Energy-efficient re-use of existing commercial buildings

Citation to Publisher Version: Andrews, Clinton J., Hattis, David, Listokin, David, Senick, Jennifer A., Sherman, Gabriel B. & Souder, Jennifer. (2016). Energy-efficient re-use of existing commercial buildings. *Journal of the American Planning Association 82*(2), 113-133.https://doi.org/10.1080/01944363.2015.1134275.

Citation to *this* Version: Andrews, Clinton J., Hattis, David, Listokin, David, Senick, Jennifer A., Sherman, Gabriel B. & Souder, Jennifer. (2016). Energy-efficient re-use of existing commercial buildings. *Journal of the American Planning Association 82*(2), 113-133. Retrieved from http://dx.doi.org/doi:10.7282/t3-0kk7-mg08.

Submission to the *Journal of the American Planning Association*

Title: Energy-efficient re-use of existing commercial buildings

Problem, Research Strategy, and Findings: Increased demand for urban living, financial incentives for redevelopment, and conducive planning regulations are leading to significant commercial building re-use. This trend represents an opportunity to upgrade the energy performance of the existing building stock in older, more walkable downtowns, and to achieve preservation goals. However, some advocates of building re-use resist imposing the cost of energy improvements on associated projects, while many energy efficiency advocates do not distinguish well between new and existing buildings. Building code officials experience this tension when reviewing improvements to existing buildings and many find that sections of the widely adopted International Energy Conservation Code (IECC) are pragmatically unenforceable. This paper characterizes the challenge using a regional survey of code officials and interviews with redevelopers, and explores how to improve outcomes. It tests policy alternatives on a representative sample of the U.S. commercial building stock and investigates how these policies might differentially affect the commercial building stock of contrasting towns (one compact and historic, the other sprawling) in the Greater Philadelphia region. Promising regulatory strategies include exempting smaller buildings and less energy-intensive occupancies and systems, and creating simple lookup tables that provide succinct guidance to redevelopers and code officials.

Takeaway for Practice: Code officials enforce longstanding life-safety codes more assiduously than they do the newer energy codes, and these codes need revisions to make them more cost-effective and enforceable. A better understanding and implementation of building energy codes can have positive implications for both energy performance and downtown revitalization. Success depends on better managing interdependencies among the national policy objective of energy efficiency, the ubiquitous local planning objective of downtown revitalization, and the details of regulating construction practices in existing buildings.

Keywords: regulation, redevelopment, energy efficiency, buildings, building codes

About the Authors: Clinton. J. Andrews PhD AICP, Prof. of Urban Planning and Policy Development, Edward J. Bloustein School of Planning and Public Policy, Rutgers University; David Hattis, MArch, President, Building Technology Inc.; David Listokin, PhD, Distinguished Prof. and Co-Director of Center for Urban Policy Research, and Graduate Director, Edward J. Bloustein School of Planning and Public Policy, Rutgers University; Jennifer Senick, MA, PhD Candidate, Executive Director, Rutgers Center for Green Building; Jennifer Souder, MLA, LEED AP BD+C, Researcher, Rutgers Center for Green Building

Introduction

Adaptively reusing existing buildings is an essential component of historic preservation, downtown revitalization, and smart growth. These worthy objectives sometimes conflict with other fundamental public mandates, such as hazard mitigation and energy security. Planners preserving historic districts and walkable downtowns may argue with energy-efficiency advocates and public safety officials about which elements of existing buildings to save or replace. The conflicts arise most starkly when governments impose regulations affecting the construction and re-use of buildings, such as applying the Secretary of the Interior Standards (36 CFR 67) in considering solar panel installation on a historic building. State and local officials draw guidance from international model codes designed to protect public health, safety and welfare as well as to preserve and improve the building stock. Many jurisdictions now have a decade or more of relevant practical experience in implementing such codes. While they have identified a range of unenforceable and conflicting code provisions, adopting code updates is politically difficult. This paper addresses aspects of the resulting problems that relate to energy efficiency.

Global warming and energy security concerns have made energy efficiency a policy priority in every sector, from buildings to transportation to industry. Buildings account for 40% of U.S. energy use (EIA 2015), and the re-use of existing buildings has great potential for improving the energy and emissions performance of the building stock. Stakeholders therefore seek workable pathways for improving the energy efficiency of existing buildings. Parallel previous debates have centered on improving seismic, wind, flood and fire safety; indoor air quality; and the economic feasibility of renovating existing buildings. Current debates about energy performance have much in common with these predecessors. This paper locates the “codes” debates in their historical, planning and policy context, reviews what has been learned to date from practice, illustrates the implications with a case study of “change-of-occupancy” provisions, and identifies important emerging roles for planners.

Building Codes

While building codes date back to ancient Babylon[1], widespread regulation of building construction in the United States only began in the second half of the 19th century.[2] Stakeholders were soon dissatisfied with the patchwork of regulations that emerged across jurisdictions, and efforts to standardize and improve the technical underpinnings of codes began. Early non-governmental standards[3] were superseded in time by three governmentally enforced model codes[4], such as the Building Officials and Code Administrators (BOCA) National Building Code (NBC). Model codes gained a central role that continues today, with the stakeholders relying since 1994 on a single model code group (International Code Council) to orchestrate consensus processes for revising and updating standards (Listokin and Hattis 2005).

The International Code Council (ICC) family of building codes includes the International Building Code (IBC), International Residential Code (IRC) and International Existing Building Code (IEBC). The ICC also develops codes for specific building systems and performance standards, such as the International

Energy Conservation Code (IECC), which sets performance standards through the regulation of building envelopes and mechanical, lighting and power systems. These codes are periodically updated to reflect current thinking in the field. Under U.S. federalism, the federal government has supported research and imposed some national policies, but building codes have remained the domain of state and local governments. Thus, innovations spread unevenly across jurisdictions.

Codes for Existing Buildings

Building code enforcement has broad implications for planning. Most relevant to this paper is the tension that exists between the desire to re-use existing buildings and the compliance costs imposed by building codes on such rehabilitation. Building codes regulate new construction and repair, alteration and addition to existing buildings. A common trigger for requiring an existing building to comply with the current new building code requirements is a change in the occupancy classification or use of a building. However, the historical orientation of model building codes to new construction, and the lack of guidance for renovation, has made upgrading existing buildings an uncertain prospect. For example, in BOCA's NBC, any change in use (e.g., from business to residential) would result in the new occupancy classification having to satisfy the standards of a newly constructed building containing that new occupancy—a difficult, expensive and uncertain retrofit. The result can be abandonment and deterioration of the building stock, or the demolition of existing and historic buildings, in favor of new construction. As for energy efficiency, property owners often forgo alterations that would trigger costly investments in energy efficiency upgrades.

"Smart codes" aim to encourage the reuse of existing buildings through a more measured approach to compliance standards and by adding predictability to the permitting process, easing the tension between reuse and investments in upgrades. The "hazard scale" is one example of a smart code approach. By clearly defining and ranking the vulnerability of different occupancies to various risks, and requiring compliance with the code requirements that address the respective risks as a building moves from a less vulnerable to a more vulnerable occupancy, the hazard scale adds predictability to the renovation process. Instead of requiring detailed structural analysis of specific hazard scenarios, the hazard scale offers a simple five-category lookup table that guides compliance and enforcement. This approach was pioneered by Massachusetts with the adoption of Article 22 (retitled Article 34) in 1979, and built upon by the Nationally Applicable Recommended Rehabilitation Provisions (1997). New Jersey pioneered the adoption of a version of this smart code, the New Jersey Rehabilitation Subcode (1998), which included a multidimensional hazard scale. The hazard scale approach was included in the 2003 initial release of the IEBC.

A similar scalar approach could be applied to building energy codes for existing commercial buildings. A New Jersey code official describes this evolutionary process: "I've been doing this since the early 90's, [and] at first the rehab code was out and out rejected. Energy was not talked about in the rehab code, [and] the builder wouldn't put in insulation. We changed the rehab code to make it better. I imagine that it will and should keep progressing." (Focus group, October 29, 2013, Philadelphia Navy Yard).

Today, the IECC's change-of-occupancy provision is a pivotal regulation, requiring that many projects meet current energy requirements. However, it appears that this provision is neither well understood nor complied with in a predictable manner.

The IECC's change-of-occupancy provision encourages energy efficiency upgrades in existing buildings by requiring compliance when a building changes occupancy that would result in an increase in demand for energy (Section 101.4.4 of IECC 2009). However, building code officials often choose not to enforce this provision, for a variety of reasons. Some jurisdictions, such as Seattle, have amended it, and others such as New York and New Jersey have eliminated this language entirely. The provision can be burdensome for applicants in terms of cost and for code officials because of its high level of technical requirements (Section 101.5.1, Compliance materials, IECC 2009); it can further be at odds with local economic development imperatives by discouraging building re-use; and, unlike clear-cut safety issues, energy efficiency may be considered a partisan political issue. The Institute for Market Transformation (2014) estimates that energy code compliance in major cities averages only 70% and is even lower in many jurisdictions, because of limited resources, low assigned priority, inadequate training, and lack of awareness. Thus, even though approximately half of the $41 billion spent on U.S. commercial retrofit and renovation in 2010 was spent on energy efficiency upgrades (McGraw Hill, 2011), the majority of these measures were unlikely to have been code compliant.

The U.S. Department of Energy views building energy code compliance as a major policy goal and has funded compliance pilot studies that try out "new" ideas, most of which in fact have some sort of track record including: (a) mandating building energy performance modeling, (b) exempting smaller projects from requirements, (c) targeting only selected building systems, and (d) developing a simple categorical scale.

Require modeling: Most codes are "prescriptive," that is, they specify which construction details and equipment standards are or are not acceptable, making enforcement easy. Some codes instead offer a "performance" path to encourage innovative design solutions. Under the performance path, the code official's challenge is how to verify that the design performs as intended. However, waiting for a year's worth of utility bills before issuing a certificate of occupancy is unrealistic. An alternative, prospective means of demonstrating which energy-efficiency features make sense for a particular building project is to simulate their performance using specialized computer software. Building energy performance simulation models, however, require substantial amounts of data about the building envelope and systems, occupancy patterns, climate, and utility price schedules, and developing these models requires much effort and expert judgment. Even though building energy performance modeling is a current requirement for most performance-path projects, it is routinely unenforced in jurisdictions such as those discussed below. One response from the U.S. Department of Energy and leading states has been to fund the development of simpler modeling tools (McConahey 2012). Designers are starting to use the tools but most code officials still lack the skills or time to review them. For example, the Massachusetts Stretch Energy Code requires energy modeling for all new building projects at or above 100,000 ft^2 of affected floor area, and for all labs and healthcare facilities exceeding 40,000 ft^2. It offers both a performance and a prescriptive path for smaller buildings down to 5,000 ft^2, and it exempts building smaller than that. Notably, it exempts ALL commercial building renovations from the modeling requirement (Mass.gov 2015).

Exempt small projects: Overburdened code officials could target their resources toward a subset of projects that promise a greater “bang” for the enforcement “buck.” They could focus their efforts on larger projects and exempt smaller projects from requirements. For example, Section 6.3.1 of the ASHRAE 90.1 2010 standard allows buildings under 25,000 ft^2 in size to meet a simpler set of energy efficiency criteria than larger buildings. Section 101.4.2 of the IECC 2012 exempts all designated historic structures and Section 101.5.2 exempts portions of buildings using less than 1 W/ft^2 to maintain thermal comfort. While this exemption strategy would decrease the burdens of regulatory implementation and enforcement, it would also reduce regulatory coverage, and therefore save less energy.

Exempt some building systems: Targeting only selected building systems is another strategy that enjoys current use. For example, Section 101.4.4 of the IECC 2009 requires upgrades of lighting as part of many changes of occupancy, but exempts mechanical systems and building envelopes. Sometimes, an expectation of increased energy consumption per unit of floor areas becomes the trigger for specific compliance requirements since this quantity for different energy uses (lighting, space conditioning, water heating etc.) varies as a function of building occupancy. A specific change of occupancy may increase energy consumption in one use and decrease it in another.

Use a lookup table: A simple categorical scale approach to building energy codes, modeled on the hazard scales of the NARRP and IEBC, could decrease arbitrary and haphazard application of the provision and reduce technical barriers to enforcement. As discussed below, there is encouraging evidence from life safety provisions of rehabilitation codes that may be relevant to the case of energy.

Energy Intensity

Annual energy use per unit of floor area is the most widely used metric for characterizing the energy performance of buildings. This seemingly simple measure, expressed in $kBTU/ft^2$ in the U.S. context, involves a host of assumptions that make for fierce debate among experts (Hsu 2014a).[5] These complications require users to take care when comparing energy intensity data.

The Commercial Buildings Energy Consumption Survey (CBECS) is currently the only widely available, detailed, nationally representative data source on energy consumption in commercial buildings. Energy Star Portfolio Manager, which represents more of an opportunity sample, has grown to include limited information about a very large number of buildings, hence USDOE and USEPA are cooperating to create a more open platform that can absorb new data from various sources as it becomes available (USDOE 2015). The most important new sources of building energy data come from the bottom-up benchmarking movement, in which state and local jurisdictions mandate that building owners report annual energy usage.[6]

Designing Energy Codes for the U.S. Commercial Building Stock

This section uses CBECS as a basis for evaluating the efficacy of four strategies for improving energy code compliance within existing buildings as they change occupancy or otherwise renovate. Table 1 shows the distribution of the U.S. commercial building stock by year constructed, based on CBECS. The median commercial building in the United States was built about 1975. Buildings constructed before 1960 (making them eligible for historic status in many jurisdictions) represent 26% of buildings but only 20% of total floor area. Buildings constructed before 1920 represent only 5% of structures and floor space. Older buildings are typically smaller than newer ones. Energy intensity is not monotonic with age, instead, it rises modestly until the 1980s and diminishes thereafter. The more important differentiator, outstripping age, climate, and size, is the principal activity that takes place in the building. Table 2 shows the wide range of resulting average energy intensities. This evidence suggests that it should be possible to target energy efficiency upgrade requirements carefully to avoid making them economically burdensome. The IECC (2012) already exempts historic structures.

[Table 1: Age distribution of U.S. commercial buildings]

[Table 2: Energy intensity of U.S. commercial buildings by principal activity]

<u>Mandating modeling</u>

An expert modeler explains: “Looking at how much I might charge for generic office buildings, assuming modeling results in a modest 10% energy cost savings: At 20,000 ft^2, my modeling costs are recovered in savings in 4.2 years; 50,000 ft^2 – 1.9 years; 100,000 ft^2 – 1.1 years; and 200,000 ft^2 – 0.6 years” (Malin 2012). According to CBECS, the median size of a U.S. commercial building is only 5,100 ft^2, suggesting that modeling efforts will only rarely be cost-effective, as Massachusetts found.

<u>Exempting smaller projects</u>

We use CBECS 2003 microdata to investigate which types of buildings and systems are worth regulating in Tables 3-6. The cost of regulation increases with the number of buildings (although factors such as total floor area also influence it), whereas the benefits potentially increase with the amount of current energy consumption. Policymakers presumably want to regulate as few buildings as possible while covering as much of U.S energy consumption as possible. Table 3 shows the percentage of all U.S. commercial buildings in each size and activity cohort. Table 4 shows the percentage of all annual multi-fuel energy consumption in U.S. commercial buildings by the same cohorts.

Table 5 shows the relative energy/buildings concentration ratio, which is mathematically identical to the location quotient often used by economic development planners. It indicates which cohorts contain a larger fraction of energy usage than number of buildings, relative to the national building stock. Cohorts with a higher ratio, especially if greater than 1, consume more energy per building than the national average and presumably should be the earliest targets for energy efficiency regulation. This can be due to high energy-intensity (kBtu/ft^2) or large floor area (ft^2).

Exempting some systems

The major uses of energy in U.S. commercial buildings include heating-ventilating-air-conditioning (HVAC), lighting, domestic hot water, and occupants' equipment loads as shown in Figure 1. Of these, code officials can influence HVAC, lighting, and domestic water heating because these are core systems installed when the building is constructed or renovated. HVAC and lighting requirements are partly a function of insulating and glazing choices made during construction of the building envelope. Unlike local code officials, federal appliance regulators have the authority to set and enforce standards for equipment owned by occupants, including cooking equipment, refrigerators and freezers, office equipment, computers, and other items. Federal law also sets equipment performance standards for HVAC, lighting, and hot water production equipment, but not for the overall systems of which they are components. Table 6 extends the cohort relative concentration ratio analysis to these three locally regulated energy-using systems within buildings, thereby focusing local code officials' attention on the portion of energy consumption they can influence.

[Table 3: Percent of Total Count of Commercial Buildings in the USA by Building Size and Principal Building Activity]
[Table 4: Percent of Total Energy Consumption in U.S Commercial Buildings by Building Size and Principal Building Activity]
[Table 5: Relative Concentration Ratios (Percent of Weighted Total Energy Consumption / Percent of Weighted Total Counts of Buildings) by Building Size and Principal Building Activity for US Commercial Buildings]
[Table 6: Relative Concentration Ratios (Percent of Weighted Total Energy Consumption / Percent of Weighted Total Counts of Buildings) by Building Size, Principal Building Activity, and Building System for US Commercial Buildings]

Policy designers typically seek to balance competing objectives of two types. First, there is a need to balance net social costs and benefits, that is, do the societal-wide benefits exceed the costs to individual building owners? That calculation plays out in negotiations over the specification of "reasonable" code requirements (as in the Massachusetts example) and the extent to which model codes are locally tailored for specific buildings and contexts. The net social benefit question has been examined elsewhere (Zhang et al 2013) and will not be further explored here. Second, there is the challenge of keeping transaction costs reasonable, by balancing the objectives of greater regulatory coverage and lower regulatory burden.

A reasonable strategy is to pursue the 80/20 rule of good management in which the policymaker targets the 20% of actors thought to be responsible for 80% of the activity.

Table 7 summarizes several policy scenarios in this spirit that consider alternative mixes of building sizes and principal building activities. Rules based on building size are easily enforced and provide an initial, coarse filter for balancing regulatory burden against energy savings. Size thresholds around 10,000 to 25,000 ft2 of floor area come close to achieving the 80/20 rule. Targeting buildings with energy-intensive principal activities brings a second dimension to the policy design that allows for fine-tuning. Finally, targeting key energy-using systems within candidate buildings allows precise focusing of regulatory attention. A plausible policy emerging from this analysis is: "This energy code provision applies to the HVAC systems of all buildings with a floor area greater than 10,000 ft^2 except those with principal activities of Education, Public Assembly, Religious Worship, and Non-refrigerated Warehouse which only have to comply if their floor area is greater than 25,000 ft^2."

[Table 7: Illustrative policy scenarios]

<u>Developing a lookup table</u>

Developing an existing-building energy efficiency policy based on analysis like that behind Table 7 represents a good first step in policy design. The next step, however, requires thinking about how to treat changes in the principal building activity (known to code officials as "change of occupancy"), which occurs frequently when existing buildings undergo renovation. A change of occupancy to a more energy-intensive use should trigger more stringent energy code requirements than a change to a similar or less energy-intensive use.

Can these subtleties be reduced to a simple lookup table, and will it work? The pioneering New Jersey Rehabilitation Subcode provides a persuasive example.[7] The New Jersey smart code had practical benefit from incorporating a lookup table of hazard scale classification to more rationally regulate change of use (Burby et al 2006), and so too an energy lookup table for different occupancies could have practical import.

Based on analysis of energy intensities by principal building activity and end use in the CBECS microdata, it is possible to identify natural clusters of activities that are not significantly different from one another. Using a 5-step clustering scheme (similar to the hazard scales in the IEBC and New Jersey Rehabilitation Subcode), the result is shown in Table 8. Changes of occupancy that stay at the same level or lower in the scale should not trigger additional requirements, whereas those that increase energy intensity, from, say, Outpatient to Inpatient Healthcare, should do so.

[Table 8: Change of Occupancy Scale]

This paper has discussed four strategies for simplifying energy code enforcement in commercial building renovations: (a) mandating building energy performance modeling, (b) exempting smaller projects from requirements, (c) targeting only selected building systems, and (d) developing simple categorical scales. Modeling is only likely to be feasible for large projects because of the expense and expertise required. Exempting smaller projects and targeting only selected building systems appear to be promising strategies, as does the simple scales. We now go to a case study to clarify how the regulatory burden/benefit tradeoff plays out locally, where the building stock may differ from the national profile.

Case Study: Greater Philadelphia

Greater Philadelphia includes nine counties spread across two Mid-Atlantic states, and it functions as an economic region and commuter-shed whose metropolitan planning organization is the Delaware Valley Regional Planning Commission (DVRPC).[8] The Philadelphia-Camden-Trenton-Wilmington (Delaware) metropolitan area is the fifth largest in the United States as of 2010 (U.S. Census, 2013). Finally, the commercial building stock is among the oldest in the United States (EIA 2007). Thus, energy-efficiency retrofits undertaken in these areas would affect many buildings and have a national impact.

In recent years, Pennsylvania has lagged in updating its building codes, which are older than the national median revision date. As of this writing, it continues to use the 2009 versions of the IBC family, whereas leading states such as California, Colorado, Maryland, and Washington have updated to more recent versions (ICC 2012 or 2015). The codes culture of this region is not cutting-edge. This makes the Pennsylvania counties an ideal location for studying implementation barriers.

We surveyed municipal officials in this five-county region to gauge their interest in and awareness of energy efficiency issues.[9] Relevant findings follow.

When asked which types of energy efficiency projects are common in commercial buildings in their municipality, respondents mentioned upgrades to building envelopes (42%), lighting (56%), and heating-ventilating-air-conditioning (HVAC) systems (65%). Fully 83% of the region's jurisdictions "opted in" to locally amend and enforce the IBC, IECC, and the IEBC, and the remainder "opted out," allowing the Pennsylvania Department of Labor and Industry to assume this role. Only 25% of responding jurisdictions, typically larger ones such as Philadelphia, allowed applicants to pursue performance-based pathways (typically requiring building energy modeling) to comply with the energy code.

When asked if there is an individual in the municipality who is responsible for overseeing municipal activities related to energy use by commercial/multifamily building owners, only 21% responded affirmatively. We found other desultory regulations or action concerning nonresidential energy use: only 16% reported that they have enacted commercial energy efficiency ordinances; just 21% have used education to promote energy efficiency in their building stock; and only 10% set master plan goals for energy efficiency in commercial and multifamily buildings. Philadelphia was usually in the minority answering affirmatively to this set of questions.

Only a minority of respondents indicated that standard methods to foster private sector energy efficiency efforts in their community were being considered or implemented by municipal officials.[10] In what amounts to a self-fulfilling prophecy, when asked about the level of demand for assistance from the municipality to pursue energy efficiency in their businesses/buildings, 87% of respondents thought there was no—or very low—demand from commercial building owners. This suggests a policy environment that is relatively indifferent to energy efficiency.

Table 9 shows the size distribution of commercial buildings for the United States, the DVRPC-PA region, and the two case study communities of King of Prussia and West Chester, PA. The table relies on local CoStar data to supplement the national data. The DVRPC-PA region, which includes the centuries-old city of Philadelphia, has a similar proportion of its buildings in each size cohort as the nation, but a larger proportion of its floor area in small commercial buildings than the country as a whole. King of Prussia, an area within Upper Merion Township, exemplifies the classic 1970's suburban pattern of office parks and includes the largest mall in the eastern United States. King of Prussia has proportionally fewer small commercial buildings and more of its total floor area in large buildings than the national profile. West Chester, by contrast, has preserved a compact, walkable downtown, which is a designated historic district. West Chester has proportionally more of its floor area in small buildings than either the region or the nation.

[Table 9: Size distribution of the commercial building stock by jurisdiction.]

[Table 10: Illustrative policy scenarios applied locally]

Table 10 shows how illustrative policy scenarios play out in each jurisdiction. Designing policies based solely on building size will have only limited efficacy in all three cases, and the prospects for approximating the 80/20 rule seem more remote than for the case of the United States as a whole. The historic community of West Chester is particularly problematic because a majority of its energy use occurs in small buildings under 10,000 ft^2 in size.

For the greater Philadelphia region, the principal building activities of health care, regional mall, hospitality, food sales, education, and office all have concentration ratios greater than one, in descending order. The list is nearly identical in King of Prussia, except that the regional mall tops the list. West Chester lacks a mall but otherwise follows the same pattern. These principal building activities warrant particular attention from code officials.

A recent renovation project involving a change of occupancy illustrates the process. In June 2012, the owner filed a permit application to convert a portion of a 3-story building located in an historic district in a case study community in the DVRPC region from offices to residential occupancy.[11] This is the most common change of occupancy in the jurisdiction. According to our 5-level energy efficiency scale, absent the historic area exemption the change of occupancy from offices ("B" in the IBC) to multi-family residential (“R2” in the IBC) would not mandate stricter HVAC or lighting requirements, but it would trigger domestic hot water requirements.

The developer has done numerous small renovation projects in this historic town, and says that he needed to install new HVAC systems anyway in order to give each apartment its own controls and to provide central air conditioning. He reported installing standard lighting systems that did not meet the wattage requirements of the energy code, and indeed reported that this code provision was not enforced in his experience. He installed energy-efficient tankless domestic water heaters in the apartments. Unlike renovations of a decade earlier, his standard practice is to add insulation whenever the building envelope is touched, in accordance with current energy code alteration requirements. It is not always possible to make much of a change because it is not cost-effective to rip out 2x4 stud walls simply to replace them with better-insulated 2x6 walls. The permit for this $65,000 renovation was approved in July 2012 and the renovation was completed that year.

A more difficult but still common change of occupancy for this developer is from retail or office (“B”) to restaurant (“A2”). According to our 5-level energy intensity scale, this should trigger stricter HVAC, envelope and domestic hot water requirements but no changes to lighting. Typically, the HVAC requirements are substantial and quite costly due to increased outside-air flow and exhaust air needs that override energy efficiency concerns on health grounds. Health inspectors often require very large domestic water heaters for such conversions which also contravene energy code aspirations for improved energy efficiency. Restaurants often change out lighting systems even though there is no code requirement to do so because they have aesthetic impacts. Building envelope changes seem relatively rare.

These vignettes, and others like it that we encountered in our fieldwork, suggest that owners undertaking renovations involving a change of occupancy (1) find it difficult to change the building envelope, and (2) find it relatively easy to change HVAC, lighting, and domestic hot water systems even though they may not be required to do so. Code officials appear to prioritize health and safety issues above energy efficiency and ignore code provisions they think are unreasonable from a cost-effectiveness standpoint.

Perceptions of Code Officials in the Region

How representative is our case study? We surveyed and conducted focus groups with a wider sample of code officials to gauge their perceptions.

In a snowball-sample survey responded to by 43 codes officials in Pennsylvania[12] more than half of respondents to this question (62%, n=21) report that more than 51% of building applications are for existing buildings, with the largest group (38% of respondents, n=13) reporting that these applications account for 75% or more of all applications. Within these, the share of existing building applications involving a change-of-occupancy classification varies greatly.[13]

These results accord well with a series of focus groups with regional building officials and building professionals (October 29, 2013, Philadelphia Navy Yard), who report that most building application activity is for existing buildings and otherwise give quite variable accounts of those that trigger compliance with the change-of-occupancy provision. To a certain extent, this variability stems from variation in the building stock and in redevelopment activity across the municipalities represented. However, it is also clear that focus group participants do not all understand the change-of-occupancy requirement in the same way. A consistent theme of these focus groups, however, is an unwillingness to enforce the existing change-of-occupancy requirement. One code official says: "we need to tell the builders that this is what has to be done, but we still get political push to bend the rules with energy code." Another observes that "most of my reviews are just the cheapest contractors, the little guy, and I see a more libertarian view of not forcing people to push the envelope." A participant from a big, reputable architectural/construction/engineering firm says: "I have never had that kind of discussion [about energy code requirements] with a code official."

Conclusions and Recommendations

The re-use of buildings in older downtowns and historic districts can advance goals of economic development and smart growth in many localities. Bringing energy efficiency to commercial building renovations is an important national priority that serves economic, environmental, and national security goals. Localities often see energy-efficiency requirements are a barrier to the re-use of buildings, and the nation will fail to achieve meaningful improvements by pursuing simplistic policies that treat existing buildings as if they were new ones; that treat all climate zones, building sizes, types, and occupancies as if they were identical; and that ignore enforcement challenges. Nonetheless, our research optimistically concludes that there need not be a tradeoff between downtown revitalization and energy efficiency policy objectives.

All regulations have associated costs and benefits. Some costs are transactional and are borne by both the building owner and the local government. Designing enforceable regulations requires striking a balance between the benefit (energy savings) and the costs of compliance and enforcement. Our research suggests that the right balance will target larger buildings housing more energy-intensive activities, and that it will exempt smaller buildings and less energy-intensive activities and systems. We believe that code officials need more enforceable energy code language that delivers simple, categorical guidance. Complex simulation models make sense for big buildings but not for the typical downtown renovation.

Both national data and a local case study suggest that older commercial buildings located in walkable and sometimes historic downtowns are likely to be small in size and do not represent a large fraction of the nation's building stock, whether measured by number of buildings or by floor area. Exempting many of them from some energy-efficiency requirements will not have a big effect on national energy demand growth. Such exemptions should have a positive effect on the pace of downtown revitalization in many jurisdictions, making energy-efficiency policy for existing commercial buildings a worthy topic for planners.

Future research should test the efficacy of our policy prescriptions in a controlled manner, determine the extent to which a cultural shift towards a conservation ethic can cause building owners to pursue greater energy efficiency on a voluntary basis, and examine regional differences more thoroughly.

References

Alliance Commission on National Energy Efficiency Policy. (2013). *The History of Energy Efficiency*. Alliance to Save Energy. Retrieved from https://www.ase.org/sites/ase.org/files/resources/Media%20browser/ee_commission_history_report_2-1-13.pdf

Bernstein, H.M., & Russo, M.A. (2011). *Business Case for Energy Efficient Building Retrofit and Renovation, SmartMarket Report*. McGraw-Hill Construction. Retrieved from http://energy.gov/sites/prod/files/2013/12/f5/business_case_for_energy_efficiency_retrofit_renovation_smr_2011.pdf

Bigott, Joseph C. (2005) Building codes. *The Electronic Encyclopedia of Chicago*. Chcago Historical Society. http://www.encyclopedia.chicagohistory.org/pages/179.html [accessed 23 January 2015].

Burby, Raymond J., Salvesen, David, and Mike Creed. (2006).Encouraging Residential Rehabilitation with Building Codes: New Jersey's Experience. *Journal of the American Planning Association* 72(2):183-196.

Dodge Data & Analytics. (2015). Construction Industry to See More Balanced Growth in 2015. Press Release. http://construction.com/about-us/press/ [accessed 27 February 2015].

Energy Information Administration (EIA), Office of Energy Markets and End Use, Form EIA-871A of the 2003 Commercial Buildings Energy Consumption Survey, Table A4. http://www.eia.gov/consumption/commercial/data/2003/#a1. [accessed 7 February 2015].

Energy Information Administration (EIA), U.S. Department of Energy. (2015). *Commercial Buildings Energy Consumption Survey (CBECS).* http://www.eia.gov/consumption/commercial/. [accessed 27 February 2015].

Energy Information Administration (EIA), U.S. Department of Energy. (2014). *Frequently Asked Questions.* Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=86&t=1

Energy Information Administration (EIA), U.S. Department of Energy. (2015). *Monthly Energy Review February 2015*. Table 2.1 Energy Consumption by Sector. http://www.eia.gov/totalenergy/data/monthly/#consumption [accessed 27 February 27, 2015].

Environmental Protection Agency (EPA), U.S. (2015) Using EnergyStar Portfolio Manager. http://www.energystar.gov/buildings. [accessed 27 February 27, 2015].

Galvan, Sara C. (2006). Rehabilitating Rehab Through State Building Codes. *The Yale Law Journal* 115(7): 1744-1781.

Hattis, David, Andrews, Clinton J., Senick, Jennifer, Souder, Jennifer. (2014) *Energy Consumption Matrices and Proof-of-Concept Compliance Guidance*. Interim report prepared for the CBEI.

Hsu, D. (2014a). How much information disclosure of building energy performance is necessary?. *Energy Policy*, 64, 263–272. doi:10.1016/j.enpol.2013.08.094.

Hsu, D. (2014b) Improving energy benchmarking with self-reported data. *Building Research & Information* 42(5): 641-656. doi: 10.1080/09613218.2014.887612

International Codes Council (ICC). (2015). *International Codes-Adoption by State (January 2015)*. http://www.iccsafe.org/gr. [accessed 7 February 2015].

Institute for Market Transformation. (2014). *Establishing a Plan to Achieve Energy Code Compliance in Cities*. A report of the City Energy Project of IMT and the Natural Resources Defense Council. http://www.imt.org/resources/codes [accessed 27 February 2015].

Keicher, Caroline. (2014). Map: U.S. Building Benchmarking and Disclosure Policies. Institute for Market Transformation, Washington, DC. http://www.imt.org/resources/detail/map-u.s.-building-benchmarking-policies [accessed 5 February 2015].

King, L.W. (2008). "The Code of Hammurabi: Translated by L. W. King". Avalon Project, Law School, Yale University. http://avalon.law.yale.edu/ancient/hamframe.asp. [accessed 23 January 2015].

Kontocosta, Constantine E. (2014). A market-specific methodology for a commercial building energy performance index. *Journal of Real Estate Finance and Economics* (12 August): 1-29. doi: 10.1007/s11146-014-9481-0

Listokin, David, and David B. Hattis. (2005). Building Codes and Housing. *Cityscape: A Journal of Policy Development and Research* 8(1): 21-67.

Malin, Nadav. (2012). Energy Modeling, Building Size, and BIM—What's Cost-Effective? *BuildingGreen.com*. http://www2.buildinggreen.com/blogs/energy-modeling-building-size-and-bim-whats-cost-effective [accessed 26 February 2015].

Mass.gov (Commonwealth of Massachusetts), Executive Office of Public Safety and Security. (2015). *Stretch Energy Code—Information*. http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/csl/stretch-energy-code-information.html [accessed 26 February 2015].

Mattera, Philip. (2006). *Breaking the Codes: How State and Local Governments are Reforming Building Codes to Encourage Rehabilitation of Existing Structures*. Washington, DC: Good Jobs First. http://www.goodjobsfirst.org/sites/default/files/docs/pdf/breaking_the_codes.pdf. [accessed 27 February 2015].

McConahey, Erin. (2012). How to use building energy modeling tools. *Consulting-Specifying Engineer* (September 24) http://www.csemag.com/magazine.html?year=2012 [accessed 27 February 2015].

McGraw Hill Construction. (2011). *Business Case for Energy Efficient Building Retrofit and Renovation*. SmartMarket Report. Bedford, MA: McGraw-Hill Construction.

New York City, Buildings Department (NYC Buildings) (2015). *History*. Retrieved 24 January 2015 at http://www.nyc.gov/html/dob/html/about/history.shtml.

Syal, Matt, Shay, Chris, and Faron Supanich-Goldner. (2001). Streamlining Building Rehabilitation Codes to Encourage Revitalization. *Housing Facts & Findings* 3 (2): 3–5. http://www.knowledgeplex.org/showdoc.html?id=1110. [accessed 27 February 2015].

Talen, Emily. (2014). *The Codes Project*. http://codesproject.asu.edu/ [accessed 25 January 2015].

U.S. Department of Energy (USDOE), Office of Energy Efficiency and Renewable Energy. (2015). Building Energy data Exchange Specification (BEDES). http://energy.gov/eere/buildings/building-energy-data-exchange-specification-bedes. [accessed 27 February 2015].

Zhang, J., Xie, Y., Athalye, R., Goel, S., Hart, R., Mendon, V., Rosenberg, M., and B Liu. (2013). *Energy and Energy Cost Savings Analysis of the IECC for Commercial Buildings*. Report No. PNNL-22760 prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory, Richland, Washington.

Institute for Market Transformation. (2014). *Code Compliance*. Retrieved from http://www.imt.org/codes/code-compliance

Table 1: Age distribution of U.S. commercial buildings

Source: CBECS 2012, except that mean energy intensity is from CBECS 2003 (will update in late 2015 when data are released)

Year constructed	Number of buildings (thousand)	Total floorspace (million square feet)	Mean square feet per building (thousand)	Median square feet per building (thousand)	2003 Mean energy intensity ($kBTU/ft^2$)
Before 1920	362	3,979	11.0	4.8	80
1920 to 1945	488	5,990	12.3	3.8	90
1946 to 1959	596	7,400	12.4	4.0	81
1960 to 1969	639	10,421	16.3	6.0	91
1970 to 1979	687	10,920	15.9	5.2	97
1980 to 1989	914	15,275	16.7	6.0	100
1990 to 1999	849	13,881	16.3	5.2	90
2000 to 2003	372	7,210	19.4	5.6	82
2004 to 2007	348	6,522	18.7	5.9	82
2008 to 2012	302	5,759	19.1	6.8	82
Total	5,557	87,359	15.7	5.1	91

Table 2: Energy intensity of U.S. commercial buildings by principal activity
Source: CBECS 2003 Table CA3

Principal Building Activity	**Mean energy intensity (kBTU/ft^2)**
Education	83
Food Sales	200
Food Service	258
Health Care	188
Inpatient	249
Outpatient	95
Lodging	100
Mercantile	91
Retail (Other Than Mall)	74
Enclosed and Strip Malls	102
Office	93
Public Assembly	94
Public Order and Safety	116
Religious Worship	44
Service	77
Warehouse and Storage	45
Other	164
Vacant	21

Table 3: Percent of Total Count of Commercial Buildings in the USA by Building Size and Principal Building Activity
Source: Derived CBECS 2003 Microdata File 15

Building Floor Area (ft²) / Principal Building Activity	1,001 to 5,000	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 to 200,000	200,001 to 500,000	500,001 to 1 million	above 1 million	Total
Vacant	2.21%	0.59%	0.42%	0.27%	0.16%	0.07%	0.03%	0.00%	0.00%	3.75%
Office	10.36%	2.61%	2.39%	0.88%	0.35%	0.22%	0.10%	0.03%	0.02%	16.96%
Laboratory	0.01%	0.03%	0.04%	0.03%	0.03%	0.04%	0.01%	0.00%	0.00%	0.19%
Nonrefrigerated warehouse	5.95%	2.18%	2.61%	0.55%	0.42%	0.16%	0.09%	0.02%	0.01%	11.97%
Food sales	3.38%	0.91%	0.24%	0.06%	0.05%	0.00%	0.00%	0.00%	0.00%	4.65%
Public order and safety	0.76%	0.33%	0.22%	0.06%	0.04%	0.03%	0.00%	0.01%	0.00%	1.45%
Outpatient health care	1.15%	0.78%	0.39%	0.08%	0.07%	0.02%	0.00%	0.00%	0.00%	2.49%
Refrigerated warehouse	0.11%	0.09%	0.06%	0.02%	0.02%	0.01%	0.00%	0.00%	0.00%	0.31%
Religious worship	3.12%	2.14%	1.70%	0.57%	0.06%	0.02%	0.00%	0.00%	0.00%	7.63%
Public assembly	2.44%	1.38%	1.41%	0.19%	0.14%	0.11%	0.02%	0.00%	0.00%	5.69%
Education	3.34%	1.16%	1.23%	0.98%	0.80%	0.32%	0.11%	0.00%	0.00%	7.94%
Food service	4.16%	1.33%	0.47%	0.12%	0.03%	0.00%	0.00%	0.00%	0.00%	6.12%
Inpatient health care	0.00%	0.00%	0.00%	0.01%	0.04%	0.05%	0.03%	0.02%	0.01%	0.16%
Nursing	0.08%	0.03%	0.08%	0.14%	0.06%	0.04%	0.01%	0.00%	0.00%	0.44%
Lodging	0.70%	0.39%	0.71%	0.32%	0.18%	0.10%	0.07%	0.01%	0.00%	2.49%
Strip shopping mall	0.70%	1.21%	1.47%	0.40%	0.34%	0.17%	0.02%	0.00%	0.00%	4.31%
Enclosed mall	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.01%	0.02%	0.02%	0.08%
Retail other than mall	4.96%	1.99%	1.71%	0.30%	0.07%	0.08%	0.01%	0.00%	0.00%	9.12%
Service	8.94%	2.05%	1.35%	0.35%	0.08%	0.02%	0.01%	0.00%	0.00%	12.80%
Other	0.83%	0.30%	0.15%	0.05%	0.06%	0.04%	0.01%	0.00%	0.00%	1.45%
Total	53.22%	19.51%	16.67%	5.37%	3.02%	1.52%	0.54%	0.12%	0.05%	100.00%

Table 4: Percent of Total Energy Consumption in U.S Commercial Buildings by Building Size and Principal Building Activity

Source: Derived CBECS 2003 Microdata File 15

Note: CBECS microdata do not include buildings with floor areas of 1,000 ft^2 or less. CoStar data for DVRPC-PA region suggests that 3% of the commercial building stock has floor areas of 1,000 ft^2 or less.

Building Floor Area (ft^2) / Principal Building Activity	1,001 to 5,000	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 to 200,000	200,001 to 500,000	500,001 to 1 million	above 1 million	Total
Vacant	0.06%	0.02%	0.03%	0.10%	0.26%	0.18%	0.09%	0.08%	0.00%	0.82%
Office	1.63%	0.98%	2.54%	2.07%	1.71%	2.22%	2.58%	1.97%	1.67%	17.38%
Laboratory	0.01%	0.02%	0.39%	0.14%	0.51%	1.48%	0.47%	0.04%	0.00%	3.06%
Nonrefrigerated warehouse	0.32%	0.27%	0.68%	0.69%	0.83%	1.05%	1.42%	0.67%	0.26%	6.20%
Food sales	1.52%	0.69%	0.66%	0.40%	0.51%	0.06%	0.00%	0.00%	0.00%	3.84%
Public order and safety	0.15%	0.18%	0.18%	0.16%	0.26%	0.49%	0.13%	0.39%	0.00%	1.94%
Outpatient health care	0.16%	0.33%	0.31%	0.26%	0.44%	0.20%	0.13%	0.00%	0.00%	1.82%
Refrigerated warehouse	0.03%	0.09%	0.05%	0.07%	0.09%	0.19%	0.00%	0.20%	0.07%	0.79%
Religious worship	0.30%	0.53%	0.86%	0.58%	0.09%	0.13%	0.02%	0.00%	0.00%	2.50%
Public assembly	0.27%	0.64%	0.90%	0.58%	0.81%	1.57%	0.37%	0.18%	0.35%	5.67%
Education	0.45%	0.52%	1.04%	2.16%	3.28%	3.09%	1.82%	0.00%	0.21%	12.58%
Food service	3.15%	1.73%	0.88%	0.48%	0.30%	0.00%	0.01%	0.00%	0.00%	6.55%
Inpatient health care	0.00%	0.00%	0.00%	0.05%	0.54%	1.04%	1.83%	2.07%	1.74%	7.28%
Nursing	0.02%	0.02%	0.11%	0.57%	0.44%	0.46%	0.18%	0.08%	0.00%	1.88%
Lodging	0.10%	0.30%	0.55%	0.75%	0.76%	1.05%	1.37%	1.06%	0.00%	5.94%
Strip shopping mall	0.21%	0.72%	1.87%	1.05%	2.12%	1.94%	0.29%	0.00%	0.00%	8.20%
Enclosed mall	0.00%	0.00%	0.01%	0.00%	0.24%	0.06%	0.12%	0.77%	1.37%	2.57%
Retail other than mall	0.89%	0.80%	1.30%	0.52%	0.27%	0.77%	0.17%	0.03%	0.13%	4.89%
Service	1.12%	0.72%	1.34%	0.55%	0.31%	0.11%	0.13%	0.50%	0.00%	4.78%
Other	0.11%	0.06%	0.09%	0.18%	0.23%	0.23%	0.40%	0.03%	0.00%	1.32%
Total	10.51%	8.63%	13.78%	11.37%	14.00%	16.32%	11.52%	8.07%	5.82%	100.00%

Table 5: Relative Concentration Ratios (Percent of Weighted Total Energy Consumption / Percent of Weighted Total Counts of Buildings) by Building Size and Principal Building Activity for US Commercial Buildings

Note: Concentrations Ratios >1 are highlighted: these should have policy priority

Note: CBECS microdata do not include buildings with floor areas of 1,000 ft^2 or less. CoStar data for DVRPC-PA region suggests that 3% of the commercial building stock has floor areas of 1,000 ft^2 or less.

Building Floor Area (ft^2) / Principal Building Activity	1,001 to 5,000	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 to 200,000	200,001 to 500,000	500,001 to 1 million	above 1 million	Total
Vacant	0.0	0.0	0.1	0.4	1.6	2.8	3.2	20.2	0.0	0.2
Office	0.2	0.4	1.1	2.3	4.9	10.2	24.7	62.0	91.8	1.0
Laboratory	1.0	0.6	9.0	5.5	20.1	36.8	45.1	232.4	0.0	16.5
Nonrefrigerated warehouse	0.1	0.1	0.3	1.3	2.0	6.7	16.0	41.0	40.6	0.5
Food sales	0.5	0.8	2.7	7.1	9.5	16.6	0.0	0.0	0.0	0.8
Public order and safety	0.2	0.5	0.8	2.8	6.4	14.4	29.4	76.9	0.0	1.3
Outpatient health care	0.1	0.4	0.8	3.2	6.6	10.5	37.3	0.0	0.0	0.7
Refrigerated warehouse	0.2	1.0	0.7	4.8	5.1	15.7	38.8	45.9	63.0	2.6
Religious worship	0.1	0.2	0.5	1.0	1.4	5.6	12.2	0.0	0.0	0.3
Public assembly	0.1	0.5	0.6	3.1	5.9	13.7	22.8	85.7	260.6	1.0
Education	0.1	0.5	0.8	2.2	4.1	9.6	16.8	0.0	165.3	1.6
Food service	0.8	1.3	1.9	3.8	9.8	0.0	17.8	0.0	0.0	1.1
Inpatient health care	0.0	0.0	1.1	4.4	12.1	20.4	59.2	132.5	295.8	44.8
Nursing	0.3	0.8	1.4	3.9	7.6	10.3	17.2	84.9	0.0	4.2
Lodging	0.1	0.8	0.8	2.3	4.3	10.7	18.3	82.8	0.0	2.4
Strip shopping mall	0.3	0.6	1.3	2.6	6.2	11.6	18.3	0.0	0.0	1.9
Enclosed mall	0.0	0.0	1.5	0.0	8.4	10.2	12.4	45.9	87.2	31.6
Retail other than mall	0.2	0.4	0.8	1.8	3.8	9.9	16.5	18.7	104.4	0.5
Service	0.1	0.4	1.0	1.6	4.0	4.3	15.8	110.6	0.0	0.4
Other	0.1	0.2	0.6	3.6	3.5	5.6	46.8	45.3	0.0	0.9
Total	0.2	0.4	0.8	2.1	4.6	10.8	21.5	69.0	113.5	1.0

Table 6: Relative Concentration Ratios (Percent of Weighted Total Energy Consumption / Percent of Weighted Total Counts of Buildings) by Building Size, Principal Building Activity, and Building System for US Commercial Buildings

Note: Concentrations Ratios >1 are highlighted: these should have policy priority

Note: CBECS microdata do not include buildings with floor areas of 1,000 ft^2 or less. CoStar data for DVRPC-PA region suggests that 3% of the commercial building stock has floor areas of 1,000 ft^2 or less.

Building Floor Area (ft^2) / Principal Building Activity	1,001 to 5,000	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 to 200,000	200,001 to 500,000	500,001 to 1 million	above 1 million
HVAC									
Vacant	0.02	0.02	0.04	0.18	1.28	2.05	2.57	19.51	0.00
Office	0.09	0.19	0.57	1.33	2.22	4.77	11.45	31.72	45.60
Laboratory	0.77	0.34	6.06	2.51	14.42	23.50	28.07	174.56	0.00
Nonrefrigerated warehouse	0.03	0.07	0.15	0.67	0.85	4.21	10.09	16.79	16.92
Food sales	0.09	0.20	0.58	1.66	2.32	4.98	0.00	0.00	0.00
Public order and safety	0.11	0.26	0.38	1.56	3.79	7.68	13.71	65.12	0.00
Outpatient health care	0.06	0.22	0.37	1.84	3.24	5.20	23.08	0.00	0.00
Refrigerated warehouse	0.06	0.01	0.32	0.48	0.57	0.75	7.96	7.05	35.28
Religious worship	0.07	0.17	0.37	0.71	0.97	3.12	3.70	0.00	0.00
Public assembly	0.08	0.30	0.49	2.46	4.74	11.87	20.11	77.27	205.68
Education	0.07	0.32	0.52	1.58	2.91	6.08	11.39	0.00	118.00
Food service	0.20	0.36	0.59	1.56	4.60	0.00	9.95	0.00	0.00
Inpatient health care	0.00	0.00	0.41	1.73	5.09	8.95	29.68	71.97	179.69
Nursing	0.12	0.24	0.38	1.34	3.47	4.60	9.13	59.99	0.00
Lodging	0.04	0.26	0.19	0.61	1.17	3.30	5.60	9.31	0.00
Strip shopping mall	0.15	0.23	0.51	1.13	2.62	4.93	8.59	0.00	0.00
Enclosed mall	0.00	0.00	0.62	0.00	3.40	5.44	6.11	21.90	36.31
Retail other than mall	0.10	0.23	0.34	0.77	1.52	3.97	5.59	4.01	19.79
Service	0.06	0.24	0.69	0.99	2.40	2.15	9.55	54.10	0.00
Other	0.07	0.09	0.34	1.58	1.56	1.29	23.58	15.37	0.00
Lighting									
Vacant	0.00	0.01	0.01	0.06	0.13	0.23	0.24	0.33	0.00
Office	0.03	0.08	0.24	0.49	1.38	2.89	6.68	15.82	25.77
Laboratory	0.07	0.12	1.43	0.87	2.72	8.78	10.49	32.69	0.00
Nonrefrigerated warehouse	0.01	0.03	0.07	0.22	0.76	1.68	4.39	20.24	17.36
Food sales	0.06	0.14	0.45	1.30	2.98	4.09	0.00	0.00	0.00
Public order and safety	0.02	0.06	0.16	0.39	0.86	2.69	6.65	5.86	0.00
Outpatient health care	0.03	0.10	0.19	0.69	1.67	2.83	7.24	0.00	0.00
Refrigerated warehouse	0.00	0.05	0.05	0.39	1.06	3.08	14.34	19.99	14.43

Religious worship	0.01	0.02	0.05	0.09	0.19	1.33	5.96	0.00	0.00
Public assembly	0.01	0.06	0.05	0.22	0.50	0.67	1.18	2.45	29.89
Education	0.02	0.04	0.13	0.28	0.55	1.47	2.39	0.00	8.05
Food service	0.06	0.15	0.21	0.55	0.57	0.00	1.32	0.00	0.00
Inpatient health care	0.00	0.00	0.27	0.95	2.33	4.22	10.69	18.60	37.09
Nursing	0.03	0.09	0.46	0.63	1.19	1.58	2.80	6.41	0.00
Lodging	0.03	0.12	0.21	0.56	1.36	2.63	4.65	27.21	0.00
Strip shopping mall	0.07	0.16	0.34	0.73	1.82	3.41	5.30	0.00	0.00
Enclosed mall	0.00	0.00	0.43	0.00	1.82	2.36	3.45	12.05	25.07
Retail other than mall	0.04	0.10	0.27	0.75	1.74	4.29	6.65	11.58	69.42
Service	0.02	0.05	0.16	0.39	1.07	1.47	5.02	40.81	0.00
Other	0.01	0.05	0.09	0.48	0.79	1.06	14.38	3.60	0.00
Domestic Hot Water									
Vacant	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Office	0.00	0.01	0.02	0.05	0.09	0.19	0.66	1.45	2.08
Laboratory	0.00	0.00	0.11	0.11	0.17	0.45	0.69	5.44	0.00
Nonrefrigerated warehouse	0.00	0.00	0.00	0.02	0.03	0.03	0.10	1.34	0.32
Food sales	0.00	0.01	0.07	0.11	0.06	0.22	0.00	0.00	0.00
Public order and safety	0.03	0.12	0.13	0.44	0.88	2.04	3.37	0.78	0.00
Outpatient health care	0.00	0.01	0.02	0.12	0.20	0.22	0.99	0.00	0.00
Refrigerated warehouse	0.00	0.00	0.01	0.01	0.03	0.02	0.10	0.24	0.13
Religious worship	0.00	0.01	0.01	0.02	0.02	0.07	0.03	0.00	0.00
Public assembly	0.00	0.00	0.01	0.03	0.09	0.10	0.26	2.33	0.94
Education	0.01	0.06	0.09	0.15	0.25	0.55	1.10	0.00	9.63
Food service	0.13	0.23	0.21	0.30	1.14	0.00	0.42	0.00	0.00
Inpatient health care	0.00	0.00	0.22	1.24	3.04	5.32	11.97	23.10	44.20
Nursing	0.08	0.37	0.37	1.57	2.10	3.35	2.74	13.16	0.00
Lodging	0.03	0.28	0.29	0.89	1.26	3.41	5.32	22.51	0.00
Strip shopping mall	0.02	0.04	0.09	0.18	0.51	0.83	0.79	0.00	0.00
Enclosed mall	0.00	0.00	0.13	0.00	0.38	0.82	1.16	3.65	7.71
Retail other than mall	0.00	0.01	0.02	0.02	0.03	0.09	0.23	0.23	0.17
Service	0.00	0.00	0.01	0.01	0.02	0.02	0.13	0.90	0.00
Other	0.00	0.00	0.00	0.02	0.05	0.13	0.69	0.10	0.00

Table 7: Illustrative policy scenarios

Note: *CBECS microdata do not include buildings with floor areas of 1,000 ft^2 or less. CoStar data for DVRPC-PA region suggests that 3% of the commercial building stock has floor areas of 1,000 ft^2 or less.

Cohorts targeted	(% of Total Energy Use)	(% of Total Buildings)
All buildings >25k ft^2	67%	11%
All buildings >25k ft^2 & Offices, Labs, Food Sales, Food Service, Inpatient Healthcare, Nursing, Strip Mall, Enclosed Mall >10k ft^2	74%	15%
All buildings >25k ft^2 & Offices, Labs, Food Sales, Inpatient Healthcare, Nursing, Strip Mall, Enclosed Mall >10k ft^2 & All Food Service > 5k ft^2	75%	17%
All buildings >25k ft^2 & Offices, Labs, Food Sales, Inpatient Healthcare, Nursing, Strip Mall, Enclosed Mall >10k ft^2 & All Food Service	78%	21%
All buildings >10k ft^2	81%	27%
All buildings >10k ft^2 except Education, Public Assembly, Religious Worship, Nonrefrigerated warehouse <25k ft^2	77%	20%
All buildings >10k ft^2 and all Food Service	86%	33%
All builings >5k ft^2	89%	47%
All buildings >1k ft^2*	100.00%	100.00%

Table 8: Change of Occupancy Scale
Note: Occupancy types at the same level in the scale have similar energy intensities in CBECS.
Source: Hattis et al 2014

HVAC	Lighting	Domestic Water Heating
1. Health Care (Inpatient)	1. Health Care (Inpatient)	1. Food Service, Health Care (Inpatient)
2. Food Service, Public Assembly	2. Food Sales, Food Service, Retail, Lodging, Health Care (outpatient), Office	2. Lodging
3. Education, Health Care (outpatient), Public Order and Safety, Office, Service, Food Sales, Retail, Religious Worship	3. Public Order and Safety, Service, Education, Warehouse and Storage	3. Public Order and Safety
4. Lodging	4. Public Assembly	4. Education, Retail
5. Warehouse and Storage	5. Religious Worship	5. All rest

Table 9: Size distribution of the commercial building stock by jurisdiction.

Size Distribution	USA	DVRPC-PA	King of Prussia	West Chester		USA	DVRPC-PA	King of Prussia	West Chester
Total	5,557,000 buildings	23,932 buildings	458 buildings	724 buildings		87,359 million ft^2	482 million ft^2	18 million ft^2	14 million ft^2
Floor Area (ft^2)	% of buildings	% of buildings	% of buildings	% of buildings		% of floor area	% of floor area	% of floor area	% of floor area
1,001 to 5,000	53	52	34	42		10	18	16	30
5,001 to 10,000	20	9	10	8		10	28	18	31
10,001 to 25,000	17	12	12	13		18	1	1	2
25,001 to 50,000	5	12	9	19		13	5	2	7
50,001 to 100,000	3	8	21	11		14	16	23	20
100,001 to 200,000	2	3	7	2		14	27	35	7
200,001 to 500,000	1	1	1	1		10	2	1	1
Over 500,000	<1	<1	<1	0		11	2	2	0
Source	CBECS 2012 Table 1	CoStar	CoStar	CoStar		CBECS 2012 Table 1	CoStar	CoStar	CoStar

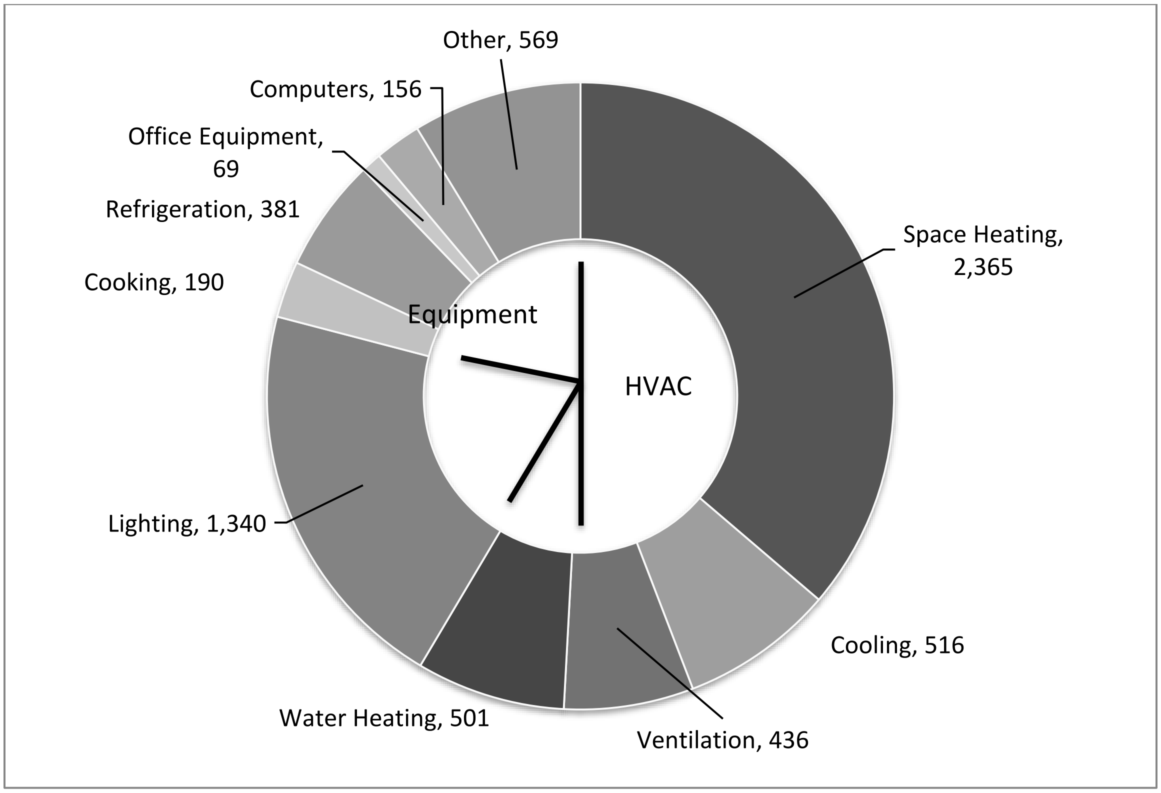
Note: CoStar reports that there are 594 buildings under 1,001 ft2 that total to less than 0.1% of the DVRPC-PA commercial building stock. CBECS does not collect comparable national data.

Table 10: Illustrative policy scenarios

Note: CBECS microdata do not include buildings with floor areas of 1,000 ft^2 or less.

Jurisdiction Cohort Targeted	USA		Greater Philadelphia (DVRPC-PA)		King of Prussia		West Chester	
All buildings with floor area greater than	% of Total Energy Use	% of Total Buildings	% of Total Energy Use	% of Total Buildings	% of Total Energy Use	% of Total Buildings	% of Total Energy Use	% of Total Buildings
25,000 ft^2	67%	11%	57%	24%	72%	38%	41%	32%
10,000 ft^2	81%	27%	59%	36%	73%	50%	43%	46%
5,000 ft^2	89%	47%	85%	45%	87%	60%	77%	54%
1,000 ft^2	<100%	<100%	99%	97%	99%	93%	99%	96%
Data source	CBECS	CBECS	CoStar+	CoStar	CoStar+	CoStar	CoStar+	CoStar

Figure 1: Major End Uses of Energy in U.S. Commercial Buildings
Source: CBECS 2003 Table E1A



[1] Law #229 of Hammurabi's Code assigns liability for faulty construction to the builder (King 2005, Talen 2014) andcolonial America saw the imposition of such regulations as far back as 1625 in Dutch New Amsterdam (New York City 2016). New York City (2015) seems to have moved first in colonial America, tracing its building code to rules established by the Dutch West India Company for New Amsterdam in 1625, which by 1674 covered construction, fire prevention and sanitation.

[2] Local insurers, housing reformers, engineers, and the construction industry first set their own standards and then persuaded local governments to codify minimum requirements for fire resistance and structural integrity, and later they addressed lighting, ventilation, heating, cooling, electricity and plumbing systems (Listokin and Hattis 2005). New York City unified its building code in 1860 and Chicago followed suit 1875 (Bigott 2005, New York City 2015). Like the planner's tools of land use regulation, the constitutional justification for building codes lies in the state's police powers.

[3] These included the National Electrical Code in 1897 and National Building Code in 1905, which emerged from quasi-consensus processes supported by the National Board of Fire Underwriters, National Fire Protection Association, Underwriters Laboratories, National Housing Association, and American Society of Civil Engineers, among others (Listokin and Hattis 2005).

[4] The three model codes included: National Building Code (NBC), Standard Building Code (SBC), and Uniform Building Code (UBC). The NBC, for example, was developed by the Building Officials and Code Administrators (BOCA) International and governed construction in many north eastern and mid-western states (Listokin and Hattis 2005).

[5] Thus, the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) measures intensity based on energy delivered to the site as reported on utility bills ("site" energy), whereas the Energy Star Portfolio Manager operated by the U.S Environmental Protection Agency performs additional calculations in order to include upstream losses due to conversion of primary fuels such as coal into energy carriers such as electricity ("source" energy) (EIA 2015, EPA 2015). There is also a need to choose between gross and usable floor area, to account for the behavior of building occupants, to

specify the date of the data given inter-annual variability in weather and thus energy use for heating and cooling, and to acknowledge that local climate likewise affects energy use.

[6] To date, the states of California and Washington, Maryland's Montgomery County, and the cities of Austin, Boston, Cambridge, Chicago, Minneapolis, New York, Philadelphia, San Francisco, Seattle, and Washington (DC) have adopted a benchmarking and disclosure requirement for commercial buildings (Keicher 2014). Their rationale is that increased transparency will drive market actors to value high-performing buildings more than those that perform poorly, thereby encouraging owners to invest in energy efficiency. A side benefit of these policies is that there is now a vastly larger amount of data available to characterize the building stock, at least in some jurisdictions.

New York City has been an early mover in benchmarking, and its rich data set has spawned a host of exciting new academic papers and policy analyses (e.g., Hsu 2014b, Kontocosta 2014). Other jurisdictions—representing most of the USA—for now must pursue alternative ways to characterize the energy performance of their building stock. The authors have performed such an exercise for the five-county region within Pennsylvania that surrounds the city of Philadelphia. The strategy has been to purchase CoStar data on the commercial building stock in the region, and to apply energy intensity metrics categorized by building age, size, and principal use, filtered for the mid-Atlantic region, all derived from CBECS microdata. The City of Philadelphia has recently implemented a benchmarking and disclosure requirement for some commercial buildings, but the neighboring jurisdictions will have to rely on a synthetic data set derived from CBECS.

[7] Burby et al. (2006) compare the change in number of building renovation permits issued in New Jersey to neighboring states. In order to isolate the impact of the Subcode, the authors control for economic conditions, the character of building stock, and the character of code enforcement. When these variables are controlled for, the authors find the Subcode to have a modest, yet statistically significant, positive impact on the number of renovation permits issued. Case studies have consistently found significant cost savings as a direct result of the New Jersey Rehabilitation Subcode and the NARRP. Mattera (2006) compiled a number of case studies on smart code benefits. Researchers assert based on case studies that the New Jersey Rehabilitation Subcode has resulted in cost savings from 10-50% (Galvan 2006) and contributed to a 60% increase in renovations in New Jersey (Syal, Shay & Supanich-Goldner 2001).

[8] The counties in Pennsylvania include Montgomery, Bucks, Delaware, Chester and Philadelphia. Camden, Burlington, Gloucester and Mercer counties are in New Jersey. The Pennsylvania portion of this region includes four of the state's five most populous counties: Philadelphia (1st), Montgomery (3rd), Bucks (4th), and Delaware (5th), yielding a total population of 4,008,994. The total population of the corresponding New Jersey counties is 1,617,192.

[9] The survey went to one or more contacts in all 239 municipalities in the five-county Pennsylvania DVRPC region. Of 351 surveys sent out there were 52 usable responses representing 49 municipalities (15% response rate on surveys, 20% of municipalities represented). Respondents represented a range of large, medium, and small communities from all five counties.

[10] These activities encompassed: including handouts/information about state or federal energy efficiency programs (40%), training about energy efficiency for commercial building owners and tenants (29%), zoning changes or provides variances for energy efficient buildings (44%), streamlined permitting for energy efficient buildings and/ or upgrades (31%), energy efficiency recognition programs for builders/ developers/ property owners (27%), and special funding (grants, lower interest loans, property assessed clean energy financing, etc.) to commercial and/or multifamily property owners for implementation of energy efficiency projects (13%).

[11] The structure has a restaurant on the ground floor that was not affected by the renovation. The building lies in the Town Center zoning district and is subject to both Historic Area and Retail District requirements, which prevent exterior changes and exempt it from energy code requirements (Section 101.4.2). The brick-faced structure was built before 1920 and it has a basement, a single-glazed shop window on facing the street on the ground floor, and original casement windows on the upper floors. The renovated 2nd and 3rd story spaces total 2,550 ft^2 and represent about two thirds of the building's total floor area. This information is based on a developer interview on January 15, 2015 in West Chester, PA.

[12] These included (members of PCCA, Pennsylvania Construction Codes Academy and/or PABCO, Pennsylvania Association of Building Code Officials).

[13] About half (56% of respondents, n= 29) say that these account for 10% or less, 33% (n=11) say they account for between 11-50% , while 6% of respondents (n=2) say that change-of-occupancy comes up more than 50% of the time and another 6%

choose “other”. As to whether and how these records could be attained, 12 out of 19 report either that these records cannot be accessed or can only be accessed through a written right-to-know request.