Stretch Codes on the Road to Zero Energy – Potholes and Speed Traps Ahead

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ABSTRACT

For more than a decade, cities and states have been adopting stretch codes (alternatively known as reach codes) that exceed the energy efficiency levels in the national model energy codes. With the growth in Climate Action Plans across the country, more cities and states are considering how stretch codes can reduce greenhouse gas emissions from their building sectors. Many efforts at the city, state and national levels, often complemented by policy goals to achieve Net Zero objectives in energy codes, are contributing to the development of stretch codes such as ASHRAE-ANSI Standard 189.1, and the International Green Construction Code (IgCC), two national "green" standards. State and local stretch code development projects frequently amend the International Energy Conservation Codes (IECC) and ASHRAE 90.1 Standard, and also reference other national level efforts, including Energy Star. This paper details how a range of stretch code efforts, working in parallel, contribute to the overall progress in energy savings, with many current stretch codes targeting 20% energy savings from ASHRAE 90.1-2013/2015 IECC. The paper explores how stretch codes trying to go beyond this level of savings face common structural, legal, and technical barriers - and then describes several initiatives that focus on removing these barriers. These include exploring opportunities to address equipment/appliance efficiency where federal preemption prohibits state regulation, and to ensure that many of the process and plug loads not covered by current energy codes can be reduced.

Introduction

According to projections from the McKinsey Global Institute, 900 billion square feet representing about 60% of the total building stock of the world will be built or rebuilt in urban areas worldwide by 2025 (Dobbs 2012, 35) These buildings – commercial and residential – once constructed can waste copious amounts of energy, resulting in higher energy bills for both owners and tenants. Carbon emissions and energy waste are essentially "locked in" by current energy codes unless steps are taken to improve building energy efficiency at the point of construction.

The point of design and construction is the key opportunity in a building's life-cycle for increasing its energy efficiency but to achieve that they must take advantage of the readily available and standard practice energy-saving strategies and technologies that exceed national energy codes. Unfortunately, most new buildings are constructed to meet only the minimum energy efficiency requirements in the codes which have been adopted at the state or local level and which are frequently less stringent than the national model codes.

This has led to many jurisdictions to promote or require more efficient design and construction standards within their borders Thus was born the concept of stretch energy codes. Application of these standards ranges from California to Vermont, and many states and cities in between. A recent report from Northeast Energy Efficiency Partnerships (NEEP) on codes has characterized this recent development in the Northeast as a "wave of new and improved stretch codes”. Massachusetts developed a stretch code in 2010 and a revision in 2016. Vermont, New York, and Rhode Island have or shortly will implement their own stretch codes (Hewitt 2017, 28) as a critical component to increasing energy efficiency in their building stock and helping to meet climate action goals. CALGREEN, a stretch code in California, first published in 2008, began to include mandatory provisions in the 2010 code cycle.

The Link to Carbon Policies and Zero Energy Goals

Much of this initial and recent interest in stretch codes is linked directly to the expanding adoption of carbon emission reduction policies. As each state or city evaluates its opportunity to reduce these emissions, attention always focuses, in part, on the building sector. Looking at the slow replacement rates for existing building stock, it becomes apparent to policy leaders that new construction and major renovations must quickly reduce carbon emissions to meet their state or local GHG emissions goals. At the current rate of energy code advancement it has been concluded by many jurisdictions that the current process for the national model codes is not a viable option to achieving their Zero Energy policy goals. They therefore turn to Stretch Codes.

There have been significant increases in the efficiency of then national model commercial and residential energy codes since the adoption of ASHRAE 90.1-2004 and the 2006 IECC. The code development cycle for ASHRAE 90.1-2010 and the 2012 IECC produced the so-called “30% solution”, the largest single leap in energy efficiency in modern code history. But the rate of improvement is slowing down for both technical and political reasons. Also, at some point the energy consumption of highly efficient buildings will largely be driven by equipment such as plugged in devices and servers that are outside the scope of current energy codes. Plug load code strategies to date include the requirement of controlled outlets (as required by ASHRAE 90.1 – 2013) and the use of efficient appliances. However, plug load strategies face significant barriers in the form of both stakeholder and legal limits.

The remainder of this paper will look at how stretch codes have pushed energy codes to date, what remaining savings are achievable in current code structures, and how moving towards codes that approach zero energy goals might be achieved both technically and through other policy mechanisms.

Potholes and Speed Traps

While stretch codes can be an effective way to help move the market to low and even zero energy buildings, there are numerous challenges that need to be considered. The following section identifies the most prevalent of these.

The Continually Shrinking Regulated Loads as a Percentage of Building Energy Use

The scope of most major energy codes is limited to the design and construction of buildings and their systems and, less comprehensively, equipment. Elements of building performance associated with occupancy and operation are traditionally outside the scope of energy codes but historically these represented a small percentage of total building use. The exception to this was certain high energy, specialized businesses such as restaurants and hospitals which had many hard-to-regulate loads. But with every new building code, as the “regulated” energy uses such as lighting shrank, many of the unregulated plug and process loads remained stable or continued to grow.

Will "Unregulated Loads" in Buildings Overwhelm Energy Use Targets in Codes?

Analysis conducted by New Buildings Institute (NBI) on commercial buildings built to the 2012 Washington State Energy Code (see Figure 1) shows that plug and process loads account for almost half of the total building energy use ((M. Frankel, and J. Edelson 2015, 13). In 2016, SeventhWave completed a plug load study for the Minnesota Division of Energy Resources and came to a similar conclusion: "Plug load energy use is most critical in building projects that are striving for a much lower energy use intensity (EUI), based on targets such as LEED or Architecture 2030. These buildings are often being designed to attain building EUIs of below 40. With rising plug loads, it can mean up to 50% of that target EUI is consumed by plug load devices. In other words, plug load usage is making it increasingly difficult to meet energy performance goals for the built environment" (Hackel 2016, 5).

Plug load reduction strategies do exist, and these are often implemented successfully. But from a code standpoint, the growing percentage of building loads that are outside the scope of traditional energy codes represents a significant challenge to the larger energy code improvement goals of reducing overall building energy use.

Construction Codes Omit Building Operations and Maintenance

Another limitation of traditional energy code scope is the inability to address energy use once the building is occupied and then operated through its useful life. This gap has three aspects:

1. Despite the best intentions of the design and construction team, systems frequently do not perform exactly as they should when the building is completed. Although codes have begun to incorporate commissioning requirements to help address these issues, the final opportunity for energy code enforcement occurs when the certificate of occupancy is issued, usually well before commissioning processes can be completed. Any oversights or omissions of the commissioning process are outside of this enforcement scope.
2. Over time, all buildings degrade in performance as set points drift, dampers begin to stick, sensors fail, filters clog, among other factors. This is a natural part of the building lifecycle that frequently is related to lack of funding and training for building operators and it has direct energy use impacts that are outside the scope of the energy code. .
3. The use patterns of the occupants themselves greatly impact energy performance. Although the design team has anticipated certain use patterns and behaviors, there is no mechanism in the energy code to help building users understand their critical role in building energy use characteristics, or to provide feedback to the occupants that might help them better address or manage building energy use. Some energy codes have incorporated feedback requirements, but these are relatively vague and open-ended in their approach.

These aspects of building energy use during the period of building occupancy represent largely untapped opportunities for building codes or policies to increase building performance.

Federal Regulations Preempt State and Local Codes

Federal law has been preventing states and cities from being able to apply efficiency regulation on most HVAC and appliance equipment since 1975. As the Energy Policy and Conservation Act (EPCA) states: “No State regulation, or revision thereof, concerning the energy efficiency, energy use, or water use of [of a product covered by a federal efficiency standard] shall be effective with respect of such covered product” (EPCA 1975).

The Washington State example is illustrative. Washington has a statutory requirement that “the 2013 state energy code must achieve a 70 percent reduction in annual net energy consumption (compared to the 2006 state energy code)” (Revised Code of Washington 19.27A.160). To help determine how Washington might achieve these statutory goals, a “Washington State Energy Code Roadmap” was developed in 2015. Regarding preemption, it states: “While the issue of multiple regulations may have been valid for the industry, the outcome (of preemption) has been an on-going resistance to updates to these requirements that would lead to higher efficiency requirements, and active legal battles by industry organizations to prevent individual states and jurisdictions from adopting efficiency upgrades. The industry continues to defend this preemption, precluding even modest improvements in heating equipment efficiency requirements in states and cities across the country. This preemption represents a significant barrier to achieving the performance goals that Washington has set for code stringency increases” (M. Frankel, and J. Edelson 2015, 5).

These restrictions on state and city energy codes have led to more complex energy code structures to comply with the requirements of EPCA. EPCA allows local and state codes to require more efficient equipment, as long as the code includes at least one combination of measures which includes covered products that do not exceed the federally mandated minimums. Four approaches to achieve this were defined in a 2013 paper titled *Overcoming Preemption: Strategies for Pushing Beyond Federal Equipment in California* (C. Worth and M. McGaraghan). They are summarized as follows:

1. Dual-Path: in which a building would have to install at least one of two required options for compliance. (Not currently in use, but has been discussed/ proposed)
2. Multi-Path in which a building would have multiple (more than two) paths to compliance (e.g., Oregon’s “pick 1 of 7 requirements”).
3. Alternate Renewables Approach in which a certain amount of renewable energy is required, which could be reduced only if other premium efficiency design options and federally covered equipment were installed (Such as in ASHRAE 189.1).
4. Market-Based Incentives use a point system where each building (or a comprehensive requirement for the building) requires a certain number of points to comply. This has been done in the State of Washington’s “additional residential energy efficiency requirements” and LEED.

Unfortunately, these approaches still offer limited headroom for states and jurisdictions who want to significantly advance energy efficiency in the building sector and stay within the purview of federal statutes. The barrier that federal preemption places on local and state policy will continue to grow as building codes become more energy efficient.

Why Codes Will Fall Short of Zero Energy Goals

As shown in Figure 1 (below) from an analysis of the history of the model codes through 2014 done by the Pacific Northwest National Labs (P. Hart and Y. Xie PNNL 2014), little progress has been made in the equipment, hot water, cooking, information technology and elevator loads since 2004. This indicates there is more progress to be made there in the near future. But many of these energy loads are comprised of preempted equipment or loads outside the scope of energy codes; i.e. "unregulated" loads, and as building energy use starts approaching zero-net energy levels, these two factors (preempted equipment and unregulated loads) make it nearly impossible to develop prescriptive energy codes at these levels. Many of the heating and cooling gains have been due to improvements in envelope performance, while the efficiency of HVAC equipment has improved at a slower rate.

In a PNNL paper from 2015 (R. Hart PNNL, 2015), the authors identified the following barriers in addition to the preemption and unregulated load problems:

- Prescriptive requirements do not necessarily lead to performance outcomes
- Diminishing returns for increasing prescriptive provisions (e.g. R-values in opaque walls)
- Not realizing benefits of better design choices (e.g. Building orientation in modeled compliance path)
- Actual energy use does not follow either predicted performance from the prescriptive path or modeled compliance paths

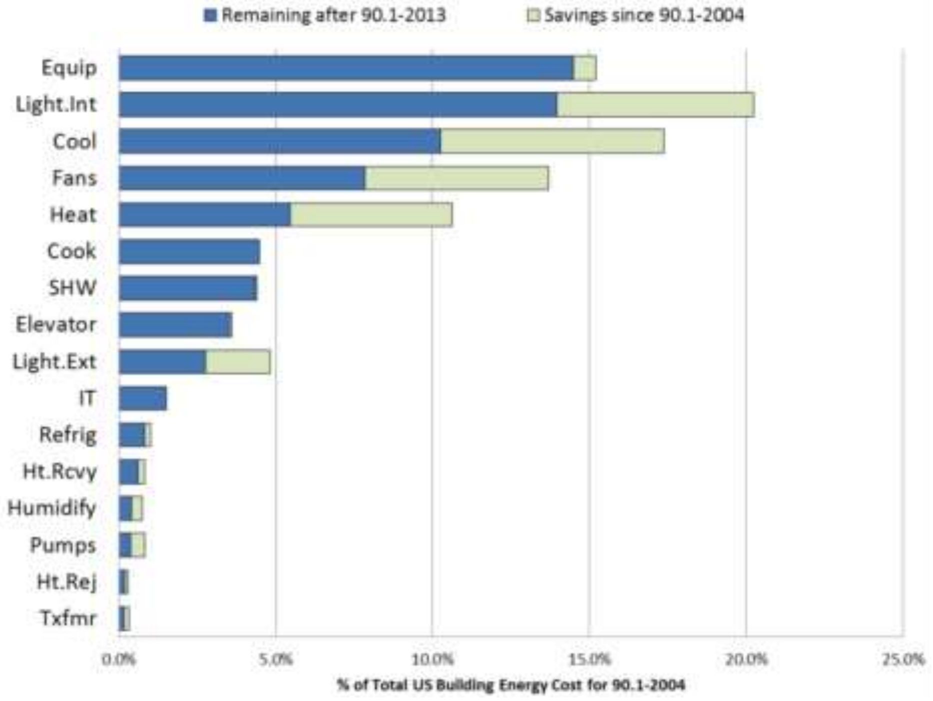

Figure 1: U.S. building energy cost by end use prioritized by post-2013 cost. *Source*: PNNL 2014

The same paper further states: "For commercial building energy codes to continue to progress as they have over the last four decades, the next generation of building codes will need to provide a path that is led by energy performance, ensuring a measurable trajectory toward net-zero energy buildings" (R. Athalye, R. Hart, M. Rosenberg, and J. Zhang 2015, 5). One performance-based path is represented by a shift towards outcome-based codes, an approach where the code regulates actual building performance, effectively bridging the gap between design and occupancy. As stated in a 2015 report on the topic: "Effectively setting building targets and performance metrics will be essential in advancing (the) application of outcome-based requirements" (Colker, R., Edelson, J. and Frankel, M. 2015, 14).

Another study by PNNL (R. Athalye, D. Sivaraman, D.B. Elliot, B. Liu, R. Barlett, 2016) uses a series of assumptions that progress in improving total building energy performance will slow. In predicting future energy savings, the report acknowledged that there will be gradual progress in HVAC (partially due to envelope improvements) and lighting, and no progress in plug loads or ancillary equipment as shown in Table 1.

	90.1-2016	**90.1-2019**	**90.1-2022**	**90.1-2025**	**90.1-2028**	**90.1-2031**	**90.1-2034**	**90.1-2037**
Electricity – HVAC	0.90	0.80	0.74	0.68	0.62	0.56	0.50	0.44
Lighting	0.92	0.86	0.80	0.72	0.64	0.56	0.48	0.40
NG – HVAC	0.90	0.80	0.74	0.68	0.62	0.56	0.50	0.44
Plug & Process	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 1: Commercial Future Code Edition Energy Reduction Factors (90.1-2013 = 1.0)

If model energy codes do indeed follow this path, they will become less relevant in the next 5 to 20 years for jurisdictions that need the building sector to contribute energy use reductions to meet climate goals. Stretch codes will need to rely on approaches that directly address these identified obstacles to become compatible with zero energy climate goals.

Repairing the Potholes and Avoiding the Speedtraps

In order for energy codes to be useful for achieving a goal of zero energy buildings, the authors believe that the following topics must be considered and addressed. While this will not be an easy task, it is never too late to repair the potholes and avoid the speedtraps.

Focus on System-Level Consumption by Building Type

One way to think about opportunities to improve building energy use through code advancement is to consider building energy end use. Some building end uses represent much more significant targets for improvement than other end uses.

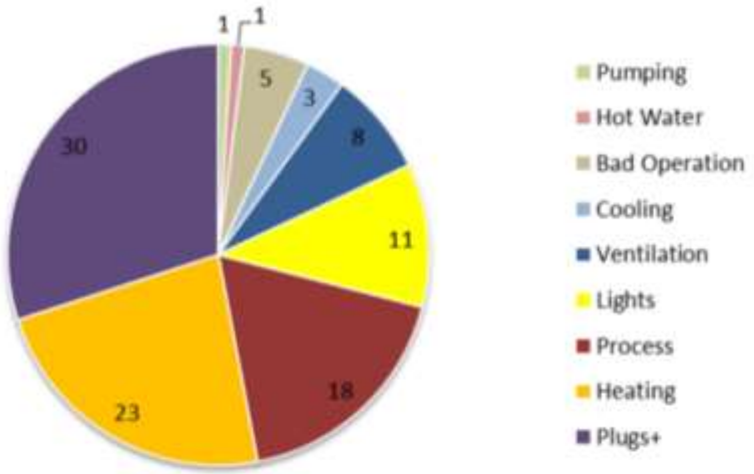

Figure 2: Weighted end use energy across building types for buildings meeting current code in Washington State. *Source*: NBI 2015

Figure 2 shows aggregated energy end use for commercial buildings in the State of Washington meeting current code requirements, meaning that it combines the population of different commercial building types with their anticipated energy use intensity and end use breakdown. We can see that plug and process loads combined represent nearly 50% of the total, driven by the relatively high EUI's associated with project types like health care and restaurant buildings. This highlights the importance of process loads in the larger building stock.

The graphic also demonstrates the significance of heating loads in the Washington climate zones, representing 23% of total building energy use. For this climate, federal preemption limits on heating equipment efficiency represent a significant barrier to performance improvement, while cooling loads represent only 3% of the total. Note also that the graph shows a 5% impact from 'bad operation'. This is a relatively conservative estimate of the kinds of operational and maintenance issues that have an adverse effect on building performance[1].

By taking into account weighted end use in the building stock subject to new construction codes, it is apparent that certain energy end uses represent areas of energy code regulation that we should focus on to improve performance.

HVAC System Selection

In their Roadmap for the Future of Commercial Energy Codes (R. Athalye, R. Hart, M. Rosenberg, and J. Zhang 2015) the authors included analysis demonstrating the wide variance in energy use due to HVAC system selection by looking at the normalized energy impact of those systems by the climate zones shown in Figure 2. HVAC types included: four-pipe fan coil (FC4P), water loop heat pump (WLHP), packaged terminal air conditioner (PTAC), constant air volume central unit (CAV), packaged rooftop unit (RTU), variable air volume with reheat (VAV-RH), and variable refrigerant flow heat pump (VRF).

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[1] Building energy modeling tools are not particularly suited to predict the energy impacts of sub-par system performance. In this case, the 'bad operations' category reflects only the impact of mis-calibrated ventilation rates and poor economizer performance.

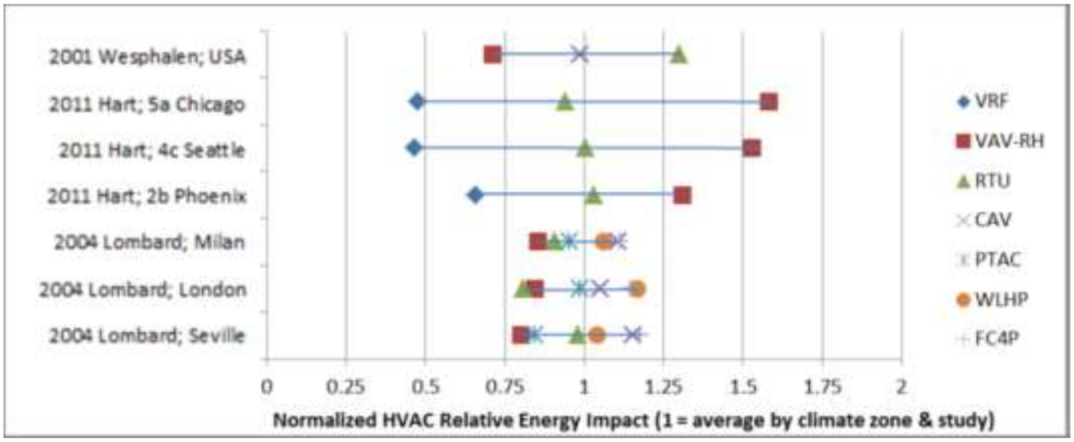

Figure 3: HVAC System Selection Impacts. *Source*: PNNL 2015

This analysis demonstrates how, given the same building, multiple HVAC system choices can be made that all meet the prescriptive requirements of the code, yet result in a wide range of energy use. While design teams can choose to specify more efficient HVAC systems and equipment, prescriptive codes cannot require such choices, and thus cannot capture the energy savings that would be gained from requiring the more efficient systems. This limitation on prescriptive codes is a consequence of the Energy Policy and Conservation Act (EPCA).

System Efficiency Metrics

One possible way for codes to level the playing field when it comes to equipment selection is to focus on the efficiency of entire HVAC systems. Metrics based on whole systems do not run afoul of the federal preemption law which only addresses equipment-level efficiency. This has been the focus of an Alliance to Save Energy (ASE) initiative known as the Systems Efficiency Initiative. They released a report in 2016 called *Greater than the Sum of its Parts: The Case for a Systems Approach to Energy Efficiency* which considers interactions within various building systems, with a focus on mechanical and lighting systems.

Regarding codes and standards, the reports claims that “both minimum energy standards (e.g. ASHRAE 90.1, IECC) and voluntary approaches (e.g. ASHRAE 189.1, LEED, EnergyStar, CEE) would need to be modified to include systems-level protocols for compliance with minimum efficiency levels, as well as with higher performance certifications required for utility rebates and other incentives” (ASE 2016, 38).

Another effort that is focused on incorporating system performance metrics into the energy code is being proposed for the Washing State Energy Code. Known as the HVAC Total System Performance Ratio (TSPR) and developed by the City of Seattle with PNNL, the approach compares the annual heating and cooling energy provided to the building to that of the annual cost of energy consumed by the building. The higher the TSPR the higher the efficiency of the HVAC system. Documentation of this approach includes a way for engineers to calculate the performance ratio using hourly building energy simulation outputs. PNNL is also developing a calculator where engineers can input the characteristics of the building and its mechanical system systems and it will set a minimum allowable TSPR target for each building type based on its characteristics and climate zone. This calculator is being developed as a module of the US Department of Energy’s Asset Rating Tool.

Looking beyond the United States, there are several countries that have developed metrics that better value the performance of the entire systems. Both Japan and Singapore offer informative examples.

Japan

Japan's Building Energy Efficiency Act, which was adopted in April of 2016, sets system efficiency requirements for air conditioning equipment in different building types by dividing the annual energy consumed for air conditioning equipment by the annual assumed cooling load for the building. This standard goes on to provide some additional credits for strategies that can improve system performance such as energy recovery and limiting refrigerant pipe runs.

Singapore

Singapore's Building Control Regulations include mandatory audit reports of chilled-water plants. The Green Mark System sets a rating level for these plants, and there are a series of adopted protocols to monitor and report performance. The requirements for the entire chilled water system are set at a single kW per ton target performance level. The target depends on the size of the system (greater or less than 500 tons). As stated in the regulation, "The kW includes all chiller, condenser, and chilled water pumping, cooling tower fans and other power related to the chilled water system".

Envelope as a System

The Passive House standard that was developed internationally by the Passive House Institute (PHI) and has been nationally modified by the Passive House Institute US (PHIUS) focuses on passive strategies such as improving the performance of the envelope and using energy recovery strategies to reduce the mechanical loads needed to heat and cool buildings. Several applications of this concept have been translated into energy codes. In the U.S., Massachusetts offers passive house compliance as an alternative compliance path for their Stretch Code and New York is considering a path for Passive House in its 2018 Stretch Code.

BC Step Code

In April of 2017, the province of British Columbia published the BC Step Code which requires better envelope performance for buildings by setting incrementally more stringent energy limits for heating, cooling and service hot water equipment as well a as a peak thermal load value. By stepping down these values over time to PHI levels of performance, the province hopes to achieve zero energy-ready status in all new construction by 2032.

Brussels, Belgium

As of 2015, Brussels became the first entity in the world to require the passive house standard for all new construction. This end goal was initiated by the adoption of a series of "leading by example" policies starting in 2004 and officially became a part of their regulation in 2007. They built the capacity for the standard internally by offering incentives, education stakeholders and getting support inter-agency support.

Lighting as a System

The proliferation of solid-state lighting in the building sector, combined with deep and on-going improvements in the efficacy of LED lighting technology has completely changed the energy use characteristics of building lighting systems. At the same time, significant new technologies and control strategies have allowed for a detailed and responsive level of lighting control not seen before in the industry.

These advances have had two major impacts on potential strategies to regulate lighting energy use in codes. First, the increases in lighting efficacy in lumens per watt have left previous code limits on LPD behind in the dust. Standard practice in the industry can typically lead to installed LPD's that are two thirds or half of the LPD's allowed in even very recent codes. And the technology continues to improve, faster than a three-year code cycle can be updated.

The second impact is that more advanced control strategies are fully capable of individual space or even fixture-level control, based on ambient light, occupancy, schedule, or use patterns. This increased flexibility for lighting use means that the nominal installed LPD is significantly less predictive of actual lighting energy use, since any given space or fixture can be individually controlled to more closely match changing actual occupancy and functional needs, rather than anticipating full-time lighting operation.

Taken together, these factors suggest that new approaches to regulating lighting energy are needed. Two aspects can be considered. First, energy codes can focus on fixture efficacy (in lumens/watt) as a performance metric, instead of emphasizing total connected load. With this strategy, lighting designers focus on selecting highly efficient fixtures to meet project needs. This approach has been adopted in some codes as the basis for exterior and parking lot lighting, avoiding complicated calculations of building perimeter, walkways and parking. This strategy also has the advantage of being applicable to a broader range of fixture applications, instead of exempting some unusual uses that are difficult to proscribe.

The other strategy for regulating lighting installations is the development of a more complex metric that better values the performance of the entire lighting system. In a proposal to ASHRAE 90.1 a method combining hours of anticipated lighting use and total connected load were combined into a proposal called a "kWh method" of interior lighting compliance. Other proposals have focused on strategies to account for the impact of advanced controls on lighting run-time. Though these metrics have not yet been adopted in code, it is anticipated that successful code strategies will be devised to more effectively integrate lighting and control technologies into an alternate metric of lighting performance.

What Jurisdiction Are Doing to Move Towards a Zero Energy Code

In the near-term, some jurisdictions are developing "Zero Energy Construction Codes." This is an energy code strategy where projects are required to demonstrate that submitted building plans are designed to achieve a zero energy outcome. Compliance with this code is based on design and construction documents, plus commissioning. There are no currently adopted examples of this type of zero code for commercial construction, but Architecture 2030 recently published a model zero code (for commercial buildings) that describes a requirement that renewables be used to offset regulated and unregulated loads. The performance baseline for this code is ASHRAE 90.1-2016. Pima County/Tucson uses an energy consumption budget based on the generation capacity of residential roof area as a design budget for residential building performance. Title 24 is using a similar approach in Title 24-2019 for residential construction where onsite energy production will generally meet all electricity consumption in a mixed fuel home, with some adjustments. A draft addendum for ASHRAE 189.1 creates a modeling format that anticipates an increased renewable requirement in 189.1-2020; scaling to a 100% renewable requirement (i.e. net zero) a few cycles hence.

Eventually, many jurisdictions would like to implement a Zero Energy Outcome Code. This is a building energy policy requiring buildings to demonstrate net zero energy use based on measured building performance outcome. A number of cities have identified the adoption of zero energy outcome codes as a long-term goal. Cities such as Boulder, New York City, Seattle, District of Columbia, San Francisco and Portland have recognized the importance of moving to a measured-outcome approach.

Conclusion

The authors find that stretch codes have made substantial progress in helping jurisdictions meet their climate emission goals in the building sector. Yet, there are significant hurdles in the construction code structure itself that will prevent these codes from fully achieving zero net energy performance, and pathways around these hurdles are only beginning to be formulated. And there is still an enormous challenge of tackling energy reductions in existing buildings - which are not generally subject to requirements that would lead to reductions in energy use or carbon emissions. As the pressure increases to reduce the carbon impacts of the building sector across the globe, stretch codes and successor policy innovations will play a major role.

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