A Codes and Standards Path to Achieving Zero Net Energy for Low-Rise Multifamily Buildings

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ABSTRACT

As California rapidly approaches the state policy target date (2020) for all newly constructed low-rise residential buildings to be Zero Net Energy (ZNE), codes and standards initiatives are underway to ensure the success of this goal. One such initiative is addressing appropriate Title 24 energy code requirements specifically for low-rise multifamily buildings, an important but often overlooked sector whose code requirements often fall between residential and nonresidential codes. Pacific Gas and Electric Company (PG&E) Codes and Standard Enhancement (CASE) team is addressing the California Title 24 changes need to achieve a low-rise multifamily ZNE energy code. The team scoped and prioritized research efforts for improving the code requirements for low-rise multifamily buildings in the following three areas: 1) code compliance modeling software (CBECC-Res) improvements, 2) develop a set of measures for adoption in 2019 Title 24 that collectively result in ZNE, and 3) chart a pathway to unite low-rise and high-rise requirements into a single set of multifamily standards in the 2022 Title 24 cycle. Low-rise multifamily-specific areas of research include: HVAC and DHW systems, lighting, ventilation requirements including indoor air quality and infiltration considerations, miscellaneous electric loads, photovoltaic system requirements and energy performance software.

Introduction and Background

Multifamily buildings hold a unique place among building sectors since they have characteristics of both residential and commercial buildings. Most multifamily buildings have some systems or construction details that are more similar to nonresidential buildings than single-family homes. Yet, they are homes with cooking, bathing, and appliance usage schedules that look nothing like nonresidential buildings, and are therefore more similar to single-family homes.

Because building codes were originally developed for structural and fire safety reasons, it was and still is important to make a distinction between low-rise construction that can be accomplished with all wood frame construction, and high-rise buildings of four or more stories. For high-rise buildings, wood framing cannot support the lateral loads dictated by California seismic requirements. From a fire safety standpoint, taller buildings cannot be easily accessed by ladder trucks, so the Fire Code has different exiting and construction requirements for high-rise buildings.

The high-rise, low-rise distinction between three and four stories was adopted by the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) for the standards they develop related to heating, cooling and ventilation requirements for multifamily

buildings. The logic was that high-rise multifamily equipment and systems are often more like those in commercial buildings than single-family homes. While not wrong for many multifamily buildings, the logic fails both when one looks at very large low-rise multifamily buildings with complex whole building systems, or high-rise multifamily buildings where each dwelling unit has its own individual system.

The California Energy Commission (CEC) began promulgating building energy standards late in the 1970s and remained consistent with ASHRAE and elements of the State building code (Title 24) that made the distinction between three-story or less versus four-story or greater. As the International Code Council (ICC) developed its energy standards, the International Energy Conservation Code (IECC), it assigned low-rise multifamily buildings to the same chapter as single-family homes, and high-rise multifamily to the nonresidential chapter.

However, this approach has fostered some serious design and energy modeling challenges. By applying energy efficiency standards developed primarily for two other types of buildings, the code processes have made it difficult to determine what specific requirements are most appropriate for multifamily. Additionally, multifamily new construction projects are often comprised of a combination of three-story and four-story buildings of the same basic design. This results in analysis and code compliance under different requirements, using different certified software programs that may provide significantly different per-square-foot energy use estimates (see Figure 1). As the building energy codes move toward ZNE baselines, code requirements and currently available analysis tools may not be appropriate for multifamily buildings and could lead to inaccurate results and frustrate California's goals.

Table 1. Comparison of Low-Rise vs. High-Rise Multifamily Compliance Model Results for California's Title 24

End Use	Standard Design		Proposed Design	
	HR	LR	HR	LR
Space Heating	21.61	21.55	19.25	18.38
Space Cooling	51.35	30.15	37.24	28.80
Fans	62.93	8.24	70.63	9.14
DHW	33.93	31.88	30.90	29.34
Pumps	0.00	0.00	2.59	0.00
Totals	**169.82**	**91.82**	**160.61**	**85.66**
% Better than Standard			**5.4%**	**6.7%**
TDV Energy Use shown as kBtu/ft2yr of Conditioned Floor Area				

Source: "The Case for a Multifamily Code," Benningfield Group. 2014)

The solution to these challenges is to develop energy efficiency standards specifically for all multifamily buildings and update the currently available analysis tools. These multifamily specific standards need to target zero-net energy to meet California's goal of ZNE for low-rise multifamily residential by 2020.

Why does it matter?

Renter households' median annual earnings are approximately $30,000, while owner households have annual earnings of approximately $60,000 (U.S. Census Bureau 3013). This is relevant to why codes need to ensure multifamily buildings are energy efficient because 87% of all households living in multifamily buildings are renters; and nearly two thirds of all renters live in multifamily buildings. As renters, they have almost no ability to affect their heating, cooling,

and water heating costs other than through behavior. They cannot add insulation or replace inefficient equipment or windows. In an inefficient apartment, this generally means they have to choose between using a less than average amount of hot water, being cold in the winter and hot in the summer, or paying a relatively high percentage of monthly income on utilities.

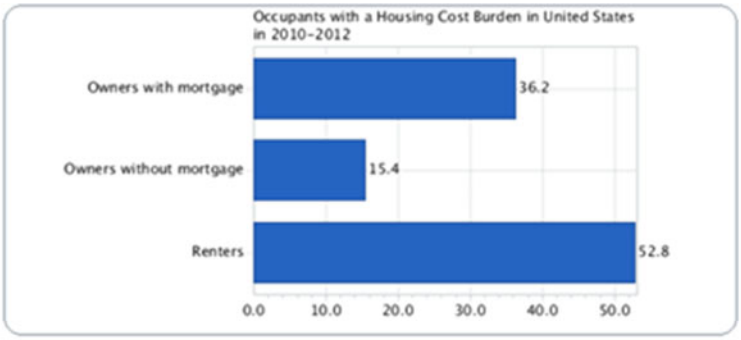

Figure 1. U.S. Households with Excessive Housing Cost Burden

Although the 47% of U.S. households with incomes less than $40,000 only use 37% of U.S. households' energy, their housing burden (rent plus utilities) is significantly higher than average. According to the most recent American Community Survey, nearly 53% of all renters have a housing cost burden exceeding the recommended maximum, 30% of monthly income. In the 2013 American Housing Survey, nearly 15% of apartment dwellers reported having received a gas shut-off notice. Oak Ridge National Lab (ORNL) estimates that in 2014 the average energy burden (percent of household income used for utilities) was 16.3% for the 39.5 million households who were eligible for weatherization assistance ($39,580 for a family of three), compared to 3.5% for non-eligible households.

Nationally, 33% of all residential dwelling units being built are in multifamily buildings. This is up from an average of 20% over the previous 25 years. According to the California Department of Finance, in every year since 2011, multifamily has represented over 50% of residential new construction in California, compared to less than 28% for years 2001-2005. In Orange County, Los Angeles and San Francisco, multifamily accounted for 67%, 81% and 89% respectively, of all residential new construction permits in 2015. Many developers who had been exclusively single-family subdivision builders, like Lennar, Richmond American, Toll Brothers and KB Homes, are now very actively involved in the multifamily new construction market.

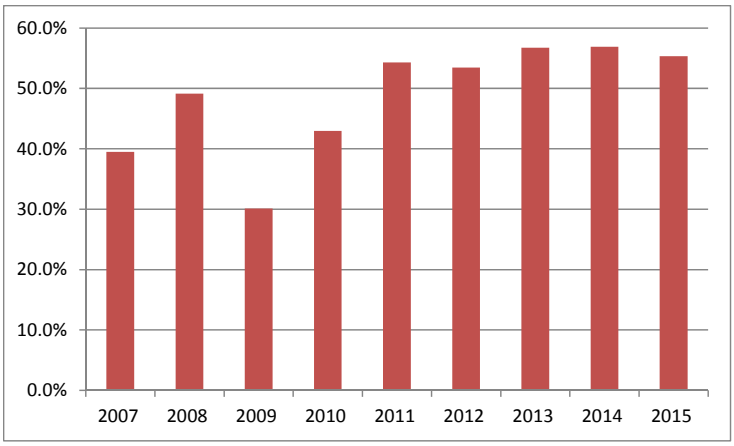

Figure 2. Multifamily as a Percentage of all California Residential Construction
Source: California Department of Finance

There are still more reasons for a focused approach to energy codes that are applied to multifamily buildings. Because high-rise and low-rise multifamily buildings are currently subject to nonresidential and single-family codes respectively, performance software used to model a four-story multifamily building is very different from the software used to model one that is three stories. Even if the two buildings use all of the same envelope measures and equipment, so that the only difference between the two is that one has an additional floor, the calculated energy use per square foot of the four-story building is generally at least double that of the three-story building; 170 kBtu/sf. versus 92 kBtu/sf for a typical project in southern California. The authors conclude that the logical explanation for this difference is in the software modeling assumptions and differences in the default requirements in the energy standards.

The larger problem is that this sort of dissonance makes it difficult for design teams and the enforcement community to fully embrace both sets of multifamily code requirements, even though they may understand the requirements.[1] Since building department personnel have a lot of structural, electrical, plumbing and other details to inspect with a limited amount of time, it is not reasonable to expect they will pay as much attention to energy details for which they question the rationale. Until code requirements applied to multifamily buildings are developed specifically for multifamily buildings, we may not get the level of enforcement we expect.

The problems can be summarized as:

1. Code requirements for high-rise multifamily construction and the software to analyze them have been developed primarily for nonresidential buildings.
2. Code requirements for low-rise multifamily construction and the software to analyze them have been developed primarily for single-family homes.
3. The split in the standards between three- and four-stories, and the dissonant modeling results create confusion when designing and analyzing multifamily projects that include both building heights.

[1] This is supported by an email from Doug Mahone to Robert Kasman (PG&E) on June 12, 2008. The email described a review of plans and models for 27 multifamily projects as submitted to PG&E's California Multifamily New Homes program. None of the 27 projects were modeled correctly, nor met the minimum requirements of Title 24, although the model authors thought they were exceeding code by at least 15%. The email was introduced into the CPUC's public record in support of updates to the Database for Energy Efficient Resources.

Without fixing these problems, it is hard to imagine how California could achieve its goal of zero net energy (ZNE) residential new construction, which includes low-rise multifamily buildings, by 2020. Similarly, it is unlikely that the IECC will result in the savings that proponents expected as long as there is an arbitrary split between three- and four-story multifamily buildings, and the measures applicable to each are those designed for single-family homes and commercial buildings respectively.

Fixing the Problems

There are two basic fixes to the multifamily building code issues discussed above: (1) develop code requirements specifically with multifamily buildings in mind, and (2) bring current scattered multifamily code requirements together into one multifamily chapter that makes meaningful distinctions between building sizes and types. One current code development effort is taking on one of those fixes, while another effort is taking on the other.

In support of the California Energy Commission (CEC), California's Investor Owned Utilities (IOUs) are focused on analyzing potential 2019 Title 24 code requirements specifically relevant to and appropriate for helping low-rise multifamily buildings achieve ZNE. The CEC does not have the resources to deal with both fixes described above at the same time, but may consider uniting low-rise and high-rise multifamily code measures in one chapter during a future update cycle (e.g., 2022).

Likewise, there is a proposal before the International Code Council (ICC) to create a chapter of the IECC in 2018 that would contain all the provisions applicable to multifamily buildings of any height. The proposal does not create any new requirements specifically for multifamily buildings, nor does it increase the stringency of the relevant requirements.

IECC Multifamily Chapter

The New Buildings Institute (NBI) and Stone Energy Associates (SEA) worked with a host of interested parties to craft a proposal that is intended to improve designers' and building departments' understanding of and compliance with multifamily code requirements, by collecting all of them in one chapter. The process involved outreach to and close collaboration with members of the multifamily construction industry, code officials, the Department of Energy, and others. Throughout that process, NBI refined and modified the initial proposal to garner the broadest possible support.

One example of how that worked is illustrated by the structure of the proposed chapter. Outreach to stakeholders explored the question of whether to have the multifamily chapter contain all of the text and tables applicable to multifamily construction, or have the chapter simply point to the relevant sections of the nonresidential and low-rise residential code chapters. Early input from stakeholders strongly supported a stand-alone chapter, but as more parties got involved, several felt that trying to write a whole chapter was too much to take on within the allowable timeframe, and others felt that simply referencing the residential and nonresidential chapters was the best way to ensure that code requirements maintained the same level of stringency. The proposal submitted to the ICC in January 2016 references, rather than restates the requirements in the other chapters. In general, stakeholders felt that in the future, the IECC should have a stand-alone multifamily chapter. This will allow for all requirements pertaining to multifamily to be developed and analyzed specifically for that building type.

NBI and SEA conducted extensive outreach to code officials and others after the January submittal, to ensure that potential supporters and decision makers understood the elements of the proposal and the rationale for it.

The National Association of Home Builders and the National Multifamily Housing Council both spoke against the proposal during the IECC hearings in Louisville, Kentucky in April 2016. Their primary concerns were that melding of the high-rise and low-rise requirements meant that some of the requirements would have become more stringent. Consequently, the IECC Committee voted the proposal down. NBI and SEA are working with ICC's building official members, who will make the final decision in a full vote of the membership at its code hearings in Kansas City in October 2016.

If the proposal is adopted, the 2018 IECC will have a multifamily chapter with all of the requirements for multifamily buildings of any height stated or referenced in one place. This should facilitate development in future cycles, of multifamily-specific requirements by adding clarity to the analyses.

California Title 24

In late 2014, Pacific Gas and Electric Company (PG&E) began looking strategically at how it could best support the CEC in its residential ZNE goals for the 2019 Title 24 Standards. PG&E and its consultants TRC Energy Solutions and SEA evaluated the current (2016) code requirements, existing measures that could help achieve ZNE residential buildings, the range and quality of available data on those measures, and the level of support necessary to ensure their inclusion in the residential sections of Title 24, Part 6. During the initial analysis, it became clear that unless measure analysis included specific attention to characteristics of multifamily buildings, the residential code applicable to all low-rise residential construction would not result in true ZNE multifamily buildings. PG&E decided to propose a code development process focused specifically on low-rise multifamily.

PG&E's team performed an initial analysis of each potential measure's code-readiness, in order to focus its limited resources on those that were most likely to be adopted. For the measures that warranted further work, PG&E's team developed research plans and timelines. This informed further prioritization of the list based again on available resources. PG&E and the other California IOUs are currently working with the CEC to determine which measures would be evaluated directly by the CEC, which would be supported by the IOUs, and which would be dropped for the 2019 iteration of Title 24.

To inform proposed code changes, each topic area will be researched individually including researching the measure and its alternatives, engaging industry stakeholders, performing energy analysis, conducting cost data collection, and completing cost-effectiveness analysis. To begin, the Codes and Standards Enhancements (CASE) team conducts literature review including identifying known data gaps, current products and practices, opportunities for energy savings, market information, use patterns, potential challenges in implementing the proposed code change, and other relevant information. The team reviews existing and forthcoming model standards (ASHRAE, IECC, and local ordinances), research, emerging technology, and academic reports, and other literature. Where possible, the team leverages data from existing incentive programs to provide information on the occurrence of measures; efficiency levels reached, such as insulation values, equipment efficiencies, and infiltration levels, and credits taken. The team engages industry stakeholders to request data, solicit feedback, and build consensus on specific aspects of the code change proposals.

Finally, the team calculates energy impacts of each proposed code change on a per-unit basis, relative to baseline energy use. If there is an existing Title 24 standard, baseline energy use is defined as the energy use of a minimally compliant 2016 Title 24 building. If there is no existing Title 24 Standard for the measure, baseline energy use is defined as the energy use of typical design practices. Cost-effectiveness is calculated for each unique code change proposal (measure) using CEC's life-cycle cost methodology, include incremental equipment and maintenance costs over the 30 year period for low-rise multifamily.

Some of the measures on the list could be effective in helping both single-family homes and multifamily buildings achieve ZNE. Of those, some might have impacts and interactions with other measures differently in multifamily and single-family homes, so research, analysis, and development of multifamily proposals is being coordinated with development of the single-family measures.

There are many kinds of differences between the single-family and multifamily buildings that would warrant a measure being treated differently in the two residential building types. The difference can be as basic as the goal of the measure and its implementation criteria. For example, air leakage in a single family home is about leakage to/from the outdoors, the garage, the subarea, and the attic and addresses heat loss/gain concerns as well as external contaminants associated with indoor air quality. Many multifamily dwellings have no connection with a garage, have another dwelling instead of a subarea below their floor, or have another dwelling above instead of an attic. In multifamily homes, leakage issues are primarily to/from adjacent dwelling units and raise concerns with neighbors' indoor pollutants as well as those generated inside the subject apartment.

Drain water heat recovery (DWHR) is another good example. DWHR has application to both single-family and multifamily buildings, but effective performance may depend on completely different installation processes and configurations. DWHR devices raise the temperature of cold water going either to the shower or the water heater, by extracting the heat from water going down the drain. In a single-family home, the drain is generally just from a shower, and the cold water it pre-heats is just that which supplies the shower. In a multifamily building, the drain/waste plumbing and the hot water source (boiler or water heater) are often both in a basement or first floor below most of the dwelling units. DWHR in that case may use the heat from collected drains to pre-heat the cold water supply to the boiler or water heater.

Another example of where the performance parameters might be different enough to warrant coordinating on single-family and multifamily measure evaluation is the set of modeling parameters for miscellaneous electric loads. It appears that apartment households' usage patterns for appliances and other plug loads are different from patterns in single-family households; and different enough to matter. Some monitored data from single-family and multifamily homes built in California during this decade indicates their usage patterns and connected loads may be different. The data were collected by a member of the IOUs' multifamily team (Redwood Energy) in support of revisions to the plug loads algorithms in the CEC's modeling program, CBECC-Res.

There may also be differences between single-family and multifamily buildings in usage schedules, operational controls, other installation criteria and verification procedures. Each of these differences, if ignored, could contribute to incomplete understanding of the estimated energy impacts of individual measures, and make it much more difficult to understand the interaction of measures. On the path to ZNE multifamily buildings, an accurate analysis of potential savings in realistic models of multifamily buildings is essential. Once the analysis is

complete, it will be important to consider verification and compliance procedures for multifamily as distinct from single-family, for all measures.

Other measures are clearly only applicable to multifamily buildings. For example, if new single-family prototype models were needed, there would be no reason to coordinate their development with the development of the multifamily prototypes. One basic single-family design functions well for almost any single-family model needed, with adjustments for size, floors, and systems. However, the one multifamily prototype used by the CEC to evaluate code measures and run tests validating software, is an eight-unit garden style apartment building. It is insufficient for modeling the potential energy impact of measures on the wide variety of multifamily building types. Important differences include the presence or absence of an interior corridor, relative amount of common floor area, height of the building, and whether or not the multifamily dwellings are in a mixed-use building. The cost effective of several measures could vary significantly, based on these differences.

The measures that made it through the initial screening are shown in the first column of

Second Stage Potential Measures
MF Prototype Models
Improvements to LR MF Compliance Processes
MF DHW
MF Drainwater Heat Recovery
Potential MF Lighting Measures
Miscellaneous Electric Loads
LR MF Measures for Additions/Alterations
Quality Insulation Installation (QII) in LR MF
LR MF Infiltration Test Methods and IAQ
MF HERS Score/ Energy Rating Index (ERI)
MF Phototvoltaics
TDV-Zero Multifamily Compliance Package

. Initial scoping analysis for these measures provided very rough estimate for annual savings of over 400 GWh and over 3.7 million therms.

Table 2. Multifamily Measures for 2019 ZNE Title 24

Second Stage Potential Measures
MF Prototype Models
Improvements to LR MF Compliance Processes
MF DHW
MF Drainwater Heat Recovery
Potential MF Lighting Measures
Miscellaneous Electric Loads
LR MF Measures for Additions/Alterations
Quality Insulation Installation (QII) in LR MF
LR MF Infiltration Test Methods and IAQ
MF HERS Score/ Energy Rating Index (ERI)
MF Phototvoltaics
TDV-Zero Multifamily Compliance Package

The CEC is leading development of measures besides those on which the IOUs' multifamily teams are working. As of May 2016, the CEC had not finalized its list of measures. Because much of the landscape for the 2019 Standards was still being sorted out, developing the pathway to a united multifamily section of Title 24 was put on hold. If adoption of a unified multifamily chapter by the IECC is successful in October, it will set the stage for 2022 Title 24 efforts.

What Outcomes Should We Expect?

The primary reason for taking a multifamily-focused approach to developing code as described above, is to cost effectively achieve larger, more certain energy savings and, ultimately, ZNE multifamily buildings. There are reasons to believe taking the approach described above is the best path to that goal. Better targeting of measures and more accurate performance analysis tools, will lead to more appropriate requirements and better design choices. At its simplest, using single-family buildings and nonresidential buildings in the analysis and code development process for multifamily buildings is, to use a carpenter's metaphor, like hammering nails with a wrench. Getting to actual ZNE multifamily buildings requires using accurate building and operational characteristics in realistic prototypes to better understand the measures that make a difference specifically in multifamily buildings.

Improved accuracy while analyzing and assessing potential measures will result in better informed decisions during building energy code adoption processes and in modeling tools algorithm updates. The improved accuracy in energy models will also allow design teams to better evaluate the cost-effectiveness of various design options.

Another source of expected energy savings, though not quantifiable, is actual savings due to anticipated increased compliance. Recently, several building departments in California indicated frustration with trying to enforce standards on multifamily buildings that often feel arbitrary, confusing, or hard to find. When they see two models for essentially the same building, differing only by one floor, showing per-square-foot estimates that often differ by more than a factor of two, building department personnel do not feel particularly confident with the accuracy and appropriateness of the energy code and the approved software. To the extent the code requirements become more appropriately targeted to this building type, and the models become more accurate in representing them, it is likely that building departments will have an easier time embracing and enforcing the code.

Conclusion

After decades of code development where multifamily was typically an afterthought, a team working toward Zero Net Energy (ZNE) Title 24 2019 building standards in California, and a team working on updates to the International Energy Conservation Code (IECC) for 2018 are addressing the needs of multifamily construction head on. One effort is focused on performing of multifamily-specific analyses of potential measures for low-rise multifamily and improvements to the accuracy of modeling software within Title 24, while the other effort is focused on uniting all of the IECC requirements pertaining to multifamily buildings into one clear chapter. Energy standards that foster development of high-performance multifamily buildings will eventually need to do both. Each of the current efforts should inform the next standards development process in the other arena and cumulatively will set the stage for a more successful

implementation of increasingly stringent code updates headed in the direction of ZNE.

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