Outcome Based Codes: Answering The Preliminary Questions

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ABSTRACT

Policymakers and the public are increasingly interested in reducing energy use. Whether due to a desire to reduce costs, greenhouse gas emissions, or imported energy, achieving these goals will depend on actual and measurable results. Today's building energy codes regulate proxies for energy use, do not require measurement and expression of actual building energy performance, and depend on incremental improvements to prescriptive criteria (e.g. equipment efficiency levels, insulation values, and lighting power allowances). Achieving the ultimate goal of net-zero energy buildings requires a different approach. Outcome-based codes establish an energy use level as well as regular measurement and reporting to assure that the completed building performs at the established level. A shift to outcome-based codes will require a dramatic change within the building community.

INTRODUCTION

Energy codes have become the poster child for improving energy use in buildings. Some funding from the American Recovery and Reinvestment Act (ARRA) was tied to the adoption and enforcement of the latest energy codes [1]. Congress has also considered legislation to set targets for future versions of model energy codes [2]. However, there seems to be little attention focused on how energy codes function, whether they are getting us to our energy goals, and what future codes will look like. Examining these issues will hopefully demonstrate how outcome-based codes can be the path forward, once many of the underlying questions and concerns are addressed.

Despite their titles, current energy codes do not regulate energy use; they regulate proxies for energy in the form of thermal envelope and building systems for heating, ventilating, air conditioning, and lighting. The codes are also based on utilization in an ideal world where equipment, insulation, ducting, windows and doors, air barriers, lighting systems, equipment, and controls are all installed perfectly; where operations and maintenance requirements are followed to the letter; and where building occupants follow the rules and make educated decisions about their energy use. The actual performance of buildings is affected by the quality of construction. Some aspects of the building, such as insulation, air sealing, duct sealing, and pipe insulation, owe their actual performance to how they are installed. Assessing building quality is subjective, and the only way to know if the as-installed performance will achieve the intended performance is through *in-situ* testing. In practice, no building is perfect, no matter the diligence of the design and construction team, operations staff, building occupants, and ownership.

Also, current codes do not cover all the energy-using functions in a building, despite the fact that they all contribute to the overall energy use as well as influence the energy use of equipment covered under the code. Plug and process loads (including office equipment and computers) and vertical transportation (i.e., elevators and escalators) generally are not included. In California, for instance, plug loads account for approximately 40% of overall energy use—even close to 65% in some building types, like hospitals and restaurants [3]. In addition to energy load, such equipment typically introduces heat into the space, which must be dealt with by the HVAC systems.

Spending for code development, implementation, training, and enforcement under the current scheme is largely unknown, but one estimate puts it at around $200 million dollars, with a total need of $810 million annually to ensure a 90% compliance rate [4]. The current compliance rates also are unknown, although some reports indicate levels around 40% [5]. This is far from the 90% compliance rate being sought under ARRA by 2017. The Department of Energy and its Pacific Northwest National Laboratory are working on protocols for measuring compliance, which several states are now piloting and other states are using for preliminary compliance assessments [7].

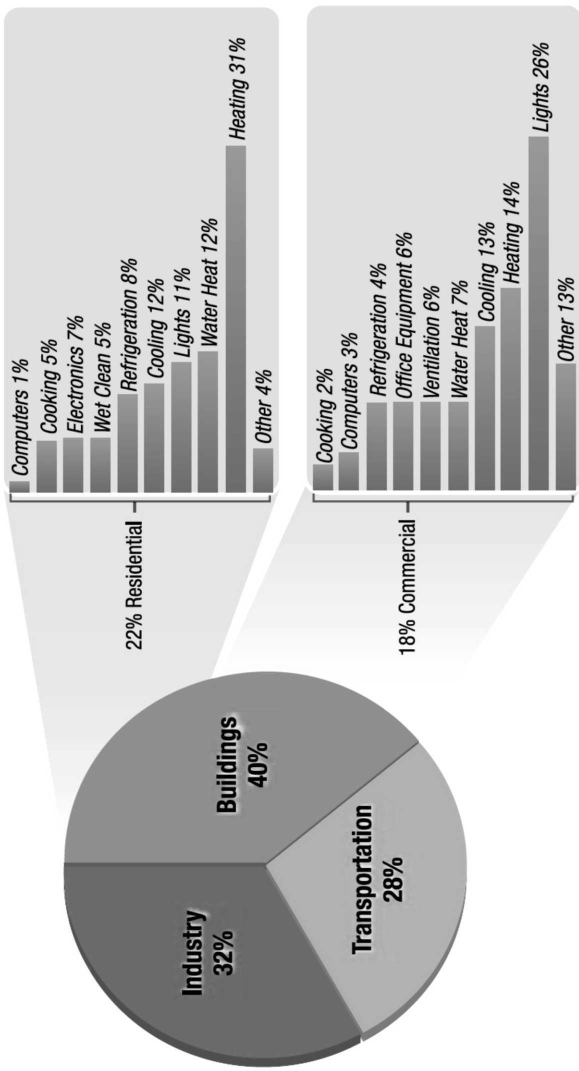

Figure 1. Energy Consumption in the U.S. [6]

CURRENT CODE FORMATS

Today, energy codes have two formats, each with their own pros and cons.

Prescriptive Codes

Prescriptive codes provide minimum characteristics for many building components (e.g., R-values for wall and ceiling insulation, U-values for windows, and SEER or EER for unitary air conditioners). In short, prescriptive codes represent a checklist of things that must be followed and the minimum acceptable specifications. Through the use of tables and descriptions, building designers and code officials can implement and enforce the requirements with little complex knowledge.

While the relative ease of use makes prescriptive codes a desirable option for design teams on small projects and for code officials with limited resources, several shortcomings are evident. Since they are based on strict requirements and are updated on a fixed cycle (currently three years), prescriptive codes can be slow to incorporate new technologies.

Prescriptive codes do not reward more efficient design decisions that look at the building as a total system. The current approach favors projects seeking minimum levels rather than those seeking high-performance [8].

As indicated above, criteria in prescriptive codes are based on the ideal situation assumption—not actual practice. Additionally, the building's anticipated total energy use cannot accurately be determined through the code by the design team because all energy uses are not included (although building energy modeling does allow for determinations based on assumptions associated with unregulated energy uses).

Despite the perception by policymakers that prescriptive energy codes will reduce energy used in new construction and renovations, there is no assurance or requirement to measure that the desired results are met. Moreover, the nature of prescriptive codes and some of the areas they do not regulate (such as window area or building geometry, e.g., surface area related to volume and floor area) negate any comparability of buildings, even if energy use were measured.

Given the nature of prescriptive codes and their development, increases in efficiency are predicated on incremental improvements in the efficiencies of individual pieces of equipment or building components. As such equipment becomes increasingly more efficient, it becomes responsible for a smaller proportion of the building's total energy use, thus making it harder to impact total energy use through the existing codes. At some point, the laws of thermodynamics, potential technology improvements, and cost will make increasing the efficiency of existing equipment types prohibitive.

Performance Codes

Performance-based codes, as currently defined within energy codes, set a desired end-state—often based on the anticipated results of parallel prescriptive codes. This allows flexibility for the design team in selecting how the intent of the prescriptive code is achieved without necessarily meeting each of the prescriptions. Such an approach is desirable for larger buildings, as it provides opportunities for trade-offs across energy-influencing systems, thus finding the most cost effective means for achieving compliance. Further, performance-based codes are technology neutral, allowing quicker incorporation of energy-saving technologies and practices into the marketplace.

However, performance codes still are based on proxies for energy use, as the prescriptive provisions are used to create a performance target for each building. Designers typically demonstrate compliance through energy modeling of the building incorporating their selected building specifications and then doing the same modeling but substituting the minimum prescriptive requirements from the code. Models that fulfill requirements under the code may not include all potentially energy-saving opportunities in the calculations, including the orientation and geometry of the building. Models are also based on numerous assumptions about the final building usage, including operating hours, occupant density, and number of computers.

While building energy modeling has improved significantly in recent years, the number of high-quality modelers remains limited. Additionally, results of energy models often do not correlate to actual building energy use [8]. This issue often manifests itself in criticism of the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) system, but such discrepancies are common in attempts at energy modeling. Buildings are complex systems with numerous variables, including building occupants themselves. Today, energy models are largely intended to determine relative energy performance between alternative designs rather than predictors of actual energy use [9].

As in prescriptive codes, performance codes do not assure that the completed building will actually perform at the levels anticipated by the code. No follow-up of actual results is required—just inspection during construction to assure that the building is constructed in accordance with the approved plans and specifications.

While the flexibility in the performance code is desirable for large buildings, small building owners often do not have the resources to invest in energy models. In addition, code officials do not necessarily have the expertise to verify the accuracy of all the model inputs to ensure that the model was developed properly. Certification of the model outputs by the architect or engineer of record, if one is required, typically is deemed sufficient.

The International Code Council's (ICC) *Performance Code for Buildings and Facilities* identifies the broad considerations necessary to set desired performance levels; while criteria on energy efficiency are included, the code focuses primarily on design to respond to hazards [10]. However, in this code the actual performance level for energy is not given. The authority having jurisdiction (AHJ) has the flexibility to set different values based on the function of the structure and the potential hazard levels. Computer models are not required, but if used in the design, the operator must be knowledgeable and experienced and the data and assumptions must be submitted as part of the documentation. This code is adopted in a few jurisdictions (Philadelphia, PA; Decatur, AL; and Lacey, WA), but it is unclear if it is actually used by design professionals (particularly for energy compliance).

In examining the application of performance codes to building safety and security, the National Research Council stated, "For performance-based regulations and design methods to be effective, there must be a logical and transparent relationship between what the regulations are designed to achieve and the methods used to achieve it." An eight-level hierarchy (see Figure 2) displays these relationships. This hierarchy illustrates how the goal "limit mass casualties" can be made operative through a performance requirement to "prevent progressive collapse" and achieved through a design approach (the alternate path method) that can be demonstrated to be effective. The important role played by test methods and standards, evaluation methods, design guides, and other verification methods is also readily seen." [11]

TODAY'S BUILDING PROCESS

Currently, most construction projects are procured using a design-bid-build or design-build process. Under these approaches, the design and construction teams are interested in satisfying their clients' needs, but long-term energy use is rarely considered one of those needs. Barring the discovery of negligence or fraud, the teams are no longer tied to the project a short period after the project's completion. The owner has no assurance that the completed building will actually perform at the levels anticipated by the energy codes, nor may they care (especially if the building is tenant-occupied and the tenants will pay for utility bills). Further, the design and construction team rarely follows up to learn whether their design is achieving the target energy use and then uses such information to make adjustments in future projects. Federal-, state-, or local government-owned or financed construction may be the exception, as there is an obvious incentive for owners to ensure compliance since they will have a long-term involvement in the building.

There are few examples of mechanisms within codes to mandate

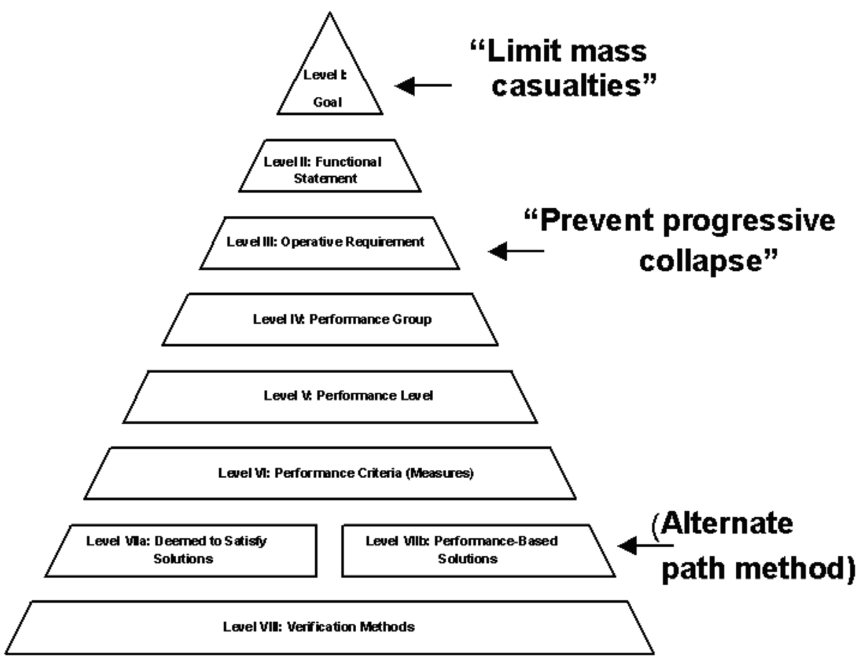

Figure 2. Performance-based Building Code Hierarchy [11]

and enforce activities such as commissioning and operations and maintenance (O&M), which can identify and rectify some of the issues contributing to the design/operation disconnect, although changes being considered in U.S. model codes and standards would include such provisions in the energy codes. The *International Property Maintenance Code* from ICC provides for the ongoing protection of occupants from health and safety hazards, but it does not include provisions related to the energy use of systems within the building [12]. Also, the design team often has little interaction with either the personnel who ultimately operate the building or the building occupants to explain the design intent, get feedback on the practicality of proposed solutions, or provide training on the systems selected, with the potential exception as noted above to owner-occupied structures.

Buildings are intended to last 30 to 100+ years, yet most of the design and specification of systems is based on returns on investment in a significantly shorter time period (sometimes as short as two to three years). With the exception of institutional and government buildings, ownership will likely change hands numerous times over the life span of the building. Over the life of the building, the costs associated with operations and occupancy of the building far exceed the cost of initial design and construction [13]. See Figure 3.

The focus on short-term returns often reflects the reality that the owner responsible for the development of the building will not own it long after completion. Such owners currently have little incentive to invest in energy savings if they will not be responsible for paying the long-term operations cost. This is also the case when energy costs are paid by building tenants but key building systems are controlled by the building owner.

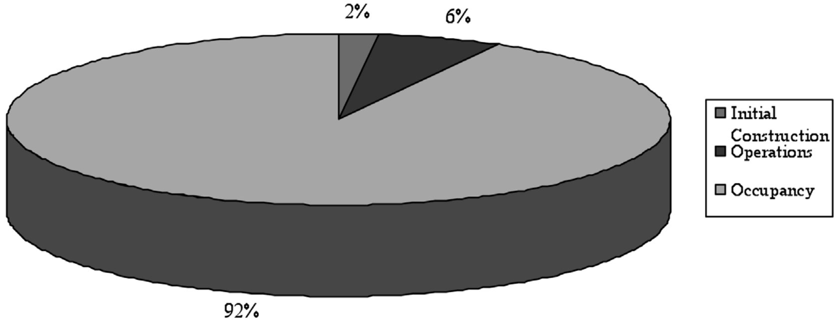

Figure 3. Typical 30-year Building Costs [13]

A few jurisdictions in the United States (California; Washington, DC; Austin, Texas; Washington state, and others) have adopted requirements to monitor and report a building's actual energy use at predetermined intervals [14]. Such requirements are intended to provide incentives and demonstrate value in investments in energy efficient buildings. The European Union's Energy Performance of Buildings Directive requires member countries to establish an energy performance certification for buildings [15].

While attempts are underway to measure actual energy performance in the U.S., there are no requirements to actually compare such performance to the anticipated energy use during the design phase.

THE BUILDING FRONTIER

Interest in green and sustainable buildings has expanded rapidly—particularly as a slow economy causes companies to differentiate or validate their products. Programs like LEED provide tools for the design and construction of green buildings. However, the focus still has been on using proxies for energy use to demonstrate energy efficiency. The relatively new LEED for Existing Buildings Operations and Maintenance (LEED-EBOM) and USGBC's Building Performance Partnership (BPP) are beginning to address the ongoing energy use of buildings and the design/operation disconnect.

Both the government and individual companies are demonstrating an increased interest in measuring and verifying data across the economy. The expansion of the internet, the constant availability of information, and the promise of the smart grid give citizens the perception that any data point is obtainable (and worth obtaining). Such an interest in data for buildings is growing. In addition to the energy performance requirements mentioned above, building automation systems, sensors, and controls are becoming widespread and capable of gathering useful building data.

Attempts to control greenhouse gas emissions and/or the desire for energy independence will require expanded focus on measuring how and where people use energy. Leading organizations within the building community, including the American Institute of Architects (AIA), the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), the USGBC, the Illuminating Engineering Society

(IES), and top design and construction firms, coupled with initiatives lead by the U.S. DOE, have identified net-zero energy buildings as the endpoint for achieving energy independence and reducing greenhouse gas emissions [16].

Net-zero energy buildings and buildings that are verifiably green across their life cycle are just beginning to enter the marketplace. However, to achieve energy independence and reduce greenhouse gas emissions, they must be more widespread. The current approach to determining and regulating energy use will not get us there; all energy uses are not included, the rate of compliance is generally unknown (not likely over 70%), and actual energy use after the project is initially occupied is not considered.

GETTING THE DESIRED OUTCOME

Recognizing the difficulties in applying current prescriptive and performance equivalence energy codes to achieve defined and measurable levels of energy use, several visionary leaders in the building community are calling for a transition to outcome-based codes [8, 17]. The ICC's *International Green Construction Code* (IgCC) may even include an outcome-based approach to energy use, once finalized this year [18]. Reports on the proceedings indicate that the development committee identified many of the potential issues identified herein.

Outcome-based codes establish a target energy-use level and provide for regular measurement and reporting of energy use to assure that the completed building performs at the established level. Such a code can have significant flexibility to reflect variations across building types and can even cover existing or historic buildings. Most importantly, it can address all energy used in buildings and provide a metric to determine the actual quality of the building construction. Despite the potential benefits of outcome-based energy codes, numerous questions must be answered before widespread utilization is possible.

What Does an Outcome-based Code Look Like?

The biggest decision is where to set the energy-use target, what it should look like, and how compliance should be verified. Ideally, we should work backwards from the stated goal of net-zero energy [3]. However, what pace is realistic for ultimately achieving net-zero en-

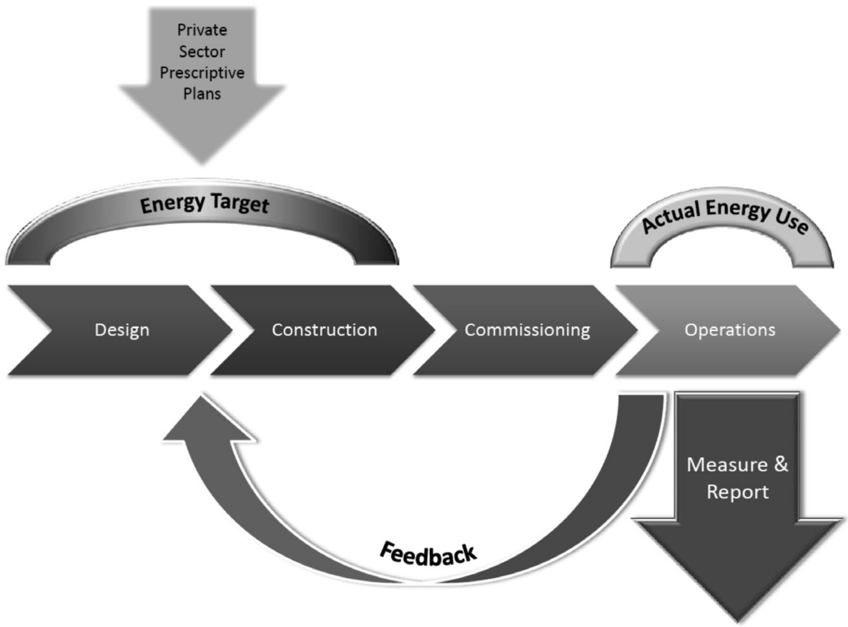

Figure 4. Diagram of an Outcome-based Code

ergy? To set a realistic starting point and a schedule for improvement, code developers must understand the current levels of building energy use not only from existing buildings but from new buildings that are designed to meet current prescriptive energy codes.

Datasets exist to get a broad-brush understanding of building energy use. The Commercial Building Energy Consumption Survey (CBECS) provides data based on the survey of approximately 5,000 buildings of different types from across the country [19]. However, the use of CBECS presents some challenges—as of January 2011, only data from the 2003 survey is available, and some building types do not have statistically significant data for certain climate zones. Improvements to CBECS or other sector-wide datasets will be necessary to have a meaningful baseline and to monitor progress toward net-zero energy goals. Reporting from code requirements can start the development of a meaningful database.

Common metrics to allow easy reporting, comparison, and verification are necessary. Should such metrics be based on current measures (e.g., kBTU/ft^2/yr), or do we need a new metric or formula that accounts for all variables, including building type, climate, occupancy, building function, and hours of operation? ASHRAE Standard 105-2007, *Standard Methods* *of Measuring, Expressing, and Comparing Building Energy Performance,* provides a standardized methodology for addressing this issue [20].

In demonstrating that the required outcome for ongoing energy use is met, the appropriate building official or other state, local, or private sector entity must establish methods for measurement and reporting to address post-occupancy compliance, whether mandatory or through a voluntary program offering incentives for compliance. These methods should also incorporate the means for checking that the reported energy use is not adversely impacting other building requirements, including indoor environmental quality (IEQ) and necessary illumination.

Stages of Compliance

Outcome-based codes will require a two-stage process for verifying compliance. The first stage would focus on the design and construction of the building. This would include plan review and on-site inspections. Code officials could continue to use existing methods for verifying building compliance, pre-occupancy.

Code officials and others may raise concerns that an outcome-based code with no prescriptive requirements, and a demonstration of results based on modeling, is too complex or expensive to enforce. As discussed below, modeling software and third-party prescriptive options can be developed and certified to demonstrate compliance. Resources and training for code officials and the building design and construction community will still be needed as they are now for current energy codes.

With a backstop based on actual energy use measured on a regular basis, a community may find it acceptable for the architect or engineer of record to certify that the plans meet the required energy use level. Inspectors would then check construction against the plans provided previously.

The second stage of compliance will be based on the measurement and reporting of ongoing building performance. This stage can be thought of as expanding *Level VIII: Verification Methods,* illustrated in Figure 2, to include ongoing verification through measurement and reporting. Since the regulation of outcomes is outside the current practice of building code enforcement, new mechanisms for ongoing enforcement and addressing noncompliance must be examined, both incentive- and penalty-based.

As discussed above, some jurisdictions in the U.S. are beginning to develop and implement the mechanisms necessary for the actual measurement and reporting, but translating these mechanisms to an enforcement process will require careful thought. Currently, most of the programs focus on measurements tied to the Environmental Protection Agency Energy Star Program's Portfolio Manager. However, jurisdictions such as California are interested in using metrics that express performance differently and can be easily compared with outputs produced during the design phase.

Establishing a common metric—or at least a method for translation and comparison of different metrics—will allow for the widest opportunity to identify best practices and share case studies. In determining the proper metric, decision makers must focus on the importance of gross energy use versus the carbon emissions associated with the energy use (which will require regional and even time-based information on the electricity supply mix). How renewables are included in the metric is also important—a building could be net-zero energy but use energy in an incredibly inefficient manner. This is particularly critical as communities begin to think about their total energy use.

Methods of normalization for variables such as weather, occupancy, building function, and hours of operation are needed to allow comparisons both across buildings and relative to the code-based outcome requirement. The AHJ will determine how frequently a building's actual energy use must be reported and the actual mechanism for reporting. Utilities may serve as an outlet for direct reporting to the jurisdiction, but currently utilities do not capture much of the information that will go into normalization. Also, on-site renewable energy use would not be captured in utility information. Owners and building managers would provide most of the normalization variables, so jurisdictions must enact validation and/or certification requirements.

Jurisdictions also must decide how long to connect the design and construction of the building with the outcomes reported. At some point, the actual energy use of a building becomes less about the initial design and construction and more about the operations and maintenance, occupant use, and renovations or system replacements. This will also help address some of the questions regarding liability for the design and construction teams.

In this initial period, where the design and construction and the outcome are connected, bonds could be used to secure continued compliance and make sure funds are available to remedy any issues leading to noncompliance. If the building remains in compliance during this period, the design and construction team would be eligible to receive the bond funds. These bonds would provide additional incentives for the professionals engaged in design and construction. Underwriters for the bonds would soon develop a method for evaluating the risk of noncompliance associated with different design and construction teams. Such methods also could find their way into how professional insurance is priced. Professionals with a good track record would be rewarded, and sub-par professionals would be incentivized to improve. After the bonded period, jurisdictions could use other potential enforcement mechanisms.

Tax schedules can be implemented based on the percentage a building is above or below the required outcome level. Utility rates or taxes on energy use can also be adjusted based on the amount of energy used relative to the baseline. The potential value of public disclosure of how individual buildings perform relative to their peers should not be overlooked. [21] At the extreme, a building's certificate of occupancy can be revoked or financial penalties such as property tax increases for gross non-compliance can incentivize bringing the building into compliance.

For new construction and existing buildings, upon sale, the jurisdiction may require that covenants or deed restrictions be placed on the property related to the ongoing maintenance and performance of the building. However, jurisdictions must examine the potential for legal action related to takings. The ICC *Performance Code for Buildings and Facilities* suggests that plan submittals and supporting documents for new buildings include deed restrictions proposed to cover future maintenance requirements and special conditions for the life of the building [10].

Impacts on the Building Industry

Beyond the policy-related decisions necessary to implement an outcome-based code, the building industry must adjust to new norms. The industry has been notoriously slow to change, due to the numerous parties engaged throughout a building's life cycle and the lack of accountability for things like energy use. Several technologies and practices are being developed and implemented that are beginning to demonstrate the need and desire to overcome this fragmentation. These include building information modeling (BIM) and integrated design, or integrated project delivery (IPD). These will be critical for the implementation of outcome-based codes. Many of the barriers identified for the use of IPD also are likely to apply to outcome-based codes. (See Figure 5.)

As the design and construction targets approach net-zero energy and ongoing measurement and reporting requirements are implemented, component-by-component and discipline-by-discipline approaches will no longer produce the desired results. The building team must understand the results of decisions made throughout the design process and the synergies across building systems. Contracting mechanisms moving forward will need to reflect the importance of such collaboration and how it impacts achievement of the final results.

Determining the roles and responsibilities of the design and construction teams in light of accountability for the building's performance is essential—particularly if the owner or an outside contractor is responsible for O&M. An engineer, architect, or contractor is unlikely to guarantee results, because such results are highly dependent on how the building is operated and maintained, as well as on the actions of the building occupants.

In an effort to avoid complex contract negotiations, building owners and developers may demand new models for project procurement and delivery. Architects, engineers, and contractors may begin to embrace these new models as they allow for long-term income streams and can eliminate some of the angst associated with outcome-based codes (including the lack of control over building occupants).

While largely associated with horizontal construction (roads, bridges, etc.), design-build-operate-maintain (DBOM) contracts may be a viable approach [23]. As indicated above, building operations and occupancy are the greatest expenditures over the life of a building. However, many of the factors influencing these expenditures are determined during the design and construction phase [24]. Bringing the design, construction, operations, and maintenance components under a single contract allows use of a whole building approach with considerations for the building's life cycle.

DBOM contracts provide incentives for the design and construction contractors to minimize operation and maintenance costs (and thus energy costs) [24]. Essentially, the building is under warranty for the length of the DBOM contract—possibly 10 to 15 years or even longer. While this places the risk on the DBOM-contracted entity, the owner loses some degree of flexibility in how the building is designed and maintained [24]. Minimum levels of O&M and mechanisms for modifications if facility needs change should be defined in the initial contract.

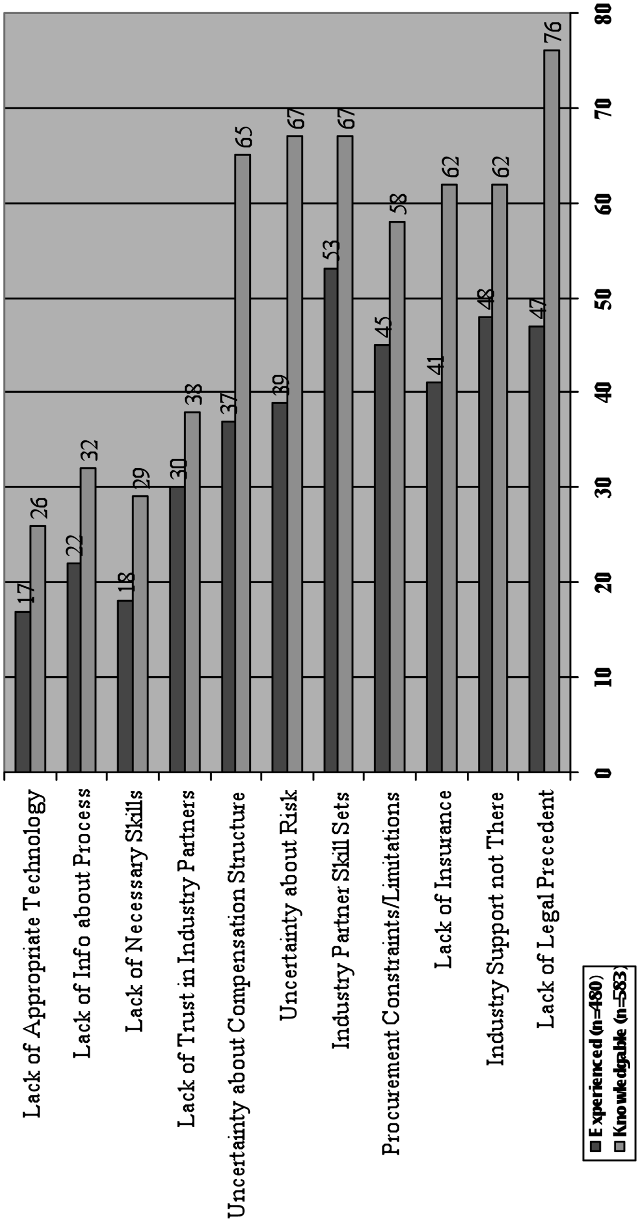

Figure 5. Perceived Barriers to Ipd [22]

Design and construction professionals will need to overcome their risk adversity and recognize that buildings are a sum of their parts and rely on the cooperation of all parties to achieve results. A recent article in *Architect* stated, "Somewhere along the way, architects became a risk adverse bunch, preferring to stay safely ensconced in the studio and letting others—owners, developers, contractors—assume economic accountability [25]." The AIA California Council states that "compensation should be based on the value added by an organization and risk should be equitably allocated [26]." However, the AIA's Integrated Practice Discussion Group recognizes the emerging opportunities for architects to expand their service offerings, including in operations and enterprise opportunities [22].

As in any contract negotiation, the responsibilities of each party must be well defined, along with the shares of profits and liabilities. Whether procurement moves to DBOM or another mechanism for building delivery, the building community must decide the format of contracts and fee schedules.

The City of Long Beach, California, recently let a contract for the design, construction, and operation of a new courthouse. The contract went to Long Beach Judicial Partners, a consortium including architect/engineer AECOM, Clark Construction Group, Edgemoor Real Estate Services Commercial, and Johnson Controls [27]. Outside of a contract process required of building developers, integrated firms or partnerships may form to allow engagement across a building's entire life cycle. In both instances, the potential impact on solo practitioners and other small businesses must be explored.

There is no doubt that the finance and insurance sectors will also play a key role in determining how a shift to outcome-based codes will proceed. Many actors within the energy efficiency community have complained that the finance, insurance, and appraisal sectors are not including energy efficient measures within their evaluations of risk or determination of value. Requirements to demonstrate actual performance may overcome some of these deficiencies.

Solutions for Producing Outcomes

For small, non-complex buildings with tight budgets, prescriptive requirements may still be desirable, and they can be developed utilizing outcome-based targets as opposed to the current method where a unique target is produced for each building. Rather than being developed through the codes process, they would be worked backwards from the necessary outcome for that building type and could be readily developed in a myriad of public and private sector forums. (For example, hotel/motel interests could develop a guideline of prescriptions that, if followed, would ensure meeting the stated target for that building type.) Manufacturers, trade groups, and existing code developers can develop plans based on synergies among specified equipment. Code developers or other third parties can certify plans to allow easy approval for jurisdictions.

Verification of both the prescriptive plans and designed buildings developed by the private sector will require modeling. As indicated above, current modeling technology and practice needs improvement. Modeling results must improve to more closely predict actual performance. Efforts are underway, including the Commercial Energy Services Network (COMNET), to provide consistency across models through the establishment of modeling rules [28]. Individual jurisdictions or the U.S. Department of Energy can approve modeling software that produces acceptable results based on modeling rules. At the end of design, the model can produce a certification that the design complies with the required outcomes. A corresponding specification list will allow inspectors to check the construction relative to the design.

Roles of Existing Code Developers

Existing code and standard developers can play numerous new roles in an outcome-based code environment. They can serve as the forums for addressing many of the questions raised here—most importantly determining the cost-effectiveness of proposed outcome requirements. They can also provide the education and training necessary to bring outcome-based codes to fruition. Research and development will be critical as well, particularly in improving building energy models and the data necessary to support them.

As indicated above, code and standard developers can develop prescriptive paths that comply with the outcome requirements. These can be similar to the Advanced Energy Design Guides produced by ASHRAE, with support from other key industry organizations [29]. Such organizations could also certify the compliance of prescriptive paths developed by others. Measurement and reporting tools will be essential for verifying ongoing compliance. ASHRAE's Building Energy Quotient and RESNET's HERS rating are examples of potential tools [30, 31].

CONCLUSION

Policymakers, building owners, and the public are interested in reducing our energy use because of cost, greenhouse gas emissions, and the need for energy independence. Buildings, as the largest energy-using sector, represent an opportunity to reduce energy consumption. However, today's codes and standards are based on proxies for energy, with no requirement to actually measure the end result, leaving many building energy uses unaddressed. In order to reach the goal of net-zero energy buildings, these methods must change, modeling capabilities must improve, and actual outcomes must be measured.

A recent report from McGraw-Hill on BIM use found that a majority of the companies surveyed attach high importance to verifying that building performance corresponds to the targets identified in design [31]. The World Business Council for Sustainable Development (WBCSD) has developed a roadmap for reducing energy consumption in new and existing buildings that calls for design fees and incentives based on actual energy performance [32].

In order to make outcome-based codes a reality, the building community must lay the foundation and address the preliminary questions.

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