Re-Inventing Building Energy Codes as Technology and Market Drivers

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ABSTRACT

Global climate change, with a time frame of decades not years, encourages policy makers to pay more attention to new construction in addition to the retrofitting of existing buildings and to upgrading the efficiency of fast-turnover appliances and lighting. Increased interest in advanced building energy codes is reflected in proposed federal legislation to set multiyear energy code targets leading to zero-energy buildings. The expectation of continuous, staged improvements in building codes – coupled with voluntary market transformation – can help drive long-term demand for energy-efficient building designs, construction materials, and installed equipment.

For building energy codes to serve as market-drivers not just followers, we need to revitalize the code development process; strengthen incentives and mandates for code adoption, compliance, and enforcement; and encourage beyond-code building practices. Increasingly stringent goals for energy codes will challenge current processes of code development, adoption, compliance, and enforcement, and may require a transition from prescriptive to performance-based code compliance, or perhaps a mixed system.

In the future, incorporating "building life-cycle performance" into energy codes would require accounting for building or component lifetimes and reaching beyond the design stage to address construction quality, acceptance testing, long-term performance, and the role of occupants. Beyond today's common metric, annual energy use per square meter of floor space, future codes could address: electricity load shape and demand-responsiveness, environmental impacts, embodied energy, metrics based on occupancy instead of (or in addition to) conditioned floorspace, code requirements or credits for features that enable future technology upgrades, subdivision- and community-scale energy systems, "locational" efficiency, and "progressive efficiency" criteria that require higher performance from larger homes and buildings.

Introduction: A Changing Environment for Building Energy Codes

The traditional policy drivers of most building energy efficiency programs have been government programs (federal, state, and local) and utility demand-side management, generally with 2-4 year evaluation cycles. Not surprisingly, these programs look for quick results from energy-saving retrofits and improved O&M in existing buildings, and from upgrades in fast-turnover lighting and appliances. New construction, at an annual rate of 1-2%, has often been judged to be too small a source of savings for these programs. Until recently, most new construction programs have emphasized longer-term R&D or voluntary programs such as tax credits and ENERGY STAR, rather than stronger energy codes.[1] Concerns for global climate change and long-term energy security are shifting the focus of energy policy to a time frame of decades not years. This in turn has helped stimulate new interest in building energy codes.

Energy code proposals in federal energy and climate bills have focused initially on multi-year targets to advance the stringency of the model energy codes.[2] While model codes are important, by themselves they do not guarantee energy savings. The effectiveness of energy codes is the product of several factors: Strong Model Codes x State Adoption x Verified Compliance x Performance Assurance. The ultimate impact of energy codes will be only as strong as the weakest of these links. In practice, there is often a tension between pushing for increased model code stringency on the one hand, and achieving timely state code adoption and effective code compliance on the other. Considering this tension, we suggest that the traditional approach – incremental advances in energy code stringency – may not be sufficient to meet national policy goals. We believe this is the time to consider new models and new strategies.

Adoption of the model energy codes has often been slow or inconsistent. Only about half the states have adopted codes at the level of the 2006 or 2009 IECC for residential buildings or ASHRAE 90.1-2004 for commercial buildings, while almost a dozen states have no energy code or a code that is more than 10 years old (BCAP 2010). And compliance rates are often poor; median compliance among those few states that have measured it is only 40-60% (Yang, 2005).

Building energy codes generally try to eliminate the least efficient design and construction practices but do little to accelerate the development and use of new energy-saving technologies and practices. A new policy framework focused on "dynamic" not static codes would define a multiyear path for periodic code updates, coupled with improved compliance and enforcement and sustained investment in infrastructure to support both code implementation and a broader market transformation in design building and construction practices (NEEP 2009; CPUC 2008). These infrastructure investments would include improved software tools; workforce training for design, construction, code compliance, and code enforcement; appraisal and finance practices that fully value energy efficiency; effective building energy management using energy consumption feedback and benchmarking; and a well informed market based on universal building energy performance rating and disclosure.

If all market actors – designers and builders, code officials, suppliers, and building owners and operators – share the expectation of periodic energy code improvements, the market response can become self-fulfilling and in turn can support state code adoption and builder compliance. This is because leading builders will find advantages in going beyond the current code, and product suppliers will see higher value and lower risk if they introduce high-performance building materials and equipment. Market leadership is even more attractive when periodic code upgrades are coupled with voluntary incentives, technical assistance, design tools, and training – all of which help point the way to the next upgrade cycle for the energy codes.

We recognize that new strategies for code advancement may pose risks, and that some code advocates may prefer the current approaches that are well understood and have delivered modest but steady gains in code stringency (most notably in the past three years). The prospect

[1] One exception to this is California (and a handful of other states), where utility regulators have allowed utilities to claim credit for energy savings from activities that strengthen building energy codes or code enforcement.

[2] The national model codes are ASHRAE Standard 90.1 for commercial buildings and the International Energy Conservation Code (IECC), issued by the International Codes Council (ICC) for residential buildings. Federal legislative proposals also authorize significant new funding for state and local code training and enforcement, although actual resources will depend on future budget appropriations and/or revenues from carbon taxes or a cap-and-trade system.

of reinventing the energy code process and linking codes more closely with market transformation is still at an early stage, with more questions than answers. Those answers will require careful field-testing of new policies and programs, and fresh ideas from many sides. This paper is intended to pose some initial questions and spark discussion on these important issues.

Innovations and Game-Changers

Code Development – New Approaches, New Participants

Energy codes traditionally specify "the *least* energy-efficient building one can legally construct." The relative obscurity and technical complexity of the code development and adoption process offers many opportunities for opponents of strong energy codes to hamper progress. Still, the national model energy codes are important as the foundation for most state energy codes, and help send a clear market signal to national builders and building suppliers.

A sea-change in the 2009 International Energy Conservation Code (IECC). After nearly two decades of modest efficiency gains for the IECC,[3] a group of stakeholders established the Energy Efficient Codes Coalition (EECC) in 2007. In contrast to the traditional code-development process, the EECC adopted a "campaign-style" approach, submitting a comprehensive package of energy code proposals for residential buildings for the IECC 2009 edition and branding it "The 30% Solution." The EECC also reviewed every residential and commercial code proposal submitted by other stakeholders and offered recommendations on each proposal. Although opponents initially argued that the EECC's packaged code proposal had over-reached, the 30% Solution highlighted the overall efficiency gains to be achieved by incorporating in the model code a set of proven and readily available energy-saving measures that addressed almost every aspect of new home construction. A second element of the EECC strategy was to recruit new voices for the energy efficiency choir. The Coalition reached well beyond the traditional code development participants to elicit support from: governors and mayors, advocates for low income housing, environmental advocates and community activists, and utilities.

While the EECC's full 30% Solution package was not adopted in the 2009 IECC, the proposal did receive six of 14 votes from the IECC Development Committee and the support of 64% of eligible voters at the 2009 IECC Final Action Hearings – just short of the required two-thirds majority. More significantly, 14 of the 21 individual elements of the "30% Solution" were incorporated into the 2009 IECC, contributing significantly to an updated residential model energy code estimated to be 10-15% more efficient than the 2006 IECC. Many other proposals supported by the EECC were also adopted. This is the single greatest improvement in stringency of the residential model energy code since it was developed in the 1980s. Moreover, the 2009 edition of the IECC provides a strong foundation for continuing efforts to fully achieve the goal of 30% improvement – or more – in the next code cycle (IECC 2012) currently underway.[4]

[3] About 20 % over twenty years, or 1% per year – see Figure 1.

[4] In parallel to the EECC's involvement in the IECC process, the leadership of ASHRAE also adopted a goal of achieving 30% energy savings in the 2010 update of Standard 90.1, used by many jurisdictions as the model energy code for non-residential buildings. ASHRAE also supplemented Standard 90.1 with other activities to support design and construction of energy-efficient buildings, including a series of Advanced Design Guides targeting 30% (and eventually 50%+) savings and a new design standard (189.1) for High-Performance, Green Buildings (see

Continued momentum toward the 2012 IECC. EECC's 2009 campaign helped to change the energy codes development landscape – shifting the debate from *whether* energy codes should be improved by 30% to *how* they can most effectively reach that 30% goal. Codes legislation pending in both the House and Senate at the time of the hearings supported this shift by encouraging participants in the IECC process to strengthen the model codes on their own terms before federal requirements (discussed in the next section) were imposed.

After questioning – sometimes vehemently – the package approach of EECC's 30% Solution, many stakeholders in the 2009 IECC proceedings have embraced this same approach for the 2012 cycle. In addition to the EECC package for 2012, several other package proposals were submitted, both residential and non-residential. These included comprehensive residential packages proposed by the US Department of Energy (DOE), a regional code advocacy group (NW Codes Group), and even the National Association of Homebuilders (who previously had opposed almost all proposals to strengthen the residential part of the IECC). A comprehensive commercial package was submitted by DOE, the American Institute of Architects and the New Buildings Institute. In addition to a new comprehensive package ("30-Plus") to boost savings beyond 30% compared with the 2006 IECC baseline, the EECC also introduced over 30 individual residential energy code proposals, including proposals to substitute the IECC for the weaker energy requirements of another model code, the International Residential Code.

In October 2009 the IECC Development Committee took the first step in the 2012 model code update proved by recommending adoption of the DOE residential package along with several proposals by the EECC and other stakeholders. Thanks to the Committee's positive recommendations, these measures can now be approved by a simple majority vote at the 2012 IECC Final Action Hearings in October 2010. On top of those provisions already adopted in the 2009 IECC, these new measures if approved will improve energy efficiency for both residential and commercial buildings by well over 30%.

National policy on multi-year code targets and code adoption. At present there is no national policy in place to require or guide efficiency gains in the model energy codes. After the initial progress with the early model energy codes in the 1980s, savings in subsequent code updates have been incremental at best, averaging 1-2 percent savings per year (see Figure 1).[5]

Until 2007, energy efficiency advocates focused mainly on incremental improvements in the model codes (and on opposing efforts by others to roll back code stringency), while also supporting model code adoption in the states. However, 2007 marked a new, complementary movement to legislate a national policy on energy codes. Multiyear energy savings targets for building codes were proposed in legislation that year, but ultimately not included in the 2007 Energy Independence and Security Act (EISA). By 2009, both the House climate bill and the Senate Energy and Natural Resources Committee energy bill included provisions to strengthen building energy codes (ACES 2009; ACELA 2009). The Senate bill called for a model code target of 30 percent savings starting in 2010 and 50 percent savings starting in 2016. The House bill had more stringent targets: 30 percent savings upon enactment; 50 percent savings by January 2014 for residential model codes and January 2015 for commercial codes; and then

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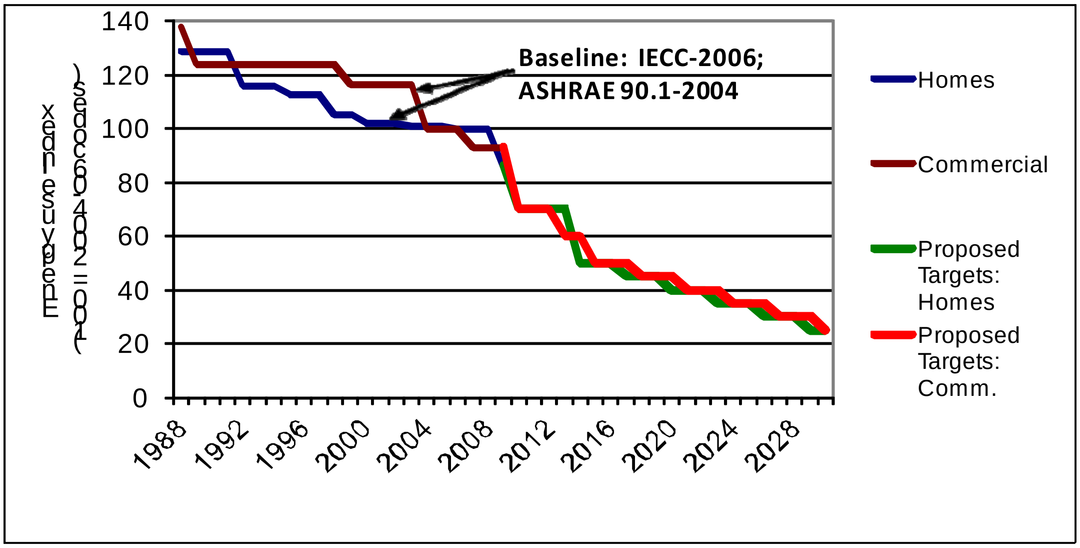
http://www.ashrae.org/publications/page/1604 and http://spc189.ashraepcs.org/). Similarly, the ICC is currently working on developing the International Green Construction Code for commercial buildings.

[5] Source: Alliance to Save Energy estimates (Nils Petermann); for historical dates based in part on DOE code determinations under Section 304 of EPCA (Public Law 94-163) as amended by EPACT-1992 (Public Law 102-486).

another 5 percent savings every three years until 2030 (Figure 1). Both bills called on states to adopt these model codes (or codes with equivalent energy savings) within one or two years, and to achieve 90% code compliance rates within 7-8 years.

Figure 1. Trends in Model Energy Codes vs Targets in Proposed Federal Legislation



If the code development goals are not met, the proposed legislation directs DOE to develop and issue model codes that do meet the targets. This is not a desirable scenario from the viewpoints of either code stakeholders or DOE officials, but the prospect of a federal government takeover of code development is designed to encourage both code development organizations and code stakeholders to focus on meeting the targets. The House bill includes language to strongly encourage and assist states to adopt the latest energy codes and to step up code compliance: 0.5% of all carbon emissions allowances (estimated at up to several hundred million dollars per year) would be devoted to code implementation by states and local governments, and other state energy funding would be conditioned on a state meeting the building code targets. Finally, if state and local governments still did not meet the goals, DOE itself would have authority to adopt and enforce building energy codes in those jurisdictions. Direct federal action, of course, would dramatically change the energy codes world. While neither the House nor Senate legislation has yet been enacted, the codes provisions have received widespread support.

In 2009, a separate group called the Building Energy Efficient Codes Network (BEECN) was formed to advocate for federal codes legislation. BEECN has taken the issue of energy codes to a broad national audience, supporting the proposed code targets, more federal funding to help states and localities adopt and implement energy codes, and provisions to link federal economic stimulus funding to state adoption of energy codes. This last provision was enacted by Congress in early 2009 as part of the economic stimulus bill (ARRA, 2009). In order for a state to receive its share of $3.1 billion in state energy program funds, the governor was required to assure DOE that the state (or local governments) would adopt the 2009 IECC and ASHRAE Standard 90.1-2007 (or equivalent energy codes), and would undertake a plan to achieve 90 percent code compliance within 8 years. While some states are proceeding to fulfill these commitments, others have yet to show that actions will match their words.

Along with the incentive of federal funding, states have access to a growing network of information, technical resources, and energy code advocates supporting the adoption and enforcement of energy codes. DOE is expanding its Building Energy Codes Program to provide code training, tools, and technical assistance, including guidance on how states can measure code compliance. The Building Codes Assistance Project (BCAP), with funding from DOE and others, provides stakeholders with information and resources on energy code benefits as well as direct assistance to states. BCAP also works closely with DOE to coordinate energy code advocacy efforts and resources. The Responsible Energy Codes Alliance (RECA) promotes state and local adoption of the IECC nationwide and provides residential code compliance guides for each state, along with other information and assistance. The National Association of State Energy Officials (NASEO) has organized workshops, webinars, and hands-on assistance to help states with code adoption and implementation.

The very real possibility that energy code targets will be enacted into federal law has played a significant role in the rapid advancement of model energy codes – and continues to do so. The lesson from the code requirements in the economic stimulus bill was that while a few states were ready to act on their own, others were clearly spurred to adopt stronger codes, sooner, as a result of this tangible federal incentive, as well as the policy attention and political legitimacy the bill focused on energy codes. Unfortunately, a few states still seem determined to resist the national call for strong building energy codes – as well as foregoing the tangible benefits to consumers, their economies, and the environment. To assure continued progress, both DOE and the states would benefit from the public reporting of progress in state code adoption and compliance, as well as federal funding criteria that base future discretionary grants on the effectiveness of a state's energy code adoption and enforcement programs.

New Paths to Code Advancement, Adoption, and Compliance

State and Regional Leadership on Code Adoption, Dynamic Codes and "Stretch Codes"

While some states have stepped forward to promptly adopt and begin enforcing the most recent national model codes, a few others, along with some municipalities, have gone even further – developing their own innovative building energy codes along with policies for continuous code improvement, voluntary "stretch codes," and a variety of "beyond-code" guidelines.[6] Use of these stretch codes and guidelines can be encouraged through non-monetary incentives such as density bonuses or accelerated permit review. Sometimes more agile than national code-setting organizations or the federal government, state and local initiatives can set a high bar for future mandatory energy codes and provide a practical "proof of concept" to justify strengthening the next round of national model codes.

Some states have demonstrated their ability to repeatedly advance the stringency of their state energy codes, often setting an example for other jurisdictions and/or the national model codes. Consider two such examples, both of which apply the concept of dynamic energy codes advancing toward long-term goals.

The California Energy Commission updates its Title 24 building energy code on a regular 3-year cycle, and has adopted a policy of using codes and other programs to achieve zero-energy

[6] For a recent compilation, see BCAP's "National Listing of Above-Code, High-Performance, and Green Building Programs" at http://bcap-ocean.org/resource/national-listing-above-code-high-performance-and-green-building-programs.

performance in new homes by 2020 and in new commercial buildings by 2030 (CEC 2009). The California market for building design, construction, and construction products knows that the code will be strengthened over time, so they can plan for timely shifts in practice and products. The current Title 24 standards were adopted in April 2008 and became effective January 1, 2010. At the beginning of 2009, the state adopted CALGREEN to take effect January 1, 2011. The California Air Resources Board estimates that these mandatory provisions will reduce greenhouse gas emissions by 3 million metric tons in 2020, and help the state reach its short-term goal of a 33 percent reduction by 2010. All parties now expect the code to be updated regularly through a public process, and to achieve significant savings in each new iteration.

Austin, Texas is currently working on a multi-year plan to move their new home market to “zero-energy capable” construction by 2015. Through a city ordinance passed in 2006, a task force identified near-term improvements for the 2007 energy code and made recommendations for successive code cycles and planned energy use reductions. [7] Overall, Austin plans to reduce energy consumption 65 percent by 2015 and to make all new homes “solar-ready.” To pursue these goals the municipal utility, Austin Energy, works closely with the Austin Building Department on code inspections and draws on this field experience to identify new energy-saving opportunities to consider for future code updates.

The above discussion implies that state, regional, or local energy code innovation and code differentiation are good, and that a continuing push toward more stringent energy codes will encourage states or localities to compete to have the “best” energy code. However, some states that have traditionally developed their own unique energy codes, like Florida, are now moving towards closer alignment with the IECC. And historically, most states and local jurisdictions have adopted some version of the national model energy codes, sometimes with modifications to meet local conditions or – unfortunately – with weakening amendments that reduce energy code stringency in response to local stakeholder objections

National code adoption advocacy groups like RECA currently promote adoption of the model energy codes without weakening amendments. As these model codes become more stringent, there may be an increased likelihood of proposed amendments that lead state or local governments to weaken rather than strengthen the codes, or adapt them to local circumstances. Simply put, energy code innovations and the testing of new compliance approaches should be encouraged where they contribute to a stronger (or more readily enforced) building code, but not where they reduce energy savings.

There are other potential downsides of state-by-state code innovation. State-specific code development is resource intensive and requires expertise and funding to develop design tools and compliance software for each state. Also, in the absence of a uniform standard for national manufacturers and large nationwide production builders there are fewer economies of scale in training and manufacturing; this can increase the cost of energy-saving designs, construction techniques, building materials, and installed equipment.

Many of the benefits of state and local code innovation, such as developing and piloting new ideas, might also be achieved through voluntary market transformation programs rather than building codes; examples include the ENERGY STAR Homes program, utility rebates and design assistance, and “stretch” codes as noted above. Promising local innovations can still be supported where the benefits appear to outweigh the down-side, especially in states like California with a long tradition of developing their own code and a well-developed code infrastructure.

[7] See http://www.ci.austin.tx.us/council_meetings/wams_item_attach.cfm?recordID=7329.

Opportunities for Utility Action on Codes

Beyond steady, regular increases in energy code stringency, there is a significant need for policy innovation on code enforcement and compliance. Utility demand-side management programs may have a significant role to play by providing design guidance and construction quality assurance – either for code compliance itself or as a baseline for beyond-code incentive programs. For example, investor-owned and municipal utilities in California are not only educating and training market actors on how to meet the state's Title 24 energy codes, but also evaluating new energy-saving measures to be considered for code upgrades. California utilities also co-sponsor "Savings by Design," a statewide program of utility design assistance for beyond-code construction.[8] This level of utility involvement depends on the willingness of regulators to recognize the value of achieving energy savings, either through code advancement or through improved compliance with current codes (National Action Plan 2009). However, if utility regulators make the unrealistic assumption that "mandatory" code compliance is already at 100%, then there is little latitude for utilities to claim savings for code-related activities, and they will likely drop the effort. Utility regulators in other states should encourage their utilities to support code development, adoption, training, and compliance activities.

Municipal utilities, regulated by their own Board or city council, often have more flexibility to take the initiative on code advancement and enforcement. For example, a group of municipal utilities in the Northwest undertook collective action to provide code inspection services to smaller jurisdictions (Smith and McCullough 2001). And Austin Energy has developed an effective model of collaborating directly with building officials on code training, inspections, and identification of new code provisions, as noted above.

The Future of Prescriptive and Performance Approaches to Code Compliance

Most energy codes today, including model codes like the IECC and ASHRAE 90.1, provide both prescriptive and performance compliance paths. The prescriptive path typically specifies component performance requirements, such as R-values for insulation or U-factors and Solar Heat Gain Co-efficients (SHGCs) for windows. In contrast, the performance path establishes a set of modeling conditions for a reference building in order to define a baseline energy (cost) budget that the proposed design must not exceed. The prescriptive path generally simplifies code compliance and enforcement, creates economies of scale for building products and equipment, and provides the benchmark for a performance path energy budget. On the other hand, the performance path allows building designers more flexibility where needed or desired.

Questions arise about the continued emphasis on the prescriptive path as codes move towards net-zero energy levels. Once the relatively easy savings are achieved, prescriptively, through efficient envelope and equipment measures, many believe that the remaining savings can only come through careful systems-level design. Based on the experience of beyond-code programs such as ENERGY STAR Homes and DOE's Building America, these additional measures may include building orientation, daylighting, thermal mass, natural ventilation, and appliance and HVAC integration, all of which may be difficult to specify prescriptively in codes. However, a well-trained designer can implement these measures using building energy simulation modeling and a code compliance path based on overall energy use – an energy performance budget.

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[8] See http://www.savingsbydesign.com/.

At the same time, a successful path to stronger codes must work with the building market as it is, and seek changes where feasible. Experience suggests that use of simple prescriptive requirements and checklists can often improve code compliance and enforcement. The new construction market, especially for homes and smaller commercial buildings, has often been resistant to change and – absent effective code enforcement – often indifferent to meeting the energy requirements of building codes (in contrast to electrical safety or structural requirements). Small homebuilders, in particular, consistently say they want simple prescriptive requirements or easily understood trade-offs. Few are interested in trying to navigate the computer-based performance compliance path, even where it might provide more design flexibility. Code officials also tend to favor simple, prescriptive code requirements which are easier to check on building plans and to inspect at the building site. On the other hand, architects for custom homes and larger buildings, along with large-volume production builders, often prefer to use the performance path for code compliance.

There is no single solution, but in anticipation that more designers and builders may be forced to turn to performance-based compliance, it is worth considering how the needed software tools and skills can be improved and made more widely available. [9] The concept of pre-defined "option packages," which specify several common ways to meet the energy code, has been used to complement the predominantly performance-based code in California and elsewhere. Option packages are also used to meet the performance criteria for programs like ENERGY STAR Homes, which specified some mandatory provisions as well as a minimum score using the Home Energy Rating System (HERS). It is worth noting that some mandatory code provisions may be needed with either the prescriptive or performance path, because they are essential to any well-crafted, durably performing building. Mandatory requirements can help avoid localized problems even where the building as a whole may meet overall performance requirements. Examples include local thermal discomfort from a poorly insulated wall, a cold window surface, or overheating in one room from too much solar gain.

From Design Performance to Operational Performance

A true "energy performance" code would consider not just building design and construction quality, but how well the completed and occupied building actually performs. Including operational performance requirements in a code would present numerous practical (and perhaps legal) challenges, but we can already see some precursors of such an operational performance approach, at least for some buildings or subsystems.

One example is the requirement for HVAC-system testing and balancing for all large buildings. This is a key part of building commissioning, which is currently referenced in ASHRAE Standard 90.1 and emphasized in the U.S. Green Building Council's LEED rating system[10] as well as the New Building Institute's advanced "Core Performance" guidelines.[11] Core Performance was adopted by Massachusetts in 2009 as the basis for their new commercial building "stretch code."

[9] California, for example, has taken three decades to build a substantial modeling and analysis infrastructure to enable architects, builders, and code officials use building simulation software to meet code requirement using Title 24's predominantly performance (energy budget) path.

[10] For LEED see http://www.usgbc.org/DisplayPage.aspx?CategoryID=19.

[11] See http://www.advancedbuildings.net/corePerf.htm.

A second example, now being considered by several states, is a requirement for energy performance rating and disclosure (energy labels) for new buildings, and possibly for existing buildings upon resale.[12] While energy performance labels would represent a step in the direction of a true operational performance system, it remains a difficult task to link the measured energy use of an occupied building to the quality of design and construction for which an architect or builder can be reasonably accountable.

Yet another step toward incorporating true energy performance in codes is the requirement to test building components for air leakage, such as duct system testing now required under the 2009 IECC, and building envelope leakage testing that is proposed for the 2012 IECC update (and currently required for ENERGY STAR Homes). Whole-building thermal performance tests using short-term predictive measurements have been available within the research community for many years but are not yet commercialized (Sonderegger et al. 1980; Subbarao et al. 1988). Additional research is needed to develop practical, short-term performance tests for sensible cooling and dehumidification performance, for hot water distribution systems, and for envelope and duct leakage in larger buildings.

One last example of an operational performance criterion: a few homebuilders offer their customers an energy performance guarantee that their utility bills will not exceed a certain energy consumption level or dollar amount.[13] Yet despite these helpful signs of a few current activities focused on actual building energy performance, a great deal of program and policy innovation will be needed to create a system of operational performance requirements that are practical, affordable, enforceable, and fair.

Beyond Annual Energy Use – New Dimensions for Building Codes and Performance

There are several other important and challenging dimensions of building energy codes that should be further explored, but an in-depth discussion is beyond the scope of this paper. Some might be pilot-tested first through voluntary programs like ENERGY STAR Homes, LEED ratings, and utility DSM incentives – or else introduced as part of a beyond-code incentive program. An initial set of issues includes:

- *Recognition of measure lifetime in code provisions* – Some energy-saving measures, like efficient mechanical systems or lighting, have much shorter expected lifetimes than other more permanent building features such as envelope components, building orientation, or general building shape and space configuration. Codes should give different weight to short *vs* long-lived measures when calculating trade-offs in an energy performance budget. As a corollary, it may be worth giving extra weight, in either the prescriptive or performance path, to those building elements that are the most difficult to change once the building is built – i.e., a policy of "no-regrets-over-the-building-lifetime."
- *"Future-proofing" today's new construction* – A number of advanced energy- saving technologies are easier and less expensive to install in a new building than as a retrofit. Examples include condensing gas furnaces, boilers, or water heaters, and rooftop PV or solar hot water. These systems are relatively costly today but may be much less expensive in the future – well before the end of the lifetime of today's new buildings.

[12] For a list of building energy labeling programs, see http://imt.org/benchmarking-and-disclosure.html.
[13] See, for example, http://www.energywisestructures.com, http://www.nchfa.com/nonprofits/HPsystemvision.aspx, http://omahanewhomes.com/energy-star/77, and http://www.segretohomes.com/e_2yr_guarantee.html.

Thus, consideration should be given to designing and constructing all new buildings to be "new-technology friendly," at least for those energy systems that are reasonable to anticipate today and where it is relatively easy or cheap to prepare a new building for a possible future installation. The Austin Energy code already requires every new home to be "solar ready"; building codes could include similar requirements to future-proof all new construction. This process should include a periodic assessment of promising new technologies whose installation costs are much less if a new building is designed to accommodate them, and where wasted effort or cost are small even if the option is not always exercised.

- *Rethink and extend the energy performance metrics in codes* – In general, the stringency of an energy code is expressed in terms of annual energy use (or energy cost) per m^2 of floor space. Energy use by different fuel types is typically combined using relative energy costs, to avoid the longstanding debate about counting energy in site *vs* source (primary) units. However, with the exception of California's Title-24 code, it is still rare for codes to consider the time-dependent value of energy, and of electricity in particular. Consistent use of time-dependent valuation of energy savings would help energy codes better reflect the societal value of saving energy. Similarly, codes should pay explicit attention to the *controllability* of both thermal and electric loads – not just to reduce predictable peak-period demand but for utility demand-response in general.[14] The usual way of measuring energy use per unit of floor space (or of building volume) is simple but misleading for some building types and for comparing buildings with very different occupant densities or operating schedules. Since energy is used mainly to serve the *people* in buildings (rather than "floorspace") perhaps we energy performance should be measured in terms of kWh (Btu, etc.) per *occupant-hour*. For special applications, specialized building performance metrics may be more appropriate than either space- or occupancy-based metrics; examples include energy use per "bed-day" (for hospitals), energy per 1000 pieces of mail processed (for a postal service facility), or energy per gigaflop of data processed (for a web-server facility).
- *Mandatory minimum requirements for certain components when using a performance code path* – As discussed above, establishing mandatory minimum requirements for certain building components when the performance path is used can help address issues that the computer models may not fully capture. For example, occupant discomfort from poor envelope insulation, poor air-sealing, or poor windows can lead to an adjustment of thermostat settings and thus higher energy use. While most codes include a number of mandatory measures (for example, the current residential IECC establishes an average minimum performance for windows) the issue of mandatory minimum requirements needs to be more thoroughly addressed if performance-based code compliance becomes the predominant method. Mandatory measures can also be used to address non-energy impacts, such as peak demand, long-lifetime measures, and future-proofing – as well as provisions such as sub-metering of major end-uses (and tenant spaces) to improve the effectiveness and lower the cost of lifetime building energy management.[15]

[14] Demand-responsive end-use systems have the ability not only to shave or shift loads at times of utility system peak demand, but to interact in real time with a "Smart Grid" to improve system reliability, better utilize intermittent wind and solar power, and reduce the amount of generating capacity needed as "spinning reserve."
[15] The latest version of ASHRAE Standard 90.1 includes provisions along these lines for non-residential buildings.

- *Determine and implement the best approach to address equipment efficiency in new buildings* – At present, residential building energy codes are largely stymied in calling for high-efficiency HVAC equipment and other efficient appliances – even though these efficient units may be much easier and less expensive to install in new construction than in existing buildings (Lekov et al. 2009). This is due to federal preemption for "covered products" already subject to federal appliance standards, including most residential HVAC and water heating equipment. While preemption does allow codes to include high-efficiency equipment as part of a prescriptive trade-off or a performance budget, such trade-offs are subject to a number of limitations. Due to federal preemption, equipment trade-offs can only be used to reduce the performance of the rest of the building; this is counter to the goal of increasing energy code stringency and savings. For example, in cold parts of the country the new home market is already demanding and receiving high-efficiency furnaces, well above the federal minimum standard. But if the code cannot set this higher level as a baseline, the result is that builders can use the high-efficiency furnace as a trade-off to install less insulation or less efficient windows.

  To avoid this "trading away" of energy savings, energy code advocates successfully offered a code change in the 2009 IECC to remove equipment trade-offs for residential buildings. On the other hand, also in 2009 efficiency advocates negotiated a "consensus standard" agreement with the HVAC industry that, among other provisions, would allow building codes to prescribe more efficient furnaces for new homes in colder regions and more efficient air conditioners in warmer regions – provided that there is also a code compliance option that does not require upgraded equipment beyond the federal standard.[16] One possible solution to the federal pre-emption clause that limits code requirements for efficient equipment in new homes would be a statutory change to permit codes to set equipment and appliance performance levels, for new construction only, above the federal minimum appliance standards. Alternatively, Congress could authorize the federal government to set a higher efficiency standard for equipment installed in new homes, where this is justified by lower installation costs or other factors.
- *Size matters!* – Finally, if one purpose of building energy codes is to help reduce energy-related GHG emissions over the long term, it is not just the energy *intensity* of new buildings that matters, but also the *scale* of these buildings and their absolute energy consumption and carbon emissions. A very large house that is "efficient" can use much more energy for its average 2.2 occupants than a modest size house with the same number of occupants. Hence the concept of "progressive efficiency," arguing that we should expect even more energy efficiency as the scale of a house or appliance (etc.) increases (Harris *et al*. 2008; Calwell 2010). Fortunately, some voluntary programs like LEED-H for homes, the latest ENERGY STAR Homes criteria, and proposals made by the Northwest Energy Codes Coalition for the 2012 IECC model residential code all call in some fashion for increased energy efficiency performance for larger homes, or else recognize a reduction in scale as equivalent to energy saved through improved efficiency.

[16] For details on this agreement see http://ase.org/content/article/detail/6187.

Energy Codes and Market Transformation

In this paper we have offered a general framework for building energy codes as a driver of new technology and market transformation, based on a framework of continuous code improvement in code stringency accompanied by improved rates of state adoption and compliance. Key elements of this multi-tiered, dynamic model for energy codes include:

- A regular, planned cycle of code review and updates, with clearly defined energy-saving targets for each stage;
- Requirements and/or incentives for states and local jurisdictions to adopt and effectively enforce the latest model building energy codes, without weakening amendments;
- A series of multiple tiers of building energy performance, similar to the multiple efficiency tiers used for "categorical" appliance energy labeling in Europe and other countries – these tiers provide a clearly-defined path for future code improvements as well as a basis for stretch codes and beyond-code incentive and recognition programs;
- Reinforcement of a multi-tier building performance scheme through requirements for public buildings (federal, state, and local) to achieve beyond-code performance, in order to provide proof-of-concept and test new ideas, to set an example for others, to provide a training ground for designers and builders, and to create an entry-market for innovative products and practices that will eventually diffuse to the rest of the market; [17] and
- Investment by government, utilities, and (where possible) by the buildings sector itself, in "soft infrastructure," including improved data, design and decision tools; professional and workforce training and certification; and both fundamental and applied R&D that is linked to demonstrations, field testing of new concepts, and priorities that reflect real-world program experience and can help push the envelope in building design, construction, and operation.

In conclusion, we believe the next few years will be an exciting, challenging, and potentially confusing time for policy and program innovation on building energy codes. No longer a "lagging sector" of energy efficiency policy, building codes – in concert with other policies – have a large untapped potential to help lead and transform building design and construction practice throughout the U.S. and in most other countries. The path ahead is promising, but also complex and uncertain, with many challenges demanding innovation and the testing of new concepts and new strategies to advance building energy efficiency.

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[17] There are examples at all levels of government of above-code policies for public buildings. New federal buildings are required to be 30% more efficient than code, and policy examples at the municipal level are found at http://cfpub.epa.gov/ceird/index.cfm?fuseaction=local.search_js

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[18] SERI is now the DOE National Renewable Energy Laboratory.