

Energy Performance of New Low-Rise Multifamily Buildings in the United States

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ABSTRACT

In recent years, the U.S. Department of Energy has conducted a series of research studies to validate the prevalence of energy efficient building technologies in the field. Much of the work has focused on single-family construction, and some has also addressed commercial energy codes. The work detailed in this paper is part of that effort, focuses on low-rise multifamily buildings in various regions of the United States, and reports on how their building codes are being implemented, both in terms of observed characteristics and also in terms of estimated energy impacts. This work is particularly significant given multifamily dwellings now represent about 35% of new residential starts in the United States, and low-rise multifamily buildings represent about 80% of these starts. Nearly 100 buildings across four states—Illinois, Minnesota, Oregon, and Washington—were sampled and represent a range of climate types from mild temperature to very cold continental.

To the greatest extent possible, the methodology developed under the project for low-rise multifamily buildings mirrored the approach established by Pacific Northwest National Laboratory (PNNL) for recent code studies. Building physical characteristics, such as insulated assemblies, mechanical systems, and domestic hot water data, were collected via a combination of architectural, mechanical, electrical, and plumbing plan reviews and field inspections. As a final step, EnergyPlus™ simulations were created for all buildings in the study to estimate both the energy use intensity (EUI) and the energy (and carbon dioxide emissions) that could be saved if features that were found to not meet code minimums were brought up to code. Also, the project included a set of structured interviews with code officials and building designers to better understand current attitudes about the low-rise multifamily sector and results from these interviews are presented and discussed.

Introduction

In recent years, the U.S. Department of Energy (USDOE) has conducted a series of research studies to validate the prevalence of energy efficient building technologies in the field. Much of the work has focused on single-family construction, and some has also addressed commercial energy codes. The work described in this paper is part of that effort but focuses on low-rise multifamily buildings in various regions of the United States, and reports on how state-level building codes are being implemented, both in terms of observed characteristics and also in terms of estimated energy impacts. Low rise multifamily buildings, defined as having no more than 3 stories above grade level, accounted for about 30% of new residential square footage in the United States as of early 2019 (BPS 2019).

Nearly 100 buildings across four states: Illinois, Minnesota, Oregon, and Washington—were sampled, which represent a range of climate types from marine to very cold continental.

(See below for exact International Energy Conservation Code (IECC) Climate Zone designations.) Both common entry and outdoor entry ('garden style') buildings were included in the work, and a parallel research project evaluated envelope air tightness and current still-evolving air tightness testing methods (Bohac et al. 2020). Finally, a set of structured interviews of building designers and other relevant professionals was carried out to gain more insight into this market. The fieldwork was completed in 2018-19.

To the greatest extent possible, the methodology developed under the project for low-rise multifamily buildings mirrored the approach established by Pacific Northwest National Laboratory (PNNL) for single-family residential buildings (Bartlett et al. 2018). This included the general approach to sampling, recruitment, and data collection, as well as data analysis and presentation.

The range of permitting dates for the sites encompassed two energy code cycles in most regions. All states in the study had adopted a variation of the International Energy Conservation Code for the structure of their state code,¹ and the code cycles that applied to the design and permitting of these buildings were typically the 2012 edition, but some were covered by the 2014 or 2015 editions (Illinois Energy Conservation Code (2015, Minnesota Energy Code 2015, Oregon Energy Efficiency Specialty Code 2014, Washington State Energy Code 2012). The low-rise multifamily occupancy presents a hybrid building type: most of the building's conditioned floor area was covered by the residential chapter of the code while portions of the building (such as corridors and common spaces) fell under the commercial code chapter.

This paper presents a very condensed version of the full report (Davis et al. 2020) and includes a brief description of sample design and analytical approaches, with examples given of the latter. The reader is encouraged to access the full report and also the companion report on building shell air tightness.

Sampling and Key Data to be Collected

The project was structured so that a cross-section of climate zones, energy codes, building designers, and builders would be represented. The sampling frame represented a distribution of IECC climate zones encompassing the milder and colder parts of the Pacific Northwest (Zones 4C and 5B), a typical Midwest continental climate (Illinois, Zone 5A), and much colder continental climates (Minnesota, Zones 6A and 7A). The IECC code requirements are calibrated to the severity of the climate, including humidity sub-designations A-C, which correspond to Moist, Dry, and Marine categories, respectively.

The primary source of the target population was Dodge 2014–2016 data provided by the Pacific Northwest National Laboratory (PNNL).² Since PNNL was the source of the data and USDOE has contracted PNNL to be a resource for energy code studies, it allows for any state in the future to use the same methods in this study to generate the target population for their own state.

To develop a sample frame three data sources were reviewed, Dodge, Building Permits Survey (BPS 2019), and the American Housing Survey (AHS):

1. F.W. Dodge data identified the total population of low-rise multifamily projects in each state and distinguished low rise multi-family projects from high rise projects. The Dodge data also allowed an estimate of the geographic distribution of the new low-rise projects in each state. This allowed the sample design to focus on

¹ Each state amended the IECC in various forms through its internal rulemaking process to formulate its own code.

² Dodge Pipeline data, a product of Dodge Data & Analytics (www.construction.com).

particular jurisdiction where low rise multifamily construction was observed by Dodge. Initially, these jurisdictions became the targets of the sampling and recruiting.

2. The Building Permits Survey combines both low- mid- and high-rise buildings in its counts. This data set documents the number of permits in each county in each state. These data were used to cover the most recent multi-family construction activity in counties of the target states.
3. The American Housing Survey does delineate between low-rise and other multifamily but only available for large metropolitan areas whose boundaries can cross state lines. It did, however, provide the ratio between all multifamily units and low-rise multifamily units. Within the metropolitan areas covered the AHS provided sufficient detail to distinguish urban areas from less dense suburban areas so ratios of low rise multifamily to all multifamily buildings could be inferred.

For the project recruiting period, BPS data were used to determine how to distribute the 25 buildings across jurisdictions within a state. The building counts obtained from the BPS were adjusted to account for the projected presence of mid- and high-rise buildings using the ratios derived from the AHS. To construct the sample frame, the project team then contacted the designated jurisdictions in each state and requested a list of all permit activity that fit the study criteria. The resulting list of buildings then formed the basis for later recruitment efforts by the project team.

As a primary challenge, the project team encountered a lack of eligible buildings under construction during the project timeframe.³ Combined with typical challenges in recruiting and gaining access to research sites this resulted in exhausting the initial proposed sample pool in several jurisdictions. In multiple cases, every jurisdiction within a given state was contacted and all potential buildings were exhausted. In these cases, the project team made every effort to leverage additional contacts and data sources to maximize the number of potential buildings and fulfill the 25-building target specified in the sampling plan.

In many jurisdictions, the required sampling plan targets could not be met; in those cases, replacement jurisdictions were selected to match on geography (urban, suburban, rural) and other relevant factors (e.g., density, type of housing, demographics).

In the end, although the survey was designed to sample evenly across state geographies, it was generally found to serve as a starting point for what we were likely to find and where we were likely to find it. New multifamily building construction counts are relatively small and, coupled with specific attributes, system types, and the ability to gain access to the site, the available pool to survey gets much smaller. The sampling plan was used to guide the data collection effort throughout, but it often required modification. The result was the team effectively surveyed every building that could be recruited to participate.

In all cases, sampling was implemented in a deliberate manner and every effort was made to preserve a broad and representative sample within a given state. The nature of the approach, starting with targets based on geographic distributions, helped to focus efforts more evenly across a given state instead of concentrating them in one area. If for no other reason than that, the team recommends future studies in other states begin with a similar sample design approach and

³This differed from similar single-family field studies conducted by PNNL. Fundamentally, there are far fewer multifamily buildings, particularly those which happen to exist during the necessary stage of construction and whose energy efficiency features are concurrently observable.

prepare to be flexible in finding sufficient study sites. Table 1 shows the final results; it is worth noting the amount of time needed to successfully recruit a site is substantial.

Table 1. Building Recruiting

State	Sample Frame Size	Target Sample	Agreed to Participate	Success Rate	Average Hours to Recruit Building
MN	250	25	25	10%	7.5
OR	249	25	24	10%	7.5
WA	463	25	25	5%	7.5
IL	105	25	21	20%	7.0

Once a building was recruited, there was an additional layer of sampling to account for the units within the building. While all buildings included in the study were new construction, many were at least partially occupied at the time of the field visit.⁴ Coordination with site contacts was made to minimize disruption from unit sampling. At each building, three units were visited in comparison to the original sample design plan of five. The change to three was based both in practicality and in observation. For occupied buildings, it meant only having to disturb three units instead of five which was often an easier sell to the building management. It also reduced surveyor time on site.

The research team also discovered that the unit-to-unit variations of the items of interest were small. For instance, the same packaged terminal air conditioner (PTAC) model is most often used in all units. The site survey approach evolved to using the unit-level visits as verification of what was obtained on the plan sets. For instance, the most important characteristics to observe were lighting power density (LPD) and the HVAC equipment (in comparison, insulation details were collected at the building level only). These were listed on plans but needed to be verified in the field. Therefore, the approach was to sample within the building one each of the most typical unit layout types (i.e., one each of a studio, 1-bedroom, and 2-bedroom).

The key items that were assessed in this work are shown in Table 2, along with the concordance to parts of the IECC. A few items were not assessed in detail (that is, evaluated for overall energy impacts), given their relative paucity in this occupancy type; these included duct leakage, pipe insulation, and hot water circulation controls. Duct leakage is not included in the low-rise study since ductwork, if present, is typically located within conditioned spaces in these buildings. Pipe insulation and hot water recirculation (temperature maintenance) controls are typically covered by commercial parts of the code; the latter, in particular, was only present in a very limited number of cases in this study. The low-rise multifamily data collection protocol also includes several additional items (marked with an asterisk in Table 1) that are directly relevant to considerable energy usage in low-rise multifamily buildings.

⁴ This is typical in multifamily construction, where buildings are often completed in phases and initial phases become occupied as later phases are completed.

Table 2. Key Energy Compliance Characteristics

Component	Data Collected	IECC Code Reference†
BUILDING		
Exterior wall insulation	R-value	Tables R402.1.2, R402.1.4
Ceiling insulation	R-value	Tables R402.1.2, R402.1.4
Foundation insulation	F-factor	Tables R402.1.2, R402.1.4
Window	U-factor	Tables R402.1.2, R402.1.4
Window	SHGC	Tables R402.1.2, R402.1.4
Exterior lighting	Wattage	Section C405.5
HVAC system (living units and common areas)*	Efficiency rating	Section C403, (referenced by IECC section R403.8)
Pipe insulation*	R-value	Section C403.2.10
Domestic hot water (units and common areas)*	Efficiency rating	Section C403
Circulating system*	Pump controls	Section C404.6
Envelope tightness**	Air changes per hour (ACH)	Section R404.4.1.2
COMMON AREAS		
Lighting (also see HVAC, domestic hot water references, above)	Lighting power density	Section C405.4.2
LIVING UNITS		
Lighting	Percent high efficacy	Section R404.1
Ventilation	Flow rating	Section M1507 (IRC), (referenced by IECC section R403.6)
Envelope tightness**	Air changes per hour (ACH)	Section R404.4.1.2
† - IECC reference. Individual state energy code references vary.		
* Additional items added for low-rise multifamily study not included in USDOE single-family studies		
**Evaluated as part of parallel air tightness study		

Building characteristics were collected via a combination of architectural, mechanical, electrical, and plumbing plan reviews and field inspections, and entered into a spreadsheet-based tool that was later queried to build a database. Data went through quality control during the field review.

Characteristics Analysis

Data analysis in this study was designed, in the main, to mirror the analytical approach of single-family studies underwritten by USDOE (Bartlett et al. 2018). Although there are differences between single-family and low-rise multifamily construction, the similar analytical approaches were intended to achieve consistency in methodologies and allow comparisons to single-family findings (when applicable). As with the single-family studies, the analysis was applied through three basic stages. The first stage assembled and summarized the data by state for key energy usage characteristics (such as insulation values, window types, mechanical system efficiencies, and so on). The second stage modeled energy consumption (of the buildings observed in the field); a divergence for the buildings in this study was the use of performance maps. (Another divergence from single-family construction in this stage was to include characteristics of common area heating and cooling systems, as these are present in many low-

rise multifamily buildings.) The third stage then calculated the potential energy savings, consumer cost savings, and avoided carbon dioxide emissions associated with full code compliance.

Data Compilation and Analysis

The analysis is set up in three stages: review/compilation of field data, then a simulation exercise involving seed buildings, and, finally, a calculation of overall energy effects from non-compliance with the applicable IECC version. This first stage of analysis involved examination of the data set and distribution of observations for individual building components (such as insulated assemblies, windows, lighting power density). A distribution of each measure was plotted by climate zone to understand the range of the data and the characteristics of low-rise multifamily buildings in each of the states. Distributions portraying the individual values also allowed comparison to code requirements, an understanding of trends in the surveyed buildings, and exploration of areas where there may be potential for improvement (that is, where a given component did not fully make it to the code requirement). Figure 1 shows a sample distribution and is explained below.

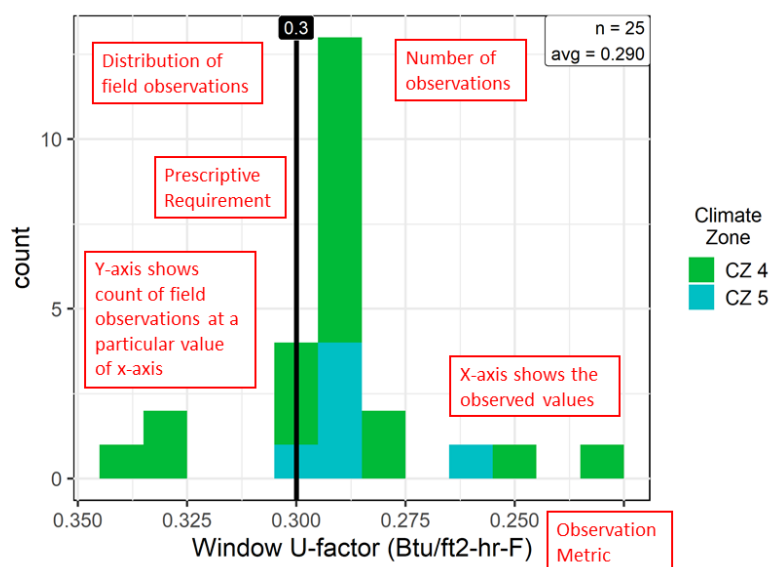


Figure 1. Sample Component Compliance Graphic

Each graph (based on the single-family study graphing standard (Bartlett et al. 2018)) is set up in a similar fashion, identifying the climate zone, and specific measure being analyzed. The total sample size (n) is displayed in the top left or right corner of the graph, along with the distribution average. The metric associated with the item is measured along the horizontal axis (e.g., window U-factor is measured in Btu/(ft²-hr-°F)), and a count of the number of observations is measured along the vertical axis. The vertical line imposed on the graph represents the applicable code requirement (e.g., the prescriptive requirement in climate zones 4C and 5B is 0.30)—values to the right-hand side of this line are better than code. Values to the left-hand side represent areas for improvement. In most states, multiple prescriptive criteria were assessed either due to differences across code years, or different requirements based on climate zone.

When this is the case, the graph will have more than one vertical line representing the applicable code requirements.

For this paper, it is not practical to show all characteristics summaries, but the full report (Davis et al. 2020) shows the characteristics graphics in full detail. Figure 2 does show an example graphic constructed for the study. In this case, the subject is slab edge insulation at Minnesota sites.

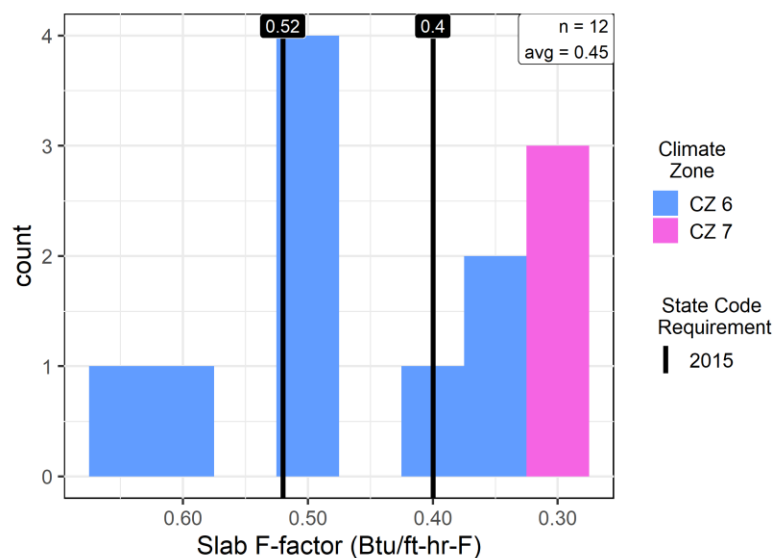


Figure 2. Minnesota Slab Edge Insulation Compliance

Characteristics summaries by component and by state were the key inputs to the next stage of the analysis. In this stage, low rise prototypes supplied by PNNL were populated with the actual characteristics observed (vs code requirements, where there was divergence) and used in batch EnergyPlus runs. These runs were employed to estimate the effect of code non-compliance on the prototypes and then this effect could be combined with statewide low-rise building counts to get to an overall estimate of the amount of energy (and carbon) associated with non-compliance.

As one would expect, some building components have a greater impact on energy use intensity (EUI), which is the annual energy use per square foot of a building, expressed in units of kBtu/ft²-yr. The location of the building also matters, since buildings sited in more demanding heating or cooling climates will have larger EUIs, all other factors being equal. What follows are capsule descriptions of a subset of modeling inputs.

- **Exterior Wall U-Value** has a nearly linear correlation with modeled EUI. The modeled EUI delta was driven by the heating season, and therefore colder climate zones had more dramatic EUI differences for differences in Exterior Wall U-Value.
- **Basement Wall U-Value** has a negligible impact on modeled EUI.
- **Slab F-Factor** has a negligible effect on modeled EUI using the garden slab-on-grade seed model. In a single-family home, with a smaller footprint and one story, Slab F-Factor is likely much more impactful on energy usage.

- **Ceiling U-Value** has a nearly linear correlation with modeled EUI. The modeled EUI delta was driven by the heating season, and therefore colder climate zones had more dramatic EUI differences for differences in Ceiling U-Value.
- **Window U-Value** has a strong correlation with modeled EUI. The correlation between Window U-Value and EUI was driven by heating and is therefore stronger in colder climates. The correlation between Window U-Value and EUI would also be driven significantly by window-to-wall ratio (WWR). The higher the WWR, the more glass on the building and the bigger an effect Window U-Value has on EUI. For the modeling done in this study, all models have the same WWR, so the effect of WWR was not captured.
- **Window SHGC** represents the amount of total solar insolation that is admitted through an insulated glazing unit. Window SHGC had a weaker correlation with EUI than Window U-Value, and its correlation was driven by cooling instead of heating. SHGC typically does more to mitigate high peak loads than to reduce EUI. The correlation between Window SHGC and EUI would also be driven significantly by WWR. As noted above, all seed models have the same WWR, so the effect of WWR was not captured.

A few more words on the modeling are in order. An energy performance map was created by taking an average code-compliant building and running a parametric analysis of only the component in question (when there is non-compliance). Results were then plotted, with the y-axis as Energy Use Intensity, expressed in kBtu/ft²-yr, and the x-axis as values of the building component in question. For this study, over 1,500 EnergyPlus™ models (USDOE 2020) were performed in order to create performance maps for all features in question. After runs were performed in jEplus, Python was used to extract, organize, and plots results. Results for Illinois are shown below (Figure 3); similar results were calculated for all states. Note Site 9 was constructed to PassivHaus standards, and this is reflected in the EUI. Also note the base load contribution to EUI was set to the same value (about 12 kBtu/ft²-yr) for all sites.

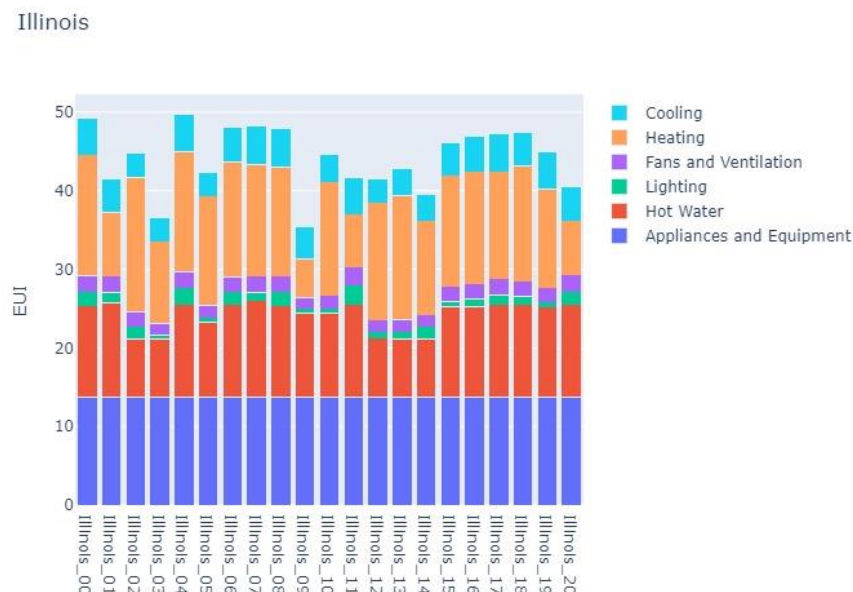


Figure 3. Final Results of Site Simulations in Illinois

A combined set of building EUIs are shown in Figure 4. This representation includes DOE climate zones; milder climates dominate the left side of the graph (lower estimated EUIs) and continental climates dominate the right side (higher heating loads and, as well, more estimated cooling load, at least for some of the sites). Even with more stringent envelope requirements, the estimated Minnesota heating EUIs are typically about twice that of those in marine climates. Figure 5 shows the average EUIs by state; this graphic shows contributions from each of the main end uses and emphasizes the increased heating loads for the Midwest sites; other end uses are relatively similar regardless of climate zone.

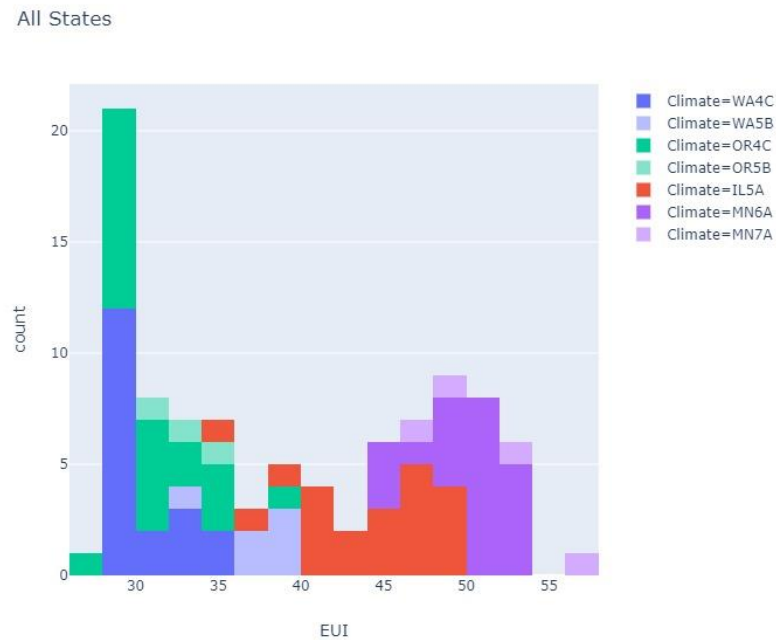


Figure 4. Aggregate EUI (kBtu/ft²-yr), all Sites by IECC Climate Zone

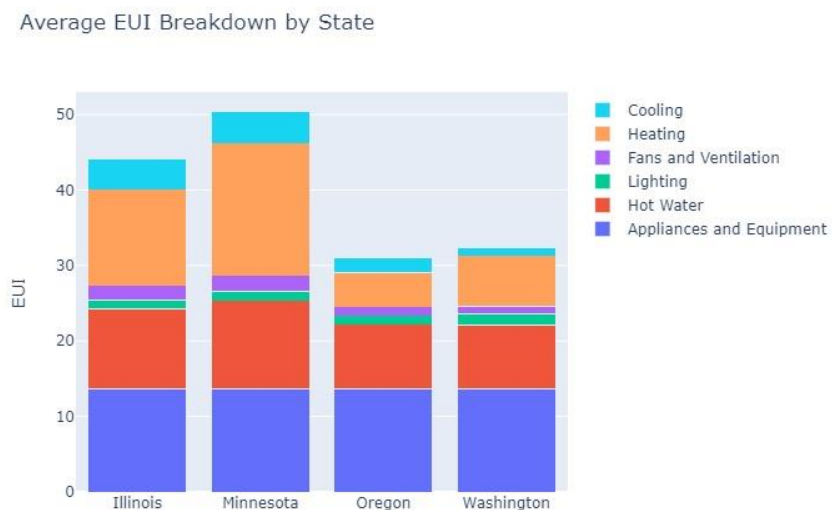


Figure 5. Mean EUI (kBtu/ft²-yr) Components by State

The final step in the analysis is to build up a statewide estimate of the energy reduction possible if all non-compliance were to be eliminated. The total modeled EUI component for non-compliance is the total EUI delta across all the buildings surveyed. This non-complying EUI is then used to calculate electricity, natural gas, and total savings on a statewide basis using the count of all relevant low-rise buildings in each state. Lighting components use electricity; architectural components that contribute to increased cooling (such as window SHGC) use electricity; architectural components that contribute to increased heating (such as window and wall U-factors) can use electricity or gas.

For envelope components that contribute to increased heating, heating systems and fuel selection used in each state and their efficiencies were used to create a ratio of natural gas to electricity usage for space heating. The ratio is used to determine how much electricity and natural gas are accounted for by the heating EUI delta.

The method for calculating excess energy use per apartment unit and assigning fuel usage assumes building component deficiencies are independent of building size. All surveyed buildings, regardless of the number of units, are weighted equally in the calculation. To convert per-unit savings to a statewide energy delta, census data (BPS 2019) are used to estimate the number of new apartment units built in the state. The surveyed buildings are considered as a representative sample.

A set of inputs gathered by the Energy Information Administration⁵ were used in to calculate energy costs and green-house gas (GHG) emissions. (Note the inputs are the same for each state and are not indexed to specific fuel mixes in the service territories that include the study buildings.)

- 1.22 \$/Therm of natural gas
- 0.11 \$/kWh of electricity
- 1.63E-02 metric tons CO₂ per Therm of natural gas
- 4.49E-04 metric tons CO₂ per kWh of electricity

Final Results- Energy and CO₂ Effects

The combination of the EUI and energy compliance components allows calculation of the effect of bringing non-complying components up to code. That is, in cases where the field review found components not fully in compliance, the effect was calculated through the modeling exercise. In this paper, due to space limitations, the combined effects are shown (Table 3). The four states surveyed in this study overall had high code compliance and, as a result, relatively low amounts of savings for bringing components up to compliance.

A few notes help to explain the contents of Table 3. The “Electricity Savings” and “Natural Gas Savings” columns show the per-apartment savings in electricity or natural gas usage. “Total Savings” was the total excess energy use for all surveyed buildings divided by the number of buildings. Natural gas or electricity was chosen based on which energy source was more commonly in excess based on the non-compliant component. “Total Number of Units Built in

⁵ https://www.eia.gov/dnav/ng/NG_SUM_LSUM_A_EPG0_PRS_DMCF_M.htm
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a
<https://www.eia.gov/conference/2015/pdf/presentations/skone.pdf>
<https://www.eia.gov/tools/faqs/faq.php?id=74&t=11>

State” is the statewide number of apartments. The number of apartments per climate zone was unavailable, so all savings for the state are lumped together. Finally, “Total Energy Savings”, “Total Energy Cost Savings”, and “Total State Emissions Reduction” are per year.

Table 3. Estimated Energy and CO₂ Benefits For Total Code Compliance (by state)

	Electricity Savings (kWh / unit)	Gas Savings (Therms / unit)	Total Savings (kBtu / unit)	Total Number of Units Built in State	Energy Savings (Btu x 10 ⁶)	Total Energy Cost Savings (\$)	Emissions Reduction (metric tons CO ₂)
Oregon	99	0	342	57,920	4,947	157,957	654
Washington	63	0	221	101,397	7,458	237,508	987
Illinois	14	2	243	53,367	4,319	70,225	677
Minnesota	5	6	582	42,675	8,281	106,027	1,342

In addition to the primary results presented above, some additional results from the combined plan and field review and modeling are as follows:

- For thermal envelope components, in each state, the majority of buildings met or were often better than the prescriptive code. In some cases, surveyed buildings were designed to qualify for energy efficiency certification programs⁶. These buildings made up at least 20% of sampled buildings in each state.
- Almost all buildings met mechanical system efficiency requirements (for both living units and common areas). In some cases, sites employed systems that were considerably more efficient than required by the applicable energy code, and this resulted in a significant reduction in modeled HVAC usage.
- Dwelling units had a majority of high-efficacy lighting fixtures, often in excess of code requirements. While high-efficacy fixtures were also typical in common areas (corridors and stairwells), lighting power densities (LPDs) in these areas were sometimes higher than prescriptive levels. High-efficacy fixtures and design/installation of fewer fixtures were observed as code-compliance strategies.

Key Actor Interviews

The study included a market research component to better understand the codes that bear on low-rise multifamily dwellings and to inform energy-code compliance education and training.

The market research was implemented through interviews with market actors and key stakeholders through an online survey designed to reach active multifamily building developers, architects, and contractors. Contacts from the study sampling and recruiting process were asked

⁶Buildings participating in energy efficiency certification programs (including those with above-code requirements) were included in the study when they were selected as a natural part of the sampling and recruiting process so as to achieve an average representation of building characteristics within a given state

to complete the online survey in order to paint a broad picture of the firms involved in this market. Interviews with stakeholders outside the study allowed us to explore in more detail issues and topics that arose as the field study progressed.

Within all four states, there were regions with growth in the low-rise multifamily market as well as regions with little to no growth. In general, interviewees indicated that mid-size cities and suburbs had more new low-rise buildings, while larger cities and rural areas had lower overall new low-rise growth. Interviewees stated that in larger cities such as Seattle, Portland, Minneapolis, and Chicago, apartment developers tended to opt for taller buildings when they were able to get a parcel of land. However, they also mentioned that low-rise buildings were more common for affordable housing development and, as that need has increased, the cities have seen some growth in this market. In rural areas or smaller suburbs, the interviewees stated that abundant land lends itself to large townhome or duplex developments rather than low-rise apartment buildings.

In general, the developers of low-rise multifamily buildings included market-rate builders and affordable housing developers. In most places, individuals estimated that market-rate builders make up most of the market. As for characteristics of the buildings, there was wide variation among building size, prevalence of mixed-use construction, and type of entry. In general, buildings with fewer units typically have separate entrances whereas buildings with more units have corridor entrances. In Oregon, the interviewees suggested that most low-rise multifamily construction includes commercial or retail space on the lower level ('mixed-use') while in Washington and Minnesota, they suggested that most low-rise multifamily construction is strictly residential. In Illinois, the interviewees stated that Chicago and the nearby suburbs relied on mixed-use construction due to land constraints while rural areas and suburbs outside of the main city center did more strictly residential buildings.

In Illinois, Minnesota, and Washington, low-rise multifamily buildings, defined as three stories or less, fall under the residential energy code. However, Chicago and Seattle count buildings up to five stories and four stories, respectively, as low-rise multifamily construction. Multifamily buildings in Chicago that are four stories follow the residential code, while buildings in Seattle that are higher than three stories follow the commercial code. In Minnesota, there seems to be some confusion around which code to follow as two interviewees stated that low-rise buildings fall under the commercial code book. Additionally, in Illinois, an energy efficiency consultant stated that buildings are not always classified correctly. For example, if a building has an underground garage and three stories of residential space above, it will fall under the residential code, but it often gets classified as commercial.

There is also confusion in Oregon regarding which code low-rise multifamily buildings fall under. One city building code official stated that only 1- to 2-unit residential buildings (including townhomes) follow the residential code; all others follow the commercial code which has provisions for residential construction. Other interviewees indicated that some projects could fall under the residential code and others might follow the commercial code. One interviewee indicated that there are currently a lot of changes in Oregon, where new code provisions went into effect on October 1, 2019.

In each of the states, most respondents mentioned that code is generally well-followed and compliance issues are not widespread. However, at least one respondent in Minnesota, Illinois, and Washington mentioned that compliance issues stem from a skillset gap, or confusion, or lack of knowledge on the topic. In Washington, another commonly mentioned issue surrounded the section of the code where developers or builders must pick a certain number of measures to implement from a larger list of measures. Respondents mentioned that this

checklist approach can lead to confusion over which items can be combined and how to apply the credits from this list.

Another issue mentioned was the lack of consistency between the building codes and the energy codes, specifically in terms of the current year adopted for each code. For example, a building code official in Illinois stated that it is difficult to abide by the 2018 IECC requirements for a tighter building if the current building code still follows the 2012 International Building Code. Illinois does not have a statewide building code for either residential or commercial new construction. For the residential code, units of local government have authority to adopt and enforce building codes, zoning ordinances, and other instruments related to construction.

When asked about how low-rise multifamily code training could be improved, most respondents did not have recommendations for additional training resources. However, respondents commonly expressed that there was a need for more resources for all building types at the time of a code change, especially because codes are changing more rapidly and drastically now. For example, every individual in Oregon mentioned the upcoming code change and how there will be an immediate need for resources and training on the new code, as large changes are expected. Similarly, respondents in other states mentioned that because the code changes every three years, more robust resources and training are needed to keep all relevant stakeholders up to date. One interviewee mentioned that the release of new resources often lags several months behind the release of a new code, which causes difficulties in designing and enforcing buildings to code.

Conclusions

The project was successful in surveying nearly 100 low-rise multifamily buildings (and about 300 living units) in three geographic regions of the US: Pacific Northwest, Midwest, and Upper Midwest. Data collection and analysis allowed a robust characterization of energy-using characteristics of these sites. For the most part, the states in the study utilized the requirements of the 2012 and 2015 cycles of the International Energy Conservation Code as part of the building permitting process. Both building plan review and field verification were used to catalog and confirm building energy details such as insulation levels, mechanical systems, domestic hot water, and lighting.

The study benefitted from earlier work on energy code compliance that was done by the Pacific Northwest National Laboratory (PNNL) on single-family homes (Bartlett et al. 2018). The templates from this work, most notably the analysis graphical approach, were helpful in summary characterizations. Many characteristics categories overlapped closely. Most of the occupied space is living units and falls under residential energy codes, and many characteristics use similar envelope construction and relatively straightforward mechanical systems and lighting. Where there were diversions, such as the heating systems and lighting employed in common areas, components could still be evaluated, and summaries and energy analyses were prepared for these elements.

Data collection and handling were built around a spreadsheet-based data collection tool; this approach facilitated a relatively efficient means of performing quality control and also fed into a series of EnergyPlus™ prototype simulations which calculated energy and avoided carbon benefits that would result from bringing sites up to full code compliance (on a statewide basis).

Interviews with about 21 building developers, architects and construction contractors revealed a wide range of awareness about residential and commercial building energy code requirements and methods for complying with those requirements. Many code details are well-understood by building designers and builders, although there remains room for improvement at

the measure level. This seems especially true as regular code updates (typically tied to IECC updates) have become routine. However, given the combination of IECC residential and commercial elements in low-rise buildings, and given local jurisdiction code exceptions/interpretations, designers and builders are often confused which code to follow. This presents a challenge and opportunity for all involved in this building sector.

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