equivalent or lower annual energy cost based on an hourly building energy simulation. An hourly model of the proposed building is compared to either a target or a reference baseline. A target can be set by building type and climate or be adjusted based on building requirements and is typically an energy use or energy cost index. A reference baseline model is similar to the proposed building with parameters set by the performance rules.

Table 1. Characteristics of code formats and approaches

Code Approach	Examples	Compliance Basis		Baseline Dimensions					
				Design		Time		Test	
		Reference Model Baseline Used	Energy Bills Used	Dependent	Independent	Current	Stable	Equivalent	Differential
Prescriptive (with System Tradeoffs)	90.1; IECC; T24*	No	No						
Prescriptive Packages	Res. Envelope T24*	No	No						
Predictive Performance Options:									
Equivalent to Current Dependent Baseline	90.1 Chapter 11	Yes	No	x		x		x	
Differential to Current Dependent Baseline	2012 IECC Performance	Yes	No	x		x			x
Equivalent to Current Independent Baseline	Title 24-2013*	Yes	No		x	x		x	
Differential to Current Independent Baseline	90.1 Apx. G; LEED; 189.1***	Yes	No		x	x			x
Differential to Stable Independent Baseline	Addendum *bm**	Yes	No		x		x		x
Equivalent to Energy Use Index Target	Canadian Energy Code	Yes	No		x	x		x	
Outcome Performance Options:									
Outcome Based Code; Energy Use Index Target	Seattle; Sweden	No	Yes						
Outcome Based Code; Differential to Stable Independent Baseline Prediction**		Yes	Yes		x		x		x

* T24 = CA Title 24; Addendum *bm* to Appendix G of Standard 90.1 (Rosenberg and Eley 2013)
**Outcome with predictive model could have other baselines with similar characteristics as predictive performance options.
*** A differential predictive performance approach has recently been approved for inclusion in ASHRAE Standard 189.1-2014
**** Shaded cells are not applicable.

The baseline has characteristics in three dimensions (design parameters, time reference, and test criteria) as shown in Table 1:

- **Design** indicates if the baseline design parameters are **dependent** on the proposed building design or follow an **independent** rule set.[5] A dependent design parameter in the baseline matches the proposed case but its efficiency is adjusted to meet prescriptive code values, for example modeling the same HVAC system type as the proposed design, with efficiency that meets prescriptive requirements. An independent design parameter (often

[5] A mix of independent and dependent design parameters is typically required. For example in Standard 90.1 Appendix G, the baseline window-to-wall ratio is independent of the proposed design while the shape of the building and number of floors is dependent on the proposed design.

referred to as an asset) is defined in the baseline and may differ between baseline and proposed building models, so the energy impacts of those differences are captured in the comparison. An example is setting the baseline HVAC system to a set type based on the building program regardless of the proposed HVAC type.

- **Time** indicates if the baseline parameters are updated to match the **current** code or based on a **stable** reference code, typically a historical or earlier version of the same code. A stable baseline allows easier tracking of code improvements, changes less often, and allows for easier development of automated software.
- **Test** indicates if the reference building must be **equivalent** to (no more energy use or cost than) the baseline or **differential**, meaning it must beat the baseline by an established percentage. A differential test is required when using a stable baseline from an earlier version of the same code.

Outcome based. Outcome based is similar to the concept covered above under predictive performance, but compliance is based on verification of actual monitored energy consumption for a specified period of time after occupancy. An outcome-based code has been in place in Sweden since 2006 (Wahlström 2010) and in Seattle, Washington (SDPD 2012).

The many varied approaches to determining compliance, are shown in Table 1 with examples of particular applications. The strengths attributable to each approach are shown and discussed further under recommendations and shown in Table 3.

Current Prescriptive Based Code Issues

Commercial energy codes in the United States and most of the rest of the world emphasize the prescriptive path. Although most include a performance path, it is an equivalent predictive performance path with a dependent baseline established by the current prescriptive code as described above. This combination of formats results in a number of issues which compromise the goal of energy efficiency.

Variation in energy use. When establishing criteria in the prescriptive path, each component is judged independently, with the goal of requiring the most cost-effective level of efficiency of each component. The result is that parallel prescriptive requirements don't guarantee equivalent energy performance. For example, the most cost-effective metal frame window has greater heat loss than the most cost-effective vinyl frame window, so the choice of a metal frame window will result in greater energy use. HVAC system type selection alone can result in energy use variations exceeding 30% (Westphalen and Koszalinski 2001). In the same building, multiple choices can be made that all meet the prescriptive requirements, yet result in a wide range of energy use. Recent attempts to limit some of the poorer energy performers from the prescriptive path have resulted in difficulty in reaching consensus (as required by the ASHRAE/ANSI process) as stakeholders dig in to protect market share or design flexibility. Recent examples include attempts to limit window area or require water cooled chillers in high cooling load applications.

The variation in energy use for similar buildings also occurs with the performance path, as it tracks a prescriptive baseline and each component's performance is adjusted to just meet the prescriptive code requirement when creating a dependent baseline reference model.

Difficult to track progress. It is difficult to track the progress of energy codes in their current format. The problem is caused by the fact that the prescriptive baseline changes with each updated version of the code making it a moving target. This makes it very difficult to compare the performance of buildings of different vintages, or to establish a deliberate improvement goal in performance requirements. How does a building 30% better than the 2004 version of Standard 90.1 compare to a building that is 15% better than the 2007 edition? Does the building that is 15% better than the 2007 Standard even comply with the 2010 Standard? How are codes progressing toward the vision of net-zero energy buildings by 2030 (Architecture 2030 2011)? This issue is especially important in the U.S. where state adoption of codes covers at least three editions of codes (DOE 2012).

Performance path rules can't keep pace with prescriptive changes. With the growing charge to code development bodies to improve energy code performance, the pace of change has increased dramatically from 32 addenda in 90.1-2004 to 110 addenda in 90.1-2013. Each addendum may impact one or more performance paths, resulting in changes. During the last several code cycles the performance path has not been fully updated to match prescriptive requirements before publication of the standard.[6]

In the search for additional savings, prescriptive requirements are becoming more complex. This is particularly problematic when a prescriptive requirement is not included in a proposed building design. Conventional and historic requirements such as wall insulation and lighting power are straightforward. But modeling some of the newer requirements has proven to be problematic. Defining the baseline building becomes a complex design problem, with many acceptable solutions. For example, Standard 90.1 now requires that large, high ceiling spaces have skylights and a daylight area equal to half the space area with daylight controls. There are many ways to meet these criteria, each providing potentially different levels of savings and requiring added cost to design for a fictional baseline building. Other prescriptive requirements that are difficult to incorporate in the baseline building are building orientation, perimeter daylighting, and exterior shading.

Diminishing returns. The approach of incrementally improving the efficiency of individual building components is reaching a point of diminishing returns. Figure 1 shows that simply increasing insulation or equipment efficiency will not achieve net zero energy targets and it is unlikely that cost-effective improvements can be applied at the same rate as in the past. For example, adding R-11 to an uninsulated wall decreases the heat loss by about 75% while adding an additional R-11 only adds an additional 11% reduction. In the case of HVAC equipment efficiency, there are concerns that the efficiencies of some classes of HVAC equipment are approaching practical and theoretical limits. So, while the overall energy use progress shown in Figure 1 seems to have a good vector toward net zero in the future, it should be noted that many of the component use indices have already been reduced close to their practical minimum, so future progress will need to occur at an integrated system level that is not easily regulated with current prescriptive approaches.

Limited credit for good design. Neither the prescriptive component path nor the predictive performance path using a dependent baseline distinguish between high and low energy design

[6] A review of Standard 90.1-2010 by the Standard 90.1 Energy Cost Budget subcommittee identified 32 published addenda that were not accounted for in the performance methodologies.

choices that fall within the prescriptive allowances. Prescriptively a building with 40% window-to-wall ratio (WWR) and air-cooled HVAC system is treated the same as one with 30% WWR and water-cooled HVAC system, even though the latter is almost certain to result in less energy use. Similarly, even the performance path using a dependent baseline would give no tradeoff credit to the more efficient choices as the baseline assumes the same system type and WWR. With an independent baseline the WWR is set, and differences in the proposed building would result in a credit or penalty. The dependent baseline (used in 90.1 Chapter 11) doesn't credit energy efficient design. Other examples include use of thermal mass to flatten heating and cooling loads, optimized orientation, natural ventilation, and passive cooling.

Expected savings may not be realized. Projections of energy savings from codes are typically estimated by building energy modeling predicting the potential of the codes to save energy. These predictions assume the code is fully complied with, and that the operations and maintenance of building energy using systems are optimized, not only at occupancy, but throughout the life of the building. Studies have shown these assumptions may be overly optimistic (Turner and Frankel 2008).

Vision for a More Effective Commercial Building Energy Code

Effective building energy codes have many goals: comprehensiveness, flexibility, ease of administration and high compliance rates all leading to lower energy using buildings. Over the last several years, a number of papers and articles have been written discussing the limitations of current codes and a future vision for energy codes (Cohan, Hewitt, and Frankel 2010; Harris et al. 2010; Eley et al. 2011; Denniston, Frankel and Hewitt 2011; CBC 2011; Rosenberg and Eley 2013). Interestingly, a number of commonalities are present in those visions:

- Future energy codes should ensure low performing design options are eliminated or balanced with high performing options.
- Energy codes should be developed with some level of overall building energy performance targeted.
- An energy code should consider the building as a system, accounting for building system and climate interactions.
- Energy codes based on performance (or predicted performance) should be supplemented by prescriptive compliance options.
- The progress of energy codes should be measured on a fixed scale that can more easily track progress towards zero energy buildings
- The scope of energy codes should be expanded to cover post occupancy energy use.
- Existing buildings need to be addressed by energy codes to ensure that once constructed, buildings are maintained and operated efficiently.
- Expand scope of energy codes to include currently unregulated loads such cooking equipment, plug loads, industrial processes, computing equipment, etc.
- Buildings must be tested and commissioned to ensure proper operation.
- Enforcement and adoption should not be compromised as energy codes progress.
- Future codes should require or encourage on-site renewable energy.

Potential Solutions

One touchstone that can be applied in choosing from multiple code format options is that compliance paths for similar buildings should result in similar predicted energy use. This is a shift from the current *variation in energy use* previously discussed. For example, if a lower performing HVAC system type is selected or window-to-wall ratio is increased, other high efficiency choices should make up the difference. If the goal is to achieve a standard of energy efficiency with energy codes, then multiple options in the code should provide a desired minimum energy performance level. Four potential solutions to the issues discussed above are reviewed here: 1) predictive performance with EUI targets, 2) differential predictive performance with a stable and independent baseline, 3) prescriptive packages, and 4) outcome based codes. Each solution is summarized with pros and cons discussed.

Predictive Performance with EUI Targets

One suggested approach to predictive performance code compliance is to establish fixed targets for energy use or energy cost based on building type, size, and climate zone instead of customizing the target based on specific building characteristics as is done with a reference building approach. EUI targets align well with management practices desiring clear and measurable goals and a predictive model can show that a building will use less energy than the target. In theory the approach has merit, but most previous attempts to use simple targets for commercial buildings have failed (Goldstein and Eley 2014). The jury is still out on more recent attempts (CCBFC 2011; Wahlström 2010; SDPD 2012). Two major drawbacks to an EUI target approach are difficulty in setting an appropriate and fair target and difficulty in having a reliable prediction of building energy use.

Setting fair and appropriate targets can be a substantial challenge. EUI targets can be developed based on actual energy use of typical existing buildings or by using prototype building models normalized for climate. Unfortunately, few buildings are typical. Even simple buildings vary in function, number and frequency of occupants, plug and process loads, hours of operations and other energy services. That makes fixed targets either too easy or too difficult to meet (Goldstein and Eley 2014). The difficulty in setting an EUI target can be demonstrated by simply viewing the wide range of energy results in any of the building energy datasets, even when adjustments are made for parameters like employees and operating hours (EPA 2012). True, those parameters can be modeled with standard assumptions—as is done in California's Title 24 *Alternate Compliance Methodology*, but then you lose one of the most important benefits of a performance based code—encouraging integrated design solutions customized for the actual loads and operation of the building. For example, a building with a transient population might benefit greatly from occupant based controls for HVAC and lighting. If that building is required to be simulated with fixed occupancy assumptions, the value of those controls will be severely underestimated, and savings from measures like reduced lighting power and energy recovery would over estimated.

Beyond setting the right target, there is substantial difficulty in having a reliable and accurate prediction, due to both the variation between modeling tools and difficulty controlling the many variables in a single model approach. An energy model is just a physics-based simplified representation of an actual building. Some simplifications are determined by the software and some by the individual modeler. For example, how often are lights turned on and off manually in each space? Will the cleaning crew override sweep lighting controls for one hour or three hours? How often will occupants open windows or raise or lower window shades? Each of these assumptions will impact the modeled energy use and thus compliance with the target.

It is well documented that different software programs can give widely different results when modeling the same building. A study for the California Energy Commission from Lawrence Berkeley National Laboratory comparing energy use of prototype building models used for California Title 24 development showed heating energy differences of over 100 % and cooling energy differences of up to 20% for the same building when modeled in EnergyPlus and DOE2.1E (Huang et.al 2007). Other studies have shown similar variations.

With the single model vs. target approach, calibration is difficult. Small changes to many simulation inputs can have a large impact on simulation results. When the changes are made in a single model that is compared with an EUI target, every model input must be scrutinized; otherwise there will be wide variation predicted energy use by multiple modelers. This is much less of an issue when a reference baseline is used or the model is calibrated to energy bills as discussed later.

Since it is quite difficult to set a fair and appropriate EUI target, and even more difficult to produce a consistent prediction of energy use for a particular building, the predictive performance with EUI target approach is not considered to be a good candidate as a code compliance method.

Differential Predictive Performance with a Stable and Independent Baseline

To avoid the problems of setting and maintaining a performance baseline that tracks the most recent prescriptive code, it is desirable to fix the baseline at some level of performance, and then apply a differential performance test. Improving the code then becomes simply a matter of incrementally ratcheting up the differential in reference to that stable baseline. This approach is in development for ASHRAE Standard 90.1 as Addendum *bm* to Standard 90.1-2010 (Rosenberg and Eley 2013). In this approach, the baseline rules use requirements from the 2004 edition of ASHRAE Standard 90.1, and require significantly better performance for the proposed building. There were two main reasons for settling on 2004 as the performance baseline. First, after 2004 the prescriptive requirements in Standard 90.1 started becoming too complex to develop rules that result in consistent modeling of the baseline (*e.g*, skylights and daylight dimming as discussed previously). The second reason to choose 2004 is that the efficiency levels for lighting power and envelope components would make reasonable enhanced mandatory minimum requirements that can be used in conjunction with a performance or tradeoff path.

An additional benefit of the stable baseline approach is that the same baseline and modeling rules can be used for both minimum code compliance and beyond code programs. The differential performance required is simply adjusted based on the purpose. Multiple uses for the same simulation ruleset make it attractive for software developers to create reliable modeling tools with automated baselines. Such tools make the reference baseline predictive process much more reliable, less prone to gaming, and more acceptable to building officials.

Having parallel baseline and proposed models is a great quality controller, avoiding the verification issues of a single model compared to an EUI target. With over a thousand inputs to an energy model, many critical, it requires a reference building comparison to reduce the inputs that need validation to a manageable level. With differential performance, only the inputs that vary between the base and proposed models need to be checked, not all of them. Quality control becomes possible.

The challenge with the differential performance approach with a stable baseline is in creating the appropriate differential target. The differential can be established by comparing current prescriptive requirements to the stable baseline, but the range of prescriptive choices means the level of efficiency will vary considerably. Choices need to be made regarding which prescriptive options define the desired level of performance. Fortunately, a working group of the ASHRAE Standard 90.1 committee has selected from the prescriptive options what it considers typical good design practice for each of 16 prototype buildings used to track the progress of the standard (Thornton et al. 2011). Comparing these standard packages to the performance baseline can establish the performance target by building type and climate location.

A differential predictive approach with a stable and independent baseline allows a reliable comparison to a known baseline, enhances the ability to track code improvement over time, rewards designers for optimization, paves the way for automated performance modeling, and creates a marked improvement in predictive accuracy.

Prescriptive Packages

Establishing a predictive performance goal ensures a minimum desired performance level, but there is also a desire to maintain prescriptive options for some buildings, particularly smaller or simpler buildings. Providing prescriptive options in the form of pre-defined packages provides turnkey solutions while maintaining the desired level of performance. In the prescriptive package approach, a building designer can choose from a number of packages or pre-selected combination options. While the long term solution may be an automated stable and independent-baseline performance model that can be easily applied to any building, until we have simple and robust tools to demonstrate compliance by predictive performance, a good transition step can include prescriptive packages.

The same packages of prescriptive options discussed above that are used to create the performance target can establish the first cost-effective, standard design package. Additional packages can be created based on prototype modeling. These packages provide a minimum energy performance level within a reasonable range and include a reasonable package for standard efficiency systems. There might be packages that allow a less efficient HVAC system type but have restrictions on other areas of the building like envelope or lighting to result in a similar desired energy performance level. Conversely, selection of a highly efficient HVAC system would allow more flexibility for other building components, such as a larger glazing area or increased lighting levels. Packages can be developed that capture the most common design choices. These additional packages along with the standard design package will be available for design teams without the need for modeling.

Once an initial set of prescriptive packages are developed, a process will be needed to add additional packages. The most likely candidates are the code development bodies themselves. Or perhaps, submission of packages could be made open to anyone, with the code bodies developing an acceptance procedure, possibly managed by a third-party.

Until simplified and robust software is available so that any building can easily achieve a stable baseline predictive performance level, prescriptive packages provide similar energy equivalency while keeping the code simple based on a selection matrix of prescriptive options. Table 2 shows an example of what a prescriptive package might look like for a medium sized office building. Note that this example is intended to simply show the flavor of a package for discussion, not present a proposed package based on analysis of energy equivalency.

Table 2. Sample prescriptive packages for medium office building type in moderate climate

Code Package	A	B	C	D	E	F
Glass area	35% WWR	30% WWR	40% WWR	40% WWR	50% WWR	25% WWR
SHGC	0.45	0.45	0.29	0.29	0.29	0.29
Opaque UA	Standard UA		90% UA	Standard UA	110% UA	
Lighting Power	0.8 w/sf	0.9 w/sf	1.0 w/sf	1.0 w/sf	0.8 w/sf	1.1 w/sf
Lighting Controls	Standard lighting controls				Small zone occupancy sensors	
Equipment	Standard Computers with flat panel displays				Network computer controls	
SWH	Standard	Standard	Standard	Standard	Condensing or HPWH	
HVAC	Standard VAV	SZ RTUs	Loop WSHP	Standard VAV	GSHP	SZ RTUs
HVAC Controls	Standard zone controls			Small zone occupancy sensors		
Heating Efficiency	Standard	Standard	Standard	Condensing Boiler	Standard	HP or Cond. Furnace
Cooling	Standard	Standard	Standard	+10% Efficiency	Standard	+5% Efficiency
Fans	Standard	CV Fans	Standard	90% Fan Power	Low pressure Ducts	VSD Fans
Plant/Other	Standard Efficiency		Advanced Pump Ctrl	Efficient Hydronic Distribution	Advanced Pump Ctrl	

Abbreviations include: heat transfer coefficient (UA), variable air volume (VAV), single zone (SZ), rooftop packaged unit (RTU), water source heat pump (WSHP), geothermal source heat pump (GSHP).

Outcome Based Codes

Outcome based codes provide the ultimate in confirmed energy performance. The actual energy use of the building is compared to the desired target. There is no question that bench-marking actual building energy use is a vital part of any energy management program and could become an extension of building energy codes. Studies have shown that buildings don’t always achieve the results predicted by simulation (Turner and Frankel 2008), and measurement is necessary to take corrective action and demonstrate movement toward an energy goal. However, is an outcome based approach a valid replacement for a building design and construction energy code? Four issues stand in the way: timing, scope, appropriate targets, and impact of the energy service level.

Design and construction codes have their lever in the occupancy permit, and waiting until the performance is proven more than a year later can create issues for an outcome based code applied to new buildings. These issues may be resolved with performance bonds, punitive utility rates, or other performance insurance mechanisms, but no matter what the penalty, failure to meet the code results in a non-efficient building added to the building stock.

An appropriate target is an issue, just as for the predictive performance EUI target approach, although for a building with measured energy use, a recently proposed methodology would allow creation of a more valid energy target by comparing post occupancy building energy use to simulated energy performance calibrated for actual operating conditions (Goldstein and Eley 2014). This approach may prove to be a valuable way to create a target for an outcome based code.

If a building is not designed and constructed to minimize energy use, but must only comply with an outcome based approach, there may be undesired consequences. If the enforcement penalties are severe enough, building owners may be forced to reduce services (e.g. hours of operation) or amenities (e.g. appropriate lighting levels or ventilation control) to comply. This is surely not a desired outcome.

There is really no reason why an outcome based code should apply only to newly occupied buildings. Future efforts in this area could focus on energy use requirements for all existing buildings, and be combined with a building design and construction code to ensure the building begins its life with the greatest possible potential for performing at low energy levels and continues to do so throughout its existence. We see the possible beginning of this approach with the development of operational rating systems and building energy disclosure laws.

So while an outcome based code would be a valuable expansion of energy efficiency regulation for all buildings, it should not be a replacement for a design and construction energy code. Instead an outcome based code should be coupled with a design and construction code, focused on the efficiency of the building infrastructure to ensure building energy use is minimized during the building life cycle.

Recommendations

Table 3 summarizes the various approaches for future codes considered here. It demonstrates that the predictive performance approach with a differential from a stable and independent baseline has the most beneficial qualities for a building design and construction code. Recommended options are shaded in green.

Table 3. Strengths of potential code options

Code Approach	Examples	Strengths of Approach						
		Ensures energy efficient design and construction	Accounts for bldg. specific operation & service requirements	Promotes optimized design	Promotes energy equivalency	Simplicity; compliance & enforcement	Design Flexibility	Compliance enforced during occupancy for persistent savings
Prescriptive (with System Tradeoffs)	90.1; IECC; T24	No	No	No	No	Yes	Some	No
Prescriptive Packages	Res. Envelope T24	Yes	No	Yes	Yes	Yes	More	No
Predictive Performance Options:								
Equivalent to Current Dependent Baseline	90.1 Chapter 11	No	Yes	No	No	No	Yes	No
Differential to Current Dependent Baseline	2012 IECC Perf.	No	Yes	No	No	No	Yes	No
Equivalent to Current Independent Baseline	CA Title 24-2013	Yes	Yes	Yes	Yes	No	Yes	No
Differential to Current Independent Baseline	90.1 Apx. G; LEED; 189.1	Yes	Yes	Yes	Yes	No	Yes	No
Differential to Stable Independent Baseline	90.1 Addendum *bm*	Yes	Yes	Yes	Yes	Yes***	Yes	No
Equivalent to Energy Use Index Target	Canada Energy Code	No	Might	Yes	Yes**	No	Yes	No

Table 3 (continued). Strengths of Potential Code Options

Outcome Performance Options:								
Outcome Based Code; Energy Use Index Target	Seattle; Sweden	No	No	No	Yes**	Yes	Yes	Yes
Outcome Based Code; Differential to Stable Independent Baseline Prediction*		No	Yes	Yes	Yes	Yes	Yes	Yes

*Outcome with predictive model could have other baselines with similar strengths as the predictive performance options.
** EUI targets make it difficult to fairly account for differences in building services and operation.
*** Independent modeled performance with a stable baseline is more likely to encourage automated and integrated compliance software with detailed checklists.

To ensure efficient building design and construction, a differential predictive performance method with a stable and independent baseline is recommended as the cornerstone of future commercial codes, supplemented by prescriptive packages for instances where modeling is not needed. To ensure reliable post-occupancy energy savings, outcome based codes for existing buildings are also recommended.

Other Considerations

There are multiple other considerations that are important to effective energy codes. At a minimum, these include more widespread adoption of model codes, improving compliance rates, appropriate commissioning or acceptance testing of installed equipment and systems, expanding code scope to cover currently unregulated building energy uses, more in-depth modeling rules for performance paths, accredited modeling professionals, and the development of automated software to allow easier compliance with a performance path. While detailed discussion of these important items is beyond the scope of this paper, they are briefly mentioned below.

- **Performance Metric**. There are a number of options including site energy use, source energy use, energy cost, and greenhouse gas emissions. In the past, it has been challenging to reach consensus on this question, but at this point the public process used to develop model codes has embraced energy cost.
- **Cost-effectiveness**. Energy code requirements are expected to be cost-effective. Ideally the set of packages for a particular building type should include several packages that are cost-effective overall. That does not mean that all packages should be required to be cost-effective. For example, if a package allows 50% glazing area (above the 40% prescriptive limit), but requires a higher-cost high-efficiency HVAC system and added opaque wall insulation, that package is a viable option for a building with a larger glazing area, even if not that cost-effective. As long as reasonable cost-effective paths exist, then the code as a whole should be deemed cost-effective.
- **Impact of Measure Life on Performance Trade-offs.** A concern about trade-offs is that a shorter-life high-efficiency item could be traded for a reduction in efficiency of a long-life item (e.g., a condensing furnace traded for lesser wall insulation). One fact ignored by the concern is that when shorter life equipment is replaced, efficiency standards are likely to be higher, so the impact would not be like replacement with today's lowest efficiency equipment. Allowing trade-offs has benefit for design, and as long as trade-offs are subject to enhanced mandatory standards as discussed below, the benefit is likely to outweigh disadvantages.

- **Enhanced Mandatory Standards.** Enhanced mandatory requirements are necessary for performance trade-offs or outcome based codes, because tradeoffs for energy equivalency can have unintended consequences. For example, equivalent energy use with single pane glazing may impact comfort and result in the space temperature setpoint being increased. Mandatory standards are more important with a defined (independent) performance baseline that expands the range of options available for trade-off credit.

Compliance. Updates to the energy code need to consider the impact on compliance. A more performance-based code could negatively impact compliance verification if the code official must verify modeling. Better solutions could include either approved software that automates the process of creating a baseline building, or third party expert verification. Again, focusing on a stable differential baseline for the performance path allows for investment in development of long-term code compliance software. Once there is more confidence in the accuracy of the simulation, the process of plan review and inspection should not be much more complicated than for prescriptive requirements. After all, each building that pursues a performance path will in effect define a specific set of prescriptive values applicable to the candidate building. The code official performs review for prescriptive values, the same as they do currently, just using a software generated list that will vary more from project to project. This process could be greatly improved in both the current and proposed scenarios by requiring energy code compliance experts to perform plan review and inspections. These experts could be building officials who focus on energy code compliance or an approved third party. Either scenario would be a vast improvement over today's approaches, which generally rely on a building official whose main priorities are life safety issues while compliance with the energy code is often an afterthought that they are not adequately prepared for nor given proper resources to complete.

Next Steps

To pursue the path toward a commercial building energy code with differential performance targets based on a stable independent baseline combined with prescriptive package options, it will be necessary to have further support for development and documentation of this approach. Some of the key steps are as follows:

- Create rules for a stable and independent baseline enabling the development of a desired level of performance and creation of automated modeling tools.
- Develop a predictive performance target and sample packages for multiple design options for a common prototype building such as the medium sized office.
- Expand analysis of packages into a broader range of simple building types to develop adoptable model language for this approach.
- Work with stakeholders to refine the package approach and get it adopted by jurisdictions for field testing.
- Analyze the range of energy use resulting from existing prescriptive options to better understand where prescriptive packages and predictive performance fit in that range to promote more consistent performance of code compliant buildings.
- Continue expanding the scope of codes to cover currently unregulated energy uses.
- Explore ways to enact outcome based codes for newly constructed and existing buildings.

Conclusions

For commercial building energy codes to continue to progress as they have over the last 40 years, the next generation of building code will need to provide a path that is led by energy performance, ensuring a measurable trajectory toward zero energy buildings.

Predictive performance with EUI targets falls short as a code mechanism, and outcome based codes–while an essential approach that should be applied to all buildings–are not a substitute for design and construction energy codes that focus on compliance at occupancy. For a design and construction code, a differential predictive performance method with a stable and independent baseline provides the best accuracy and potential for a highly automated approach that could eventually be applied to most buildings. At some point in the future, tools that demonstrate predictive performance compliance may become so simple that there will no longer be a need for any prescriptive path. As a bridge, prescriptive packages can provide a transition from the current component prescriptive approach, while providing flexibility and improved energy equivalency.

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