OUTCOME-BASED ENERGY CODES ON THE WAY TO NET ZERO

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ABSTRACT

The topic of outcome-based codes has been gaining in prominence and momentum in the energy codes world. Even though there is often confusion about what the term actually means, it is already being introduced into policy. In this way, the early success of the concept could be its undoing. An under-developed or poorly founded implementation could significantly hinder the widespread adoption of the concept. Therefore, there is a need to take a step back and look at the concept of outcome-based codes and offer some definitions of the terms, identify the components involved and take a look at what are the reasonable next steps.

INTRODUCTION

Energy codes are a hot topic. Sometimes a small wonkish corner of energy efficiency policy, energy codes have moved from the fringes of energy efficiency policy to center stage. Policy makers, energy agencies and environmental groups pursuing aggressive climate change agendas have realized that energy codes are one of the simplest, most effective tools available to reduce building energy use.

Already the result has been a much-accelerated adoption of code stringency increases driven directly, through state-level legislation, and indirectly by formal policy initiatives on the part of the U.S. Department of Energy and other major organizations. For energy code experts who have been advocating for more stringent codes for years this is all welcome news, but looking forward there is apprehension that unrealistic expectations are being set. Currently, there is a gap between the level of code stringency and increases that can be put into place within the current structure of the codes and the capability of the market to deliver building improvements. However, new code developments and adoptions in the West Coast states, the International Energy Conservation Code ("IECC", which is used in most of the rest of the country) and ASHRAE/IESNA 90.1 updates are rapidly closing that gap. To move into the realm of extremely low or zero-net-energy buildings as envisioned by the 2030 Challenge [1] and other policy initiatives, significant changes will need to be made in code structure and language, as well as in implementation and enforcement strategies. Within this context, the concept of 'outcome-based codes' has emerged as a possible solution and the concept has quickly gained traction and momentum.

At the 2010 American Council for an Energy Efficient Economy (ACEEE) Summer Study Conference, The Northwest Energy Efficiency Alliance (NEEA) and the New Buildings Institute (NBI) presented papers on outcome-based codes and hosted an informal session on the same topic. The NEEA paper was based on the outcome of discussions by an ad-hoc assembly of energy code and policy experts from the four Pacific Northwest states and California[1] convened by NEEA and NBI. The NBI paper

[1] Attendees at the meetings were: John Hogan, Jayson Antonoff – City of Seattle; Chuck Murray – Washington State Department of Commerce; Martha Brook – California Energy Commission; Eric Makela, Dave Conover, Todd Taylor – Pacific Northwest National Laboratories; Vincent Martinez, Ed Mazria – Architecture 2030; Dave Hewitt, Mark Frankel, Sean Denniston – New Buildings Institute; David Cohan – Northwest Energy

was based on a draft white paper written by NBI in partnership with the Preservation Green Lab (PGL, a policy initiative of the National Trust for Historic Preservation) and the City of Seattle to advocate for the addition of an outcome-based compliance path to codes based on the specific challenge of existing buildings. This white paper is a part of Seattle's plans to introduce a pilot for outcome-based code compliance for existing buildings. NBI has also partnered with the Department of Energy (DOE), Environmental Protection Agency (EPA), American Institute of Architects (AIA) and the National Trust for Historic Preservation (NTHP) to try to get an outcome-based compliance path added to the International Green Construction Code (IgCC) currently in development.

All of these efforts have demonstrated the power of the concept of outcome-based codes and the momentum that is already behind them; however, NBI's involvement in these efforts has also demonstrated that there is a high level of confusion about just what an 'outcome-based code' actually is and that there is even a lack of a clear language for talking about the issues involved. At the ACEEE Conference, the question, "Is this even a code?" was raised. This has made it clear that there is a need to step back and define just what outcome-based codes are, what the vocabulary is, and what they will require to implement.

DEFININING THE TERMS

The need to define the terms can be illustrated by a term that is already in the code world: performance-based codes. This is an entrenched term in the arena of energy codes with an established meaning. The problem is that 'performance-based codes' does not refer to a code that is based on performance, nor does it refer to actual building performance. There is the risk of the same thing happening with the terms and concepts in this discussion.

Code Basis vs. Code Compliance Path

In the United States there is currently no nation-wide building energy code. Instead, there is a patchwork of codes, standards and voluntary programs set at the national, state and local levels. Although there is diversity in the nationwide landscape of codes, all codes currently in effect share one element in common: they are all ultimately based on a set of prescriptive requirements for building components: levels of insulation, U-factors for windows, efficiency ratings for HVAC equipment, etc. This is what it means for an energy code to be prescriptive-based, these lists of prescriptive requirements set the standard for compliance. The standard way to demonstrate compliance, therefore, is for a building to include components that meet these prescriptive requirements.

In order to offer more flexibility, many jurisdictions also have an alternate compliance path based on computer modeling. An approved piece of software is used to model the performance of a proposed design and compare it to the performance of a baseline reference model of the same building specified so that it would meet all of the prescriptive requirements of the code. If the energy consumption of the model of the proposed design is less than the energy consumption of the reference model, then the design complies with the code. The modeled performance path allows designers to step away from the prescriptive minimums when it is advantageous for the building design. They can trade off lesser levels than required by the prescriptive requirements by adding an equal level of energy performance elsewhere in the building. However, even though compliance is demonstrated by a performance model, the compliance standard is still determined by that set of prescriptive requirements.

This practice is frequently referred to as a performance-based code when it is actually a modeled performance-based compliance path within a prescriptive-based code. The standard for compliance is still that list of prescriptive requirements. A performance-based code would have a compliance standard that is based on some kind of energy performance target. Compliance could still be demonstrated through modeling the building's performance. The difference would be that the modeled performance would be compared to a performance target rather than a model of the building as if it met the prescriptive requirements. Compliance could even still be demonstrated through a prescriptive-based path. A set of prescriptive requirements could be crafted and analyzed to, on average, produce a building that meets that performance target.

Efficiency Alliance. The meetings were intended for brainstorming and concept development and did not result in a formal agreement about outcomes.

Currently, all energy codes in the US are prescriptive-based and there are no true performance-based energy codes in force.

Outcome-based Compliance and Outcome-based Codes

Ultimately, both prescriptive requirements and energy modeling are proxies for actual building performance. An outcome-based compliance path would be based on actual, measured building performance rather than these traditional performance proxies. Actual, measured performance would then be compared to whatever compliance standard that is set by the code, whether the code is prescriptive- or performance-based. Therefore, the current effort with the IgCC is an attempt to add a new outcome-based compliance path to the traditional prescriptive and modeled performance-based paths already present. It is not an attempt to transform the IgCC into an outcome-based code. The IgCC would still be a prescriptive-based code, but it would have a third compliance path based on actual outcomes.

An outcome-based code would be a particular kind of performance-based code. In it the performance targets would be derived from the actual performance outcomes from a survey of buildings. Modeling could be used as a basis for those targets, but the shortcomings of this approach will be discussed below.

WHY OUTOME?

Ultimately, the goal of energy codes is to set standards that will ensure certain levels of actual energy performance for buildings. Within this context, prescriptive requirements and performance modeling are really proxies for actual building energy outcomes. As proxies, they are only as good as their underlying assumptions and can therefore leave gaps between them and actual performance. Making the shift from performance proxies to actual performance outcomes can close that gap.

Limitations of Prescriptive Codes

Until now, code revisions have followed a pattern of ever more stringent prescriptive standards. This has been a very successful approach to energy codes. It has offered a predictable, easily understood and relatively inexpensive way for the owner and designer to achieve code compliance while also providing clearly defined building elements for code officials and inspectors to inspect and verify. It has also offered a fairly clear way to advance the code. In addition to advancing code triggers, requirements for building elements can be tightened and the scope of requirements can be expanded.

However, this approach has limitations as we advance toward Zero Net Energy and Ultra Low Energy buildings, both for new and existing buildings. Improving the insulating properties of the envelope produces continuously diminishing returns. Each ratchet up of the R-value or down of the U-value is less cost effective than the last. The efficiency levels of some pieces of equipment in buildings are beginning to push against the theoretical limits of the technologies. Hopefully new, fundamentally more efficient technologies will be developed, but they can't be required until they exist. There are many design approaches that can improve efficiency - such as orientation, restricting window-to-wall ratios or restricting volume heights– that prescriptive requirements could be expanded to cover. However prescriptive requirements for orientation could make it impossible to build a code compliant building on some sites and restricting design elements like window-to-wall ratios or volume heights would considerably limit design freedom. There are many passive strategies such as daylighting that can provide significant energy savings, but not all passive strategies are appropriate for every site and the implementation of some strategies has significant design impacts. Prescriptive requirements for passive strategies could have the same effects of limiting design freedom or making some sites unbuildable.

Additionally, it is very difficult to create prescriptive standards that can effectively deal with the complex issues of integrated design. The issue of daylighting illustrates this quite well. Daylighting with advanced controls of the electric lighting system can lead to significant energy savings and is beginning to be seen as a must for high performance buildings. Restricting window-to-wall ratios results in significant space conditioning energy savings, but at a certain level those restrictions would make daylighting ineffective. Likewise, requiring exterior shading can reduce solar gain and thus space conditioning energy, but can also interfere with effective daylighting and also limits design freedom. The same features that make windows more effective insulators also typically reduce the visual transmittance of glass and interfere with daylighting. The many different daylighting strategies are affected by all of these factors in different ways, and even the same strategy can be affected very differently depending on the window orientation or local climate. The set of conditional requirements that would be needed to implement daylighting requirements in tandem with increasingly stringent building envelope requirements would quickly chip away the simplicity that has historically been one of the greatest strengths of prescriptive codes.

All Energy

A substantial portion of the energy used in buildings is not regulated by energy codes. This energy falls broadly under the categories of process loads, which include manufacturing and food preparation equipment, and plug loads which refer to energy-using equipment that is not built-in during construction. These loads are significant (almost always >20%) in all building types as they include all computer and office equipment, entertainment systems and appliances. In some types of facilities, such as medical or industrial buildings, they can be the dominant energy use. As energy codes become more stringent, regulated loads will shrink meaning that the percentage of overall building energy use from process and plug loads will grow. As an example, if one assumes that code-regulated energy use in a building is 75% of the total then it would require a 25-30% increase in code stringency to reduce overall consumption by 20%. It is clear that long-term energy reduction goals cannot be met through codes unless their scope is increased. Encouragingly, there is already a starting point for this as ASHRAE/IESNA Standard 90.1 currently contains criteria for a number of common process loads (e.g. kitchen hoods in restaurants, fume hoods in laboratories, condenser heat recovery to pre-heat water for laundries in hospitals). To be effective, however, requirements will have to address controls for plug loads as well as the equipment itself.

Operational factors are another issue. Current energy codes have very limited means of assuring that buildings perform as they were intended. They are a part of the construction code and their reach typically ends at the Certificate of Occupancy. Commissioning (or acceptance testing) requirements for equipment can have an impact on operational issues, but they are a snapshot and can only assure that equipment has been properly installed and configured for that one moment in time. Since the requirements precede occupancy, they cannot assure that the settings are appropriate for the ongoing use of the building nor that they will persist long term. The most efficient building can be operated very inefficiently, and current codes have very little ability to affect that simple reality.

Innovation and Flexibility

Prescriptive-based codes also provide very little flexibility or room for innovation. In prescriptive-based compliance, the only way to demonstrate compliance is by the inclusion of those particular building elements. There is no flexibility to pursue other approaches that might suit a design better, be more readily available, be more cost effective or even achieve higher efficiency goals. New technologies such as advanced mechanical equipment and innovative, energy-saving design techniques must make their way into codes that are usually on a 3-year development cycle before they can be included in code requirements. If they are alternatives to code-required elements, they can also then end up effectively banned from buildings. Even though modeled performance-based compliance paths provide considerably more flexibility, they still face some of these problems. The modeling is guided by protocols built into the code so until those approaches to efficiency are recognized by the code, they cannot be used to achieve compliance. This would be true for a performance-based code just as much as it is for prescriptive-based codes.

Prescriptive-based codes can inhibit innovation in another way. Since they, by their nature, only address certain aspects of building design and construction, they create a de facto roadmap and direction for R&D efforts in the building efficiency market. The requisite nature of codes creates a significant market for the products they require and R&D is prejudiced to flow to those solutions that can be required by code. There is less incentive to invest R&D resources other solutions that save energy but will not aid code compliance. This de-incentivizes investment in those other energy-saving solutions. It also de-incentivizes R&D research into fundamental design approaches to energy savings since these too are difficult to require in prescriptive codes.

Compliance

In response to the American Recovery and Reinvestment Act (ARRA), every state has committed to achieve 90% energy code compliance. However, the Institute for Market Transformation has estimated that it will require $810 million to achieve that goal. This reveals one of the other weaknesses of energy codes based on performance proxies:

the difficulty in assuring that the actual outcome aligns with the proxy. Verifying compliance requires multiple inspections at different stages of construction in order to check all the various features of the building. This "boots on the ground" approach to compliance is very labor intensive. There will probably always be a need for onsite inspections, but the move to outcome-based compliance can simplify assuring compliance significantly. The proof of compliance will be obvious in the measured performance of the building. If it is not designed or constructed properly, it will not perform.

THE PARTS OF OUTCOME-BASED COMPLIANCE

There are three primary components of an outcome-based compliance path: the performance targets, a reporting mechanism and an enforcement mechanism. Development is needed on all three of these components before outcome-based compliance will be ready for wide-spread deployment.

Setting the Targets

The biggest technical obstacle to adding an outcome-based compliance path to energy codes is the issue of setting performance targets. Different building types consume energy very differently. In terms of energy per square foot, unrefrigerated warehouses use about half the energy used by offices, offices use less than half the energy used by sit-down restaurants, which use half the energy used by fast food restaurants. Even the same building type will consume different amounts of energy depending on the severity of its climate zone or the use schedule of the building. In order to set targets for an outcome-based compliance path, a single performance number is insufficient; a matrix of values that account for these different conditions will need to be created.

The creating of credible performance targets will require a comprehensive analysis of building performance. Although a significant amount of analysis goes into code development and other building science research, modeling the way to performance targets presents a handful of problems. Significant deviations have been noted between modeled and actual building performance, and there is only limited information about the consumption from historically unregulated loads such as plug and process loads. For this reason, there is a need for widespread building performance metering to fill the data gap. In this regard, we are not starting from scratch. CBECS (Commercial Building Energy Consumption Survey) is one significant repository of building performance data. While CBECS contains a wealth of performance data, it is not perfect. It is only updated every three to four years, and the last public update was for 2003. Additionally, while the data is statistically significant on a nationwide basis for many building types, the sample is not robust enough to dig down to regional and sub-regional levels for all building types. CBECS also contains only commercial buildings and does not contain information for all buildings types (multi-family housing is one significant gap). Disclosure requirements such as those already adopted in Seattle, New York, and Washington DC, the optional disclosure requirements of the IgCC, and those being considered in many other jurisdictions are a step in the right direction, but these kinds of disclosure ordinances will need to become more widespread in order to assemble sufficient data to begin to set performance targets. There will also be a need for a mechanism to gather, collate and analyze all this buildings data. Although existing datasets may be incomplete, they are still useable. Performance targets can be set for those building types in those climate zones for which significant performance data exists.

A comprehensive matrix of performance targets is the ideal, but that is not the only way to set performance targets. In the interim, existing structures can be leveraged to produce targets. These interim solutions will not work for every building type of course. This is the advantage of adding outcome-based compliance as an additional path rather than as an outright replacement for existing code frameworks; it does not have to work for every building as long as there are other paths available.

Reporting

The second component is a reporting mechanism. The actual performance of buildings will need to be gathered and reported to the relevant authority. Buildings will need equipment capable of measuring and storing performance data. Not all buildings even have their own utility meter. Therefore this metering equipment will need to be required by the code in any building seeking outcome-based compliance. Owners will need a means of delivering that information to the authority. The authority will need a way to validate and collate that data. There is a potential synergy here with benchmarking efforts. They will also require a means to validate and collect data. These two efforts could be easily combined.

Enforcement Mechanism

Setting performance targets might be the biggest technical obstacle, but introducing a new compliance path to existing energy codes represents a significant policy change in the way building departments operate. The energy-related involvement of building departments typically ends with the Certificate of Occupancy. Building officials make inspections during and after construction and the granting of the Certificate of Occupancy is contingent on those inspections. An outcome-based compliance path would extend the involvement of building officials well after the Certificate of Occupancy. While this mode of compliance might actually decrease the amount of effort and expense expended by building officials, implementing it will require new policies, procedures, forms, training and perhaps new fees and penalties. There is also the significant question of what to do when a building fails to comply. Unlike a non-compliant design, it has already been built and changing it could be a significant issue.

A conservative approach to implementation can ameliorate many of these issues. Every code cycle involves changes to the code and will require some degree of new policies, procedures, forms and training, so there is a natural transition point/period for change. The new compliance path can be added first to reach/green codes adopted by more motivated and sophisticated jurisdictions that would be more flexible and more enthusiastic about the opportunities afforded by the approach. It could also be introduced first to governmental buildings as a part of a push for greater efficiency or greater accountability in energy performance. Concerns of compliance can be addressed through policies such as requiring non-compliant buildings to go back through traditional compliance paths, establishing requirements for “compliance bonds” that would be forfeited or used to bring non-compliant buildings into compliance.

Enforcement could also be moved outside of the building department. Vancouver, British Columbia is in the early process of developing an outcome-based compliance path. They have considered using property taxes, utility surcharges and performance bonds as their enforcement mechanism. As of this writing, they have tentatively chosen performance bonds. Buildings that fall below performance targets could be assessed higher property taxes or assessed some other tax. A tax could be assessed on the energy consumed by a building above the performance target, or utilities could be required to institute a tiered rate structure based on performance targets. A performance bond would require a developer to put up a certain sum which would be forfeited if the building failed to meet its performance target. An advantage to these approaches is that they allow a non-compliant building to be continued to be occupied while still providing motivation for building owners to bring their non-compliant buildings into compliance.

A Universal Energy Scale

Although not a requisite component for an outcome-based compliance path, a universal energy scale would help ease the transition and help solve many other problems faced in energy codes. New energy codes are often described as an improvement of X% over the previous code. This is immediately confusing because, as described above, not all energy is regulated under the code so it is not clear whether X% refers only to regulated energy use or to whole-building energy use. It gets more complicated, however, when describing changes that occur over multiple code cycles. As Charles Eley noted recently, “Percent savings is confusing because the codes frequently change…. ASHRAE updated Standard 90.1 in 1999, 2001, 2004, and 2007. Early green buildings claimed savings of 40% or more relative to ASHRAE Standard 90.1-1999, but many of these buildings would fail to comply with the most recent ASHRAE and California codes….[P]ercent savings becomes confusing and unstable as policy makers set goals for zero net-energy buildings and as energy codes become more stringent.”

What is needed is a fixed baseline which is nationally accepted, preferably one based on whole building energy use and in which zero is equal to zero-net-energy. References could then be made to being X% lower than the baseline and everyone would immediately understand where that puts us on the path to zero-net-energy. The U.S. Department of Energy is well positioned to create and promote such a standard.

A related topic is that there is little understanding of how current energy codes actually perform. Recent code equivalence studies have suggested a much lower total energy use for buildings that meet code requirements than independent studies of the building stock have implied. For example, a recent study by a federal lab comparing ASHRAE 90.1-2007 with the newly released ASHRAE 189 standard suggested that 189 would deliver a 30%

energy improvement over 90.1-2007. (One-third of this comes from renewable energy generation.) If you compare the predicted energy use for office projects in these two codes, the analysis suggests that energy use for projects built to code requirements are ~35 kBtu/sf/yr and ~20 kBtu/sf/yr respectively.

Comparing this to actual energy use of some office buildings in Seattle suggest that these results may not be supportable. The City of Seattle has one of the most stringent energy codes in the country – generally more stringent than 90.1-2007 – along with an aggressive enforcement policy. One of the best performing new buildings in the city, with a recent Energy Star score of 100, demonstrates metered annual energy use of 42 kBtu/sf/yr – 25% more energy than the equivalence study suggests a less stringent code will deliver.

These results imply that, from a policy standpoint, we may be significantly over-estimating the stringency of our existing codes. In addition to de-emphasizing the magnitude of the building efficiency problem, it becomes very difficult to justify on-going code stringency improvements, both from a policy and an individual project basis. Consider: if the analysis under-estimates actual building energy use by 30%, then the marginal savings from other building efficiency improvements are likewise under-predicted by 30%. For many measures, this makes the difference between a measure that is deemed to be cost effective, and one that is not. For both program-wide incentives and individual projects, this information discourages design performance improvements by underestimating their potential energy impacts.

CONCLUSION

Existing energy code frameworks have been very successful in saving energy in buildings. However, as we look to our energy codes for more aggressive energy savings, existing frameworks may not present the best solution. This creates the need for an additional, alternate compliance path that can fill the gaps left by existing frameworks. An outcome-based compliance path would bypass the obstacles presented by both prescriptive and modeled performance compliance paths through focusing on outcomes.

This solution is not without barriers. Introducing an outcome-based compliance path to existing energy codes will require not only foundational development work, but will also require a fundamental shift in the way that buildings comply with energy codes and receive their Certificates of Occupancy. Outcome-based codes will require much more pervasive benchmarking in order to determine credible performance targets for a broad selection of building types and to determine performance histories of individual buildings. Perhaps more profoundly, code compliance will have to shift from something that occurs before building occupancy begins to something that occurs after building occupancy occurs. This is a fundamental shift in the way that building officials interact with buildings. While it also presents the opportunity to simplify the verification of energy code compliance—a building either performs or it doesn't, there are not building components to check, no models to verify—it is still a fundamental change and carries the challenges of all policy change.

For these reasons, there is the need to begin to take those foundational steps now. For those steps to be taken, the conversation needs to proceed with a consistent set of definitions and common understanding of the issues involved.

REFERENCES

1. Architecture 2030, *The 2030 Challenge*, http://architecture2030.org/2030_challenge/the_2030_challenge, accessed May 12, 2010.
2. US Department of Energy "Understanding Building Energy Codes and Standards," http://www.energycodes.gov/implement/pdfs/codes101.pdf.
3. American Recovery and Reinvestment Act, Public Law 111-5.
4. Institute for Market Transformation, *$810 Million Funding Needed to Achieve 90% Compliance with Building Energy Codes*, Washington, DC, 2010.
5. United States Department of Energy. *Energy Information Administration. Commercial Buildings Energy Consumption Survey (CBECS)*, 2003. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set10/2003html/c16.html, accessed May 12, 2010
6. Turner, C., Frankel, M. *Energy Performance of LEED® for New Construction Buildings.* New Buildings Institute, March, 2008.
7. Architectural Energy Corporation, *Rethinking Percent Savings: The Problem with Percent Savings and the New Scale for a Zero Net-Energy Future*, California, 2009.