Measuring What Matters: A Methodology for Moving From Code Compliance to Code Evaluation

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ABSTRACT

Commercial energy codes and compliance are critical tools for increasing efficiency in new commercial buildings. However, assessing commercial energy code compliance can be a complex and costly endeavor. In addition, a narrow emphasis on code compliance limits feedback that could be used to design better code initiatives and more effective enforcement efforts. There is no universal understanding of what is meant by commercial energy code compliance. This paper explores these issues and argues that improved energy performance should be the salient outcome of energy codes and code compliance as a singular goal is too narrow to warrant the level of energy and resources required to obtain reliable commercial building data. Evaluating codes should be directed at the perennial need to understand and improve the construction of new buildings. The paper presents findings from a recent code evaluation pilot designed to test an integrated, empirically-based methodology to evaluate compliance and energy performance in fully constructed and occupied commercial buildings. The objective of this methodology is to determine how new commercial buildings are actually being built, what level of code compliance is achieved, and how that compliance influences energy use. To achieve this objective, the pilot emphasized compliance within the context of overall energy use. Compliance was determined by collecting detailed characteristics for the sampled buildings and then analyzing by major system type, including envelope, mechanical, and lighting. This approach allowed for direct comparison of compliance findings, detailed characteristics, system designs, and the actual energy performance for these buildings.

Introduction

The need for significant improvements in commercial building energy performance requires an evaluation methodology which can deliver a better understanding of current practices in construction and code enforcement. Code evaluation methodologies that only fine-tune how to measure compliance for individual measures and deliver compliance rates, without an understanding of the underlying building practices or energy use associated with compliance, provide limited insights for identifying code program opportunities. A key driver for the development of the code evaluation methodology presented in this paper was the need for alternative strategies that can deliver meaningful input for a number of commercial new construction interventions, including code development and enforcement as well as utility programs and initiatives.

Commercial energy codes and compliance are critical tools for increasing efficiency in new commercial buildings. However, assessing commercial energy code compliance can be a complex and costly endeavor. This paper argues that code compliance as a singular goal is too narrow to warrant the level of energy and resources required to collect reliable commercial building data. It also presents the design and pilot results for an integrated, empirically based methodology for evaluating building characteristics, code compliance, and energy performance in fully constructed and occupied commercial buildings. This methodology uses benchmarking to assess code progress over time and was tested as part of a Pilot Study in the Northwest funded by the Northwest Energy Efficiency Alliance (NEEA). The insights from the Pilot Study will be applied to a large-scale commercial code evaluation in the Northwest. The compliance and energy analysis results from the Pilot Study are discussed in this paper.

A central tenet of this methodology is that code evaluation should be directed at the perennial need to understand and improve the construction of new buildings. Codes as a policy instrument are designed to influence current practice in building design and construction. For example, codes influence building characteristics and design, which should then impact energy use. Ideally, codes target deeper and deeper energy savings and reduce energy use over time. A key research objective for this methodology is to determine if this intention is actually being realized. Is there a relationship between commercial energy code compliance and actual (not modeled) energy use? If so, what are the characteristics and designs that are driving the differences? For example, do compliant offices use less energy than non-compliant offices and do compliant offices built to the current code use less energy than offices built to the previous codes?

If code programs seek to influence current practice and reduce energy use, then current practice and energy use should be at the heart of the code evaluation. A compliance determination can be an important factor in the overall evaluation but it should be supported by documenting the building characteristics so that the building systems contributing to the energy use can be understood and used to improve future codes.

The onsite data collection for this methodology is time-intensive, but is ultimately a more cost-effective and sustainable approach to code evaluation than research focused on compliance verification. For example, this methodology is designed to provide the core characteristics and energy use data to develop a commercial new construction baseline, assess code compliance, and benchmark energy use over time. As a result it can deliver a wide spectrum of value to state, regional, or municipal code programs. For example, the data can be used to:

- Benchmark new construction EUIs
- Benchmark new construction practices
- Connect characteristics and energy use
- Support regional, state, and utility conservation potential assessments
- Identify major compliance and design gaps
- Inform commercial code and program development
- Inform enforcement efforts
- Inform the design and building communities

Background

At the time that this commercial code evaluation methodology was created, there was no established approach to grappling with the challenges involved in assessing commercial code compliance. For example, one of the most recent commercial code compliance pilots assessed compliance on an individual component basis (PNNL 2010). The reviewer was instructed to look at a sample of buildings during construction and evaluate the items observed based on the relevant energy code requirements. Compliance was then assessed as the percentage of all measures that met the code in each building. However, because the reviews were not conducted on completed buildings, construction schedules precluded the collection of all code requirements at each building. Although, this approach is useful for determining compliance at the measure level for a sample of buildings, it does not produce the necessary data to assess building-wide compliance for individual buildings or the design features of the buildings that may have compromised or enhanced its energy use.

A key driver for the methodology described in this paper, was the desire to expand beyond the component-centric nature of codes and recent code assessments to better understand the relationship between code compliance and end-use and overall building energy requirements. Energy codes designed to control the efficiency of individual building components are not likely to deliver more than incremental savings over time. To achieve deeper savings over the coming decades, energy codes will need a major overhaul to allow building designers and engineers to significantly decrease building energy requirements. Code evaluations must be geared to support this transformation and shift from building components to building systems.

In addition, in all but the simplest or smallest commercial buildings, code compliance decisions are made by different people. Understanding this design context is critical for effective code evaluation. The architect typically controls the building envelope and decides on tradeoffs of building component performance that would allow the design of the building to be executed; the mechanical engineer designs the mechanical system and is responsible for compliance with that section of the code; and the lighting designer specifies the lighting system to meet the code lighting power density (LPD) and the lighting control requirements. To provide actionable information to code programs, utility programs, and the design community, each of these areas can and should be evaluated separately as cohesive systems.

To support the energy focus of the code evaluation, the compliance assessment in this methodology does not attempt to determine compliance on a measure-by-measure basis. Instead, it focuses on key determinants of energy use within each system such as total building heat loss rate (UA), LPD, and specific mechanical and controls[1] components. These items are used to determine compliance and compare compliance with the actual energy use of completed buildings. The objective of this methodology is to determine how new commercial buildings are actually being built, what level of code compliance is achieved, and how that compliance influences energy use.

Northwest Code Context

Commercial energy codes have been evaluated in the Northwest on several occasions. The most comprehensive was conducted in 1997 by Ecotope for the 1994 Washington State Energy Code (Baylon et al., 1997). In addition, code compliance was assessed in 1992 for the 1989 Washington and Oregon energy codes (Baylon et al., 1992) and as part of NEEA-sponsored commercial baselines in 2001 for 1997–1998 new construction starts (Baylon et al., 2001), and in 2008 for2002–2004 new construction starts (Baylon and Kennedy 2008a). All of this work focused on field evaluation of constructed buildings. Compliance focused on overall building

[1] Due to insufficient data, only exterior lighting controls compliance was analyzed in the Pilot Study.

systems, namely: envelope; heating, ventilation, and air conditioning (HVAC); and lighting. This approach allowed an assessment of both compliance and baseline building practice.

In the Northwest, the vast majority of commercial buildings are built following the prescriptive path[2]. Commercial energy codes in virtually all Northwest jurisdictions are actually an amalgam of three prescriptive codes, each aimed at different parts of the building (envelope, mechanical systems, and lighting systems). Within each of these code sections, the designer is allowed to trade off requirements within the design context. For example, the heat loss rate of building envelope components can be traded off against the glazing area; or increased lighting power in one part of the building can be traded off against decreased lighting power in another part of the building. This feature suggests that the underlying structure of a compliance review should be subdivided into the three major commercial building code systems.

Proposed Commercial Code Evaluation Methodology

The following methodology was designed and tested as part of the Commercial Code Evaluation Pilot Study (Storm et al. 2016). This methodology will be the foundation for NEEA's future state-level commercial code evaluations in the Northwest. This paper focuses solely on the code compliance and energy performance assessment components of the pilot. The pilot also included a survey of jurisdictions to test an approach to assessing barriers to code enforcement.

Code Compliance Analysis

Code compliance was determined by reviewing fully constructed and occupied buildings in a sample of 12 commercial buildings in Washington State. The buildings were all permitted under the 2009 Washington State Energy Code (WSEC). A diverse subset of building types was targeted to ensure that the compliance protocol could be tested on a variety of systems and building types. The primary building types selected for the Pilot Study were Education, Multifamily, Office, Other Health,[3] Retail, and Warehouse.

The building review included a combination of code and as-built documentation as well as field review of building characteristics. For each of the three areas of compliance (envelope, mechanical, and lighting), the plans and onsite survey data were compared to code requirements. The analysts then assessed and recorded compliance as yes/no for each subcomponent of the review and for each of the three main systems. Binary compliance logic was used to combine the subcomponents and assess the overall compliance of each system. For example, if the interior lighting power was not in compliance, the entire lighting system was listed as non-compliant regardless of the characteristics or compliance of the other components of the lighting code.

Energy Performance Analysis

The energy performance assessment uses empirical data to explore relationships between energy use and compliance. It was also designed to demonstrate how energy performance can be

[2] Unlike in California, only about 5% of the commercial buildings in the Northwest select the performance modeling path (Baylon and Kennedy 2008a).
[3] Other Health includes healthcare buildings other than hospitals such as clinics.

used as an indicator of new construction progress and the effectiveness of energy code requirements over time.

Ecotope collected electric and gas utility billing data for a minimum of 12 months for each building. Analysts conducted the billing analysis in two phases. First, the bills were compiled into a total annual bill for electricity (kWh) and natural gas (therms). These values were converted to common units (kBtu) and summed. An energy use intensity (EUI) was developed for each building based on the conditioned floor area data collected during the compliance assessments. The second phase was to use EZ Sim[4] to disaggregate the energy use by end use. EZ Sim is a billing analysis tool that uses change-point analysis to estimate heating and cooling usage and then draws on actual building end-use characteristics to disaggregate billing baseloads into end-use EUI estimates. Total and end-use EUIs were compared with the compliance findings for the Pilot buildings. The EUIs were then benchmarked against a prior a baseline study to test the potential to identify progress in building energy use over time by building type.

Code Compliance Analysis Results

The technique used in analyzing code compliance in this Pilot Study involved a binary, aggregated approach. This binary method is straightforward, but it is not very forgiving. For example, if a building heat loss is above the maximum allowance, it receives the same non-compliance score whether the excess is a mere 5% or a much more significant 50%. There are alternative methods for determining compliance that could be conducted using the same underlying characteristics data set. One aspect to consider is the various possible goals of the compliance rate. For example, if the compliance rate is intended to indicate enforcement effectiveness, a binary approach is desirable. Alternatively, when assessing the degree of compliance by the designers and the potential impact on energy use, it may be more beneficial to determine a scale of non-compliance. For example, compliance for a given system, such as mechanical, could be provided as an average of the binary compliance for the various measures reviewed for the system (preferably weighted according to the likely energy impact of each measure).

Compliance for each of the three major areas of the code is shown in Figure 1. Each area contains compliance subcomponents, which are discussed later in this section. Although service water falls under the mechanical section of the energy code, it is a distinct enough system that it is useful to assess separately and is done so in this pilot. Using the binary compliance logic method, only half of buildings meet all three parts of the code. In the Pilot Study, failure to comply was equally distributed across the envelope, mechanical, and service water. All buildings complied with the lighting requirements.

Figure 2 compares the observed heat loss (gathered from architectural details and specifications) for the all the buildings reviewed and the code requirements for those buildings. Ten of the 12 buildings did meet the code, although usually by a small margin. The two smallest buildings in the sample (11051 and 11678) substantially exceeded the code requirements for building envelope.

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[4] EZ Sim documentation and download: http://www.advancedbuildings.net/index.php?q=ez-sim

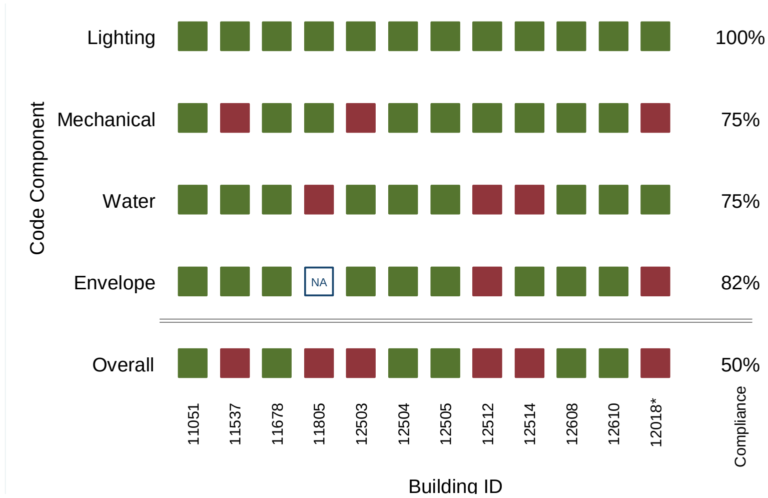

Figure 1. Overall compliance by major code components. *Source:* Storm et al. 2016.

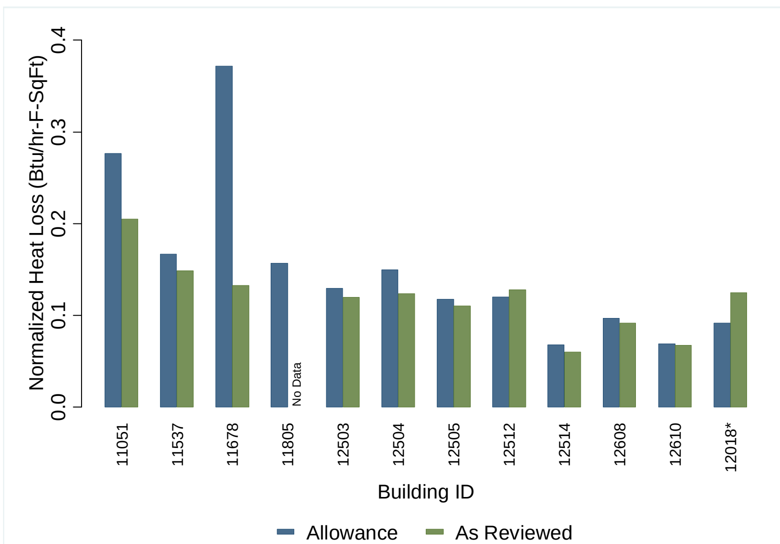

Figure 2. Building heat loss estimate normalized by floor area. *Source:* Storm et al. 2016.

Figure 3 shows mechanical system compliance which was assessed in three categories: equipment efficiency, economizer, and heat recovery.[5] About half the sample did not require heat recovery, but almost all buildings were required to meet the economizer requirements. Only one building had no cooling equipment and was exempt from this requirement. Three buildings did not pass the mechanical code evaluation; one building failed to meet the efficiency requirement of the cooling tower, and two other buildings did not have the necessary heat recovery for large ventilation systems. The one building that did not meet the economizer criterion had an economizer in the main HVAC system, which was a variable air volume (VAV) system, but did not economize the server and equipment rooms as required by the code.

[5] Although mechanical and lighting controls compliance is included in the code evaluation methodology, only exterior lighting controls were analyzed in the Pilot Study due to insufficient characteristics data for mechanical and interior lighting controls.

Figure 3. Mechanical subcomponent compliance. *Source:* Storm et al. 2016.

Lighting system compliance was assessed for both interior and exterior maximum lighting power requirements. In all cases, the lighting power requirements were met by the buildings reviewed. To varying degrees, all the buildings reviewed made use of LED lighting in their interior lighting designs. In most cases, the LED technology was used to substitute for applications that would have used incandescent lamps. Only the multifamily buildings used significant numbers of incandescent lamps. Figure 4 compares the interior LPD code allowance with the LPD of the Pilot Study buildings. Overall, the LPD observed in these buildings was about 25% less than the code allowance in the 2009 WSEC.

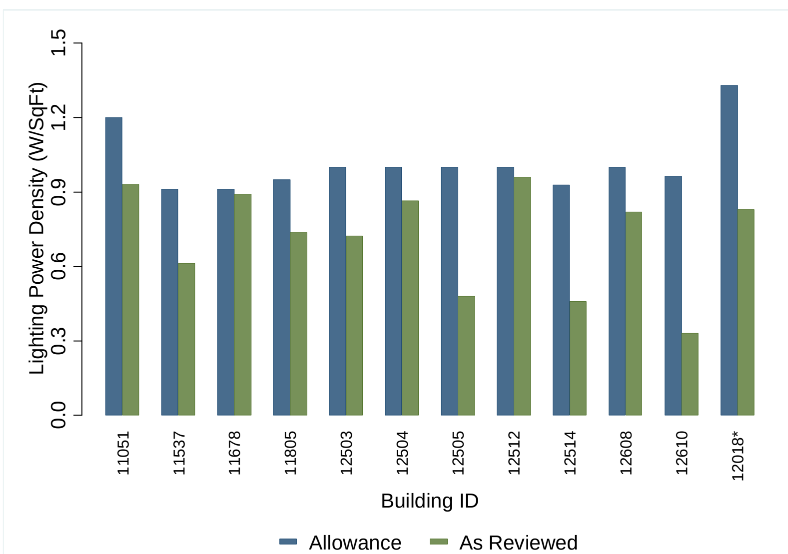

Figure 4. Interior lighting power density by building. Source: Storm et al. 2016

Exterior lighting was often a significant part of the lighting power (although usually less than a quarter of the interior lighting power). In the Pilot Study buildings, parking area lighting was exclusively LED-based, and many applications, such as walkways and building façade lighting, were usually based on LED technologies. This approach typically resulted in substantial reductions in exterior lighting power when compared to the allowances in the energy code. In all cases, the exterior lighting controls were code-compliant, using either photocell controls or timer controls to control lighting during daytime hours. Figure 5 shows compliance with the exterior lighting allowance. The exterior lighting was normalized by building area to make them graphically more comparable with one another and with the interior lighting summaries.

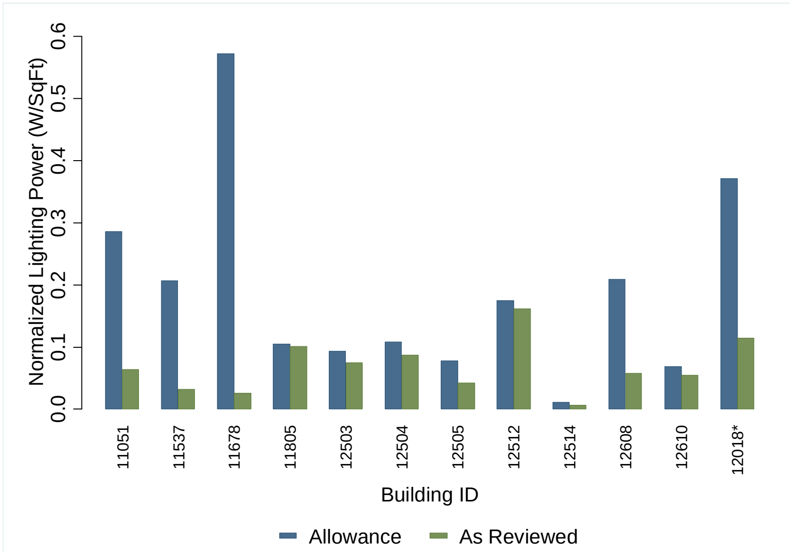

Figure 5. Exterior lighting power normalized by building area. *Source:* Storm et al. 2016.

Energy Performance Analysis Results

Compliance Correlations by Building Type and End Use

The following two graphics demonstrate how total and end-use EUIs can be used to correlate compliance with energy use. Figure 6 presents the total building EUIs with an indication of compliance and non-compliance for each building. Compliant buildings are green bars; non-compliant buildings are red bars. The specific, non-compliant systems are identified above each bar. Non-compliant systems include Envelope (E), Lighting (L), Mechanical (M), and Water (W). Figure 7 again shows the total EUI by building, but with the disaggregation of Heating, Cooling, Fan, and Other.

While this Pilot Study included only a small number of buildings, with a representative, state-level sample, the type of analysis shown in these graphics could be used to compare the energy use of compliant versus non-compliant buildings by building type. For example, on average, do non-compliant schools have higher EUIs than compliant schools? The end-use EUIs would allow additional analysis to compare the energy use with compliance at the system level. What systems are out of compliance in the non-compliant schools and what impact do the EUIs for those systems have on the total building EUIs? The compliance and energy performance assessments together provide the data to answer these questions and can help provide a deeper understanding of the underlying design decisions that are driving both compliance and energy use. These insights can be used to improve the performance of new commercial buildings by: designing better, more targeted codes for each major building system; tailoring and improving enforcement efforts for each major building system; and exploring opportunities for new measures and market transformation in the new construction industry.

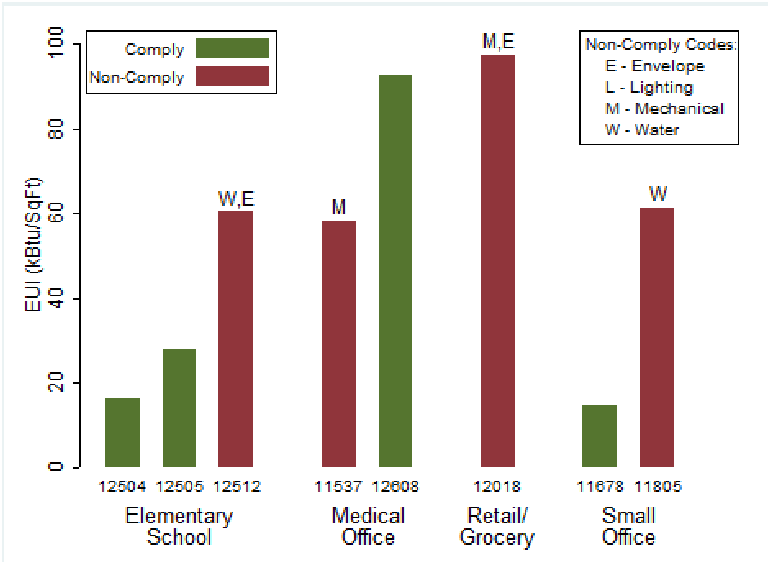

Figure 6. Total EUI by compliance status. Source: Storm et al. 2016.

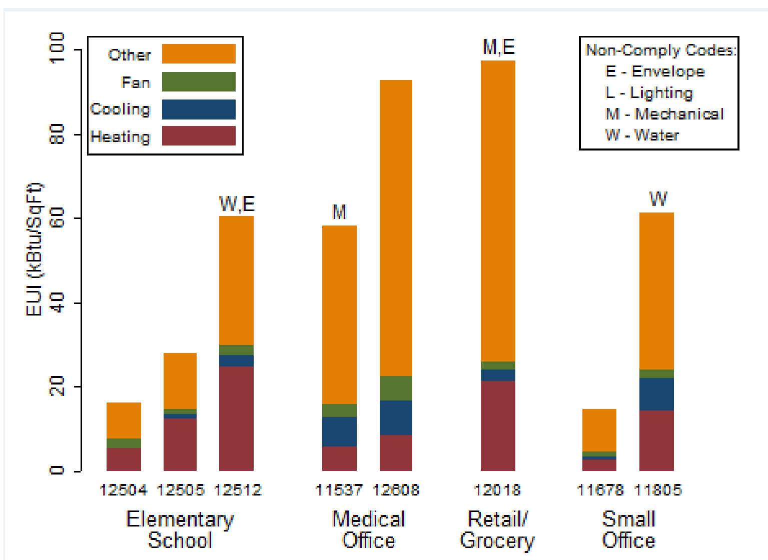

Figure 7. Total EUI by end use. *Source:* Storm et al. 2016.

Energy Benchmarking

The methodology tested in the Pilot Study also delivers the data and analysis necessary to benchmark energy use and building characteristics such as UA, LPD, and mechanical systems across cohorts of buildings permitted under various code cycles. Although there are differences in occupancy and other building characteristics across cohorts, the distribution of energy use in particular building types can be relatively small (Baylon et al. 2008b).[6] Given the distribution of energy use *within* building types, changes in building performance over time (as a result of codes or changes in design practice) would be observable with reasonable sample sizes. When implemented on a larger sample, these types of comparisons can become the first step toward producing a time series energy performance review of commercial buildings.

Ecotope compared the EUIs and characteristics for the twelve Pilot Study buildings with the most recent northwest commercial new construction baseline study (Baseline Study) (Baylon and Kennedy 2008b). The Baseline Study included a Washington State sample of 150 buildings typically built to the 2001 WSEC. The buildings were permitted by the end of 2004 and constructed and occupied by early 2006. Figure 8 compares the EUIs for the Pilot Study with the average EUIs from the Baseline Study. The boxplots represent the Baseline Study EUI distributions for each building type; the middle line in the boxes indicates the median EUI. As illustrated in the graph, the EUIs for most of the compliant Pilot Study sites (green dots) have drifted well below the Baseline median EUIs. In most cases, the EUIs for the non-compliant Pilot Study sites (red triangles) are much closer to the EUI median from the Baseline Study, indicating less improvement than the compliant sites. However, they are all still below the Baseline medians to some degree. These Pilot Study findings are not indicative of actual energy performance progress over time, but these types of inferences could be made when applying this analysis to a representative sample.

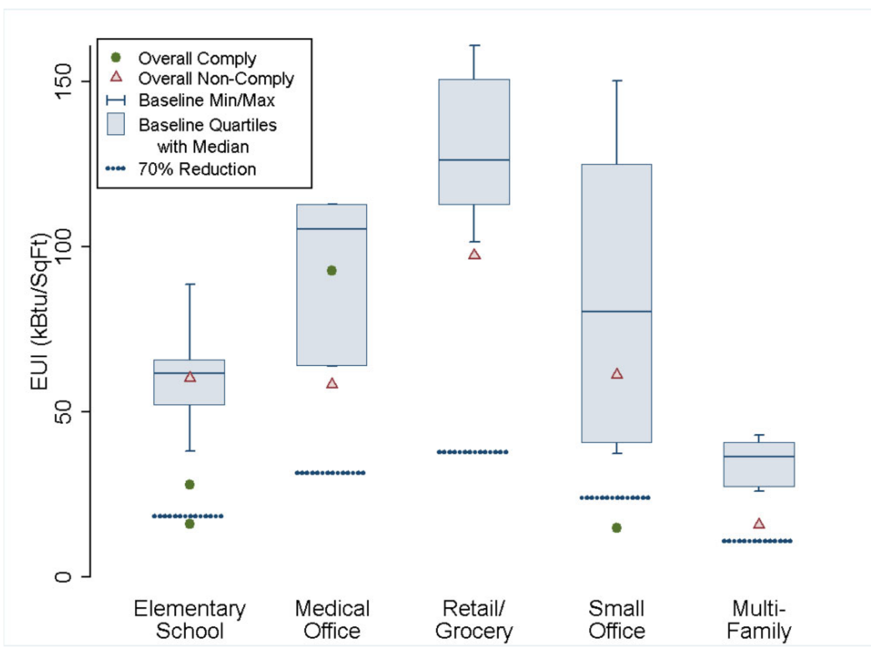

Figure 8. Comparison of Pilot Study vs. baseline annual EUIs by building type. *Source:* Storm et al. 2016.

[6] See Baylon et.al. 2008b for the distribution of energy use for a large sample. In most major building types the ratio between mean EUI and the standard deviation (the coefficient of variation) for individual building types was about 0.30.

The blue dotted lines in Figure 8 show indicate the level of energy performance that would be required to achieve a Washington State mandate to reduce energy in new buildings by 70% below the 2006 code baseline. As the graphic shows, most non-compliant Pilot Study EUIs (red triangles) are well above the 70% target (dotted line), whereas the compliant buildings (green dots) are mostly close to or below the target. With a representative sample, this type of analysis would help identify the influence of compliance on efforts to meet energy reduction targets.

These comparisons provide insight into the relative performance of the buildings and also track the change in energy consumption between the Baseline Study buildings and this small Pilot Study sample. In a larger sample, average EUIs across building types, rather than individual building, could be compared to previous baselines. This type of analysis would visually benchmark the changes in EUIs across time.

An alternative approach to assessing code progress across cohorts and code cycles is to evaluate particular code requirements that are easily comparable across buildings. To illustrate this approach, Figure 9 shows a comparison of the LPD between buildings in the Pilot sample and buildings in the Baseline Study. In this figure, the Pilot Study observations are superimposed over the Baseline Study building distributions.

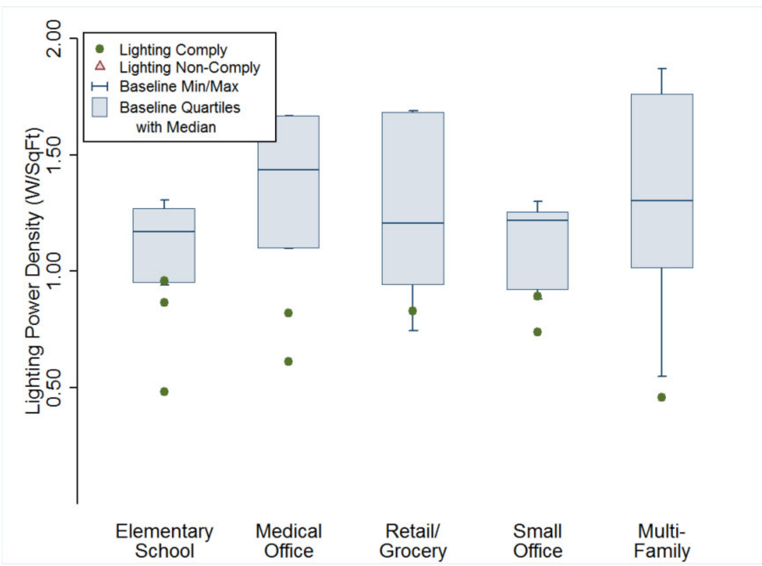

Figure 9. LPD Comparison of Pilot Study to Baseline Data by Building Type. *Source:* Storm et al. 2016.

The overall assessment of the Pilot Study suggests that generally these buildings are performing better than a sample of buildings from a construction period about eight years earlier. Although this sample is inadequate to make a definitive comparison, the method provides a high-level comparison which could show progress, or lack of progress, by individual building types. The characteristics benchmarking shows a similar story. With a larger, statistically representative sample comparable to the Baseline Study, this comparison could provide valuable insights into EUI improvements and trends over almost a decade of code changes.

Conclusions

This methodology is organized around the idea that improved energy performance should be the salient outcome of energy codes. The building systems and energy performance assessed in the Pilot Study provided insights that can be linked to observed energy usage. Although compliance is an important by-product of this analysis, understanding what factors are driving the consumption of energy in the commercial sector will provide the basis for future code initiatives and for future efficiency measures across the region. The Pilot Study confirmed that the central framework and strategies of this methodology can deliver multifaceted and actionable findings. This framework can be used to focus regional resources on a deeper understanding of energy use in commercial new construction and its relationship to the energy code and enforcement practices over time.

This methodology for a code evaluation cycle can ultimately contribute to a tighter relationship between code program efforts, market signals, and actual energy use in the new commercial building stock. It allows for the increased possibility that code programs can be increasingly responsive to ongoing market evolutions in new construction. The integrated code evaluation approach can deliver diverse data, analysis, and insights within an overall market transformation framework. The interaction of code planning, specific energy efficiency initiatives, and a consistent code evaluation framework can help transform new construction in the commercial sector.

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