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Commercial ZNE Market Characterization – Final Report

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2 Executive Summary

2.1 Introduction and Methodology

California set bold goals for zero net energy (ZNE) buildings, including a goal by the California Public Utilities Commission (CPUC) for all new commercial buildings, and 50% of existing commercial buildings, to be ZNE by 2030[1]. The purpose of this study was to support the Statewide ZNE goal by identifying drivers and barriers to the commercial ZNE and ultra-efficient building market, identifying lessons learned from current ZNE and ultra-efficient buildings, estimating the absolute and relative market size of the ZNE and ultra-efficient buildings market, and estimating energy use intensity (EUI) of ZNE and ultra-efficient buildings compared to code built buildings. Based on results, the goal of the study was to assess opportunities to further understand and develop the ZNE and ultra-efficient market and provide analysis and recommendations.

The IOUs scoped this study in 2017 and in the years since, the State agencies have intensified their focus on GHG reduction goals, and the IOUs have increased focus on GHG and demand response (DR). While it was beyond the scope of this study to investigate the impact of ZNE on these topics, the TRC team provides a high-level description of how reducing energy load in buildings through the strategies used to achieve ZNE (energy efficiency and distributed energy resources) can reduce GHG and help meet DR goals.

As an overview of data collection, the study reviewed existing literature related to ZNE, conducted interviews with 80 commercial building market actors – most of whom had experience with ZNE or ultra-efficient buildings, interviewed six staff from jurisdictions with reach codes, and compared modeled and measured EUI of ZNE and ultra-efficient buildings with code compliant buildings – both those built to new construction and to vintage code requirements.

This study uses the term “ZNE and ultra-efficient buildings” to collectively refer to all of the following types of buildings:

1. “**ZNE performance**”: ZNE performance buildings have shown through actual energy use and renewable energy generation data (e.g., energy monitoring or billing data) that their annual energy use is equal to or less than their energy production
2. “**ZNE Emerging**”: ZNE Emerging buildings have publicly stated a goal of reaching ZNE but have not yet demonstrated achievement of that goal. These buildings may be in the planning or design phase, under construction, or have been in operation for less than twelve months. Others may have been operating for at least a year, but their measured energy use data either has yet to achieve ZNE, or the data to document ZNE performance was not available.
3. “**Ultra-efficient**”: Ultra-efficient buildings do not quite meet the ZNE specification for performance but are significantly more efficient than buildings that just meet building code requirements.

2.2 Key Findings

2.2.1 Market Actor Interpretations of ZNE, Drivers, and Barriers

Most market actors interviewed use a site-based definition of ZNE. The greatest discrepancy in the interview results for the definition of ZNE related to the role of onsite combustion sources, with nearly one-fifth interpreting ZNE as either excluding natural gas or as zero net carbon. Most interviewees reported they are knowledgeable about ZNE and ultra-efficient buildings, and their main questions related to how ZNE fits into new statewide goals, including decarbonization and electrification; these findings are likely because the market actors interviewed have experience with ZNE or ultra-efficient buildings.

[1] CPUC, “California Energy Efficiency Strategic Plan”, 2008, p. 31. Available at: https://www.cpuc.ca.gov/general.aspx?id=4125

Most market actors reported high interest in working on ZNE and ultra-efficient buildings in the next five years and anticipate their work in this area to increase. The majority of market actors interviewed reported that they track energy use in all ZNE and ultra-efficient buildings. Almost all (91%) of market actors reported the property owner is the person who most influences the decision about whether a commercial building will be ZNE. The literature and interviews identified multiple drivers to ZNE including:

- Non-energy benefits to building owners and occupants, of which improved occupant health or indoor air quality, improved marketability, improved thermal comfort, meeting greenhouse gas goals, and improved occupant productivity were identified most often by interviewees
- Policies in support of ZNE, including the California Energy Efficiency Strategic Plan, California Executive Order B-18-12 requiring all new state buildings and major renovations designed after 2025 to be ZNE, and a University of California commitment for carbon neutrality for its campus operations by 2025
- Organizational missions that value ZNE
- Long-term cost savings
- Incentive programs that support ZNE

The market actor interviews and literature identified several barriers to ZNE and ultra-efficient buildings, including the following:

- Cost concerns, including concerns with first incremental first costs, value engineering removing efficiency or renewable energy measures, and insufficient budget
- Lack of awareness or experience by the project team, including resistance to change, lack of team coordination, and vague goals
- Technological challenges, including difficulty placing enough renewables onsite, difficulty accounting for occupants' behaviors and plug loads, pursuing renewable energy prior to efficiency, and lack of commissioning, and
- Challenges posed by ordinances and other regulations, including historic building ordinances that can restrict efficiency or renewable measures, and height limitations and tree ordinances that can restrict rooftop PV
- While estimating incremental cost is challenging due to lack of construction cost data (particularly for comparable buildings by type and location), most market actors interviewed (57%) reported that the incremental cost for designing and constructing ZNE or ultra-efficient buildings is typically 5% or less. However, a significant fraction of respondents (13 to 14%) reported the design and construction incremental costs can exceed 20%. Interviewees were split into thirds for estimating that operation and maintenance would cost more, less, or about the same for a ZNE or ultra-efficient building compared with standard practice buildings. While data are sparse for ZNE and ultra-efficient buildings, studies have shown an increase in valuation for beyond code buildings – including meta studies that found that LEED buildings have a 15-17% premium in rental rates and a 10-31% premium in sales price compared to non-rated buildings.

While estimating incremental cost is challenging due to lack of construction cost data (particularly for comparable buildings by type and location), most market actors interviewed (57%) reported that the incremental cost for designing and constructing ZNE or ultra-efficient buildings is typically 5% or less. However, a significant fraction of respondents (13 to 14%) reported the design and construction incremental costs can exceed 20%. Interviewees were split into thirds for estimating that operation and maintenance would cost more, less, or about the same for a ZNE or ultra-efficient building compared with standard practice buildings. While data are sparse for ZNE and ultra-efficient buildings, studies have shown an increase in valuation for

beyond code buildings – including meta studies that found that LEED buildings have a 15-17% premium in rental rates and a 10-31% premium in sales price compared to non-rated buildings.

2.2.2 Approaches to ZNE and Ultra-efficient Buildings

Market actors reported various approaches to successfully designing and buildings a ZNE or ultra-efficient building, including several strategies for reducing incremental cost.

- Establishing clear efficiency and renewable energy goals during the conceptual design phase,
- Using iterative energy modeling to test options, and
- Having strong coordination among team members.

Regarding onsite solar PV, most market actors reported they prefer to use onsite PV (both rooftop and site-based, such as on covered parking) instead of off-site. The most commonly cited reason for not incorporating PV at a project was insufficient unshaded roof space (68% of respondents), followed by high first cost (32% of respondents – multiple responses allowed).

The TRC team used the CEC website and a literature review to identify at least sixteen jurisdictions (cities or counties) in California with commercial reach codes or green building ordinances that included energy efficiency requirements (e.g., achieve LEED Silver). Almost all ordinances apply to new construction projects only. Most ordinances require specific measures (e.g., outdoor lighting or cool roofs) and none require ZNE. The planners and building officials interviewed here reported the primary drivers for reach codes included municipal goals and increasing State requirements. A major challenge to reach code adoption – including the scope of measures that the reach code can included and buildings it can apply to (particularly retrofits) – is meeting cost effectiveness tests. To side-step cost effectiveness requirements, some jurisdictions reported they are exploring voluntary guidelines, or using methods such as faster planning approval to encourage (but not require) greater efficiency or renewable energy in buildings. Several jurisdictions noted they are exploring decarbonization or greenhouse gas reductions as part of the next reach code cycle.

2.2.3 Market Size

The TRC team found an upward trend in adoption of ZNE and ultra-efficient buildings. The number of ZNE and ultra-efficient projects has increased and includes both public and privately-owned buildings. While small projects (less than 25,000 sf) dominate the ZNE and ultra-efficient market, medium (between 50,000 and 100,000 sf) and large (greater than 100,000 sf) ZNE and ultra-efficient buildings have shown an increase in the past few years. Various types of projects are ZNE or ultra-efficient, and education (33%) and office (29%) buildings comprise the largest shares. Almost one-quarter of the identified ZNE and ultra-efficient projects are retrofits.

Relative to the total market, ZNE and ultra-efficient buildings comprise approximately 0.4% of the total new construction market over the past three years. In contrast, beyond code buildings – analyzed here as those that participated in Leadership for Energy and Environmental Design (LEED) or the IOU Savings by Design (SBD) program comprised approximately 11% of new construction buildings. There are ZNE or ultra-efficient buildings in every climate zone in California, and the largest fraction of the market is in the Sacramento area (Climate Zone 12) where almost 1% of total new construction is ZNE or ultra-efficient.

2.2.4 EUI Analysis

EUI analysis found that ZNE is feasible for many types using efficiency and onsite solar PV. Based on modeling, nonrefrigerated warehouses can achieve ZNE through Title 24-2019 efficiency and solar PV. Retail buildings and small offices and small schools can achieve ZNE through efficiency measures only moderately more efficient than Title 24-2019 requirements and rooftop PV. Large offices and large schools can achieve ZNE by exceeding Title 24-2019 efficiency requirements and including rooftop PV and small levels of onsite solar (through covered parking or community solar). However, hospitals, hotels, and restaurants have high EUIs and would require reductions to process loads and significant onsite or off-site solar to achieve ZNE. The EUI analysis found large energy savings opportunities compared with Title 24-2019.

The TRC team had limited modeled and measured data for the same ZNE and ultra-efficient projects to compared modeled with measured performance. But based on data available, a comparison indicates that across all ZNE projects, the modeled energy consumption correlates with measured energy consumption, but results may not be consistent for each project.

2.3 Summary of Recommendations

The TRC team developed the following summary of findings and recommendations. Section 11 provides more detail. Appendix (Section 15) provides this information in a format to facilitate the IOUs' Response to Recommendations process.

Figure 1. Summary of Recommendations

Lead (Support)	Findings and Justification	Recommendation
Immediate Research Needs		
IOUs (CPUC)	Since the study was scoped, the State has increased its focus on greenhouse gas (GHG) reduction	**1) Revisit ZNE goals to meet GHG emissions and demand response needs** • Investigate options for achieving ZNE in prototype buildings, and their impacts on GHG and demand • Identify a new loading order for efficiency, renewables, and load management by building type and location
CPUC (IOUs)	Cost-effectiveness requirements prohibit aggressive action	**2) Monetize non-energy benefits (NEBs)** • Quantify NEBs through literature review and program-incentivized occupant surveys • Include customer and utility NEBs in cost-effectiveness calculations
CEC (IOUs)	"Percent better than Title 24" does not track progress	**3) Develop Energy Design Rating (EDR) type metric for commercial buildings** • CEC leads, but IOUs can help define baseline systems by building type
Codes and Standards		
CEC (IOUs: through Statewide Utility CASE Teams)	a) Current trajectory is ~3% EUI reduction each Title 24 Cycle b) Hospitals, hotels, and restaurants have large loads not regulated by Title 24 or Title 20 c) Title 24-2019 requires residential (not commercial) distributed generation	**4a) Accelerate net energy reduction each code cycle** • Require deeper savings through greater prescriptive trade-offs **4b) Continue to investigate opportunities to bring more loads under Title 24 or Title 20** • Short-term: Shift to EDR-type metric • Long-term: Shift to outcome-based codes **4c) Add requirements for renewable energy and load management** • Provide flexibility so project teams can meet the specific needs of each site

Lead	Findings and Justification	Recommendation
Reach Code and Local Ordinance Recommendations		
Local Jurisdictions (IOUs, through Reach Code Programs)	a) New requirements can be more contested than renewals b) Projects may not complete plan review goals c) Cost effectiveness limits scope of reach codes d) Offering "carrots" will increase participation in voluntary pathway	**5a) Update existing requirement separately from new developments** **5b) Impose enforcement mechanism,** such as a deposit that is refunded if goals are met **5c) Establish voluntary standards** to encourage deeper energy savings or reach retrofits **5d) Encourage participation of voluntary standards through rewards,** such as density bonuses or tax incentives
CPUC & Local Jurisdictions (CEC, CARB, IOU Reach Code Staff)	a) California has no policies to directly regulate energy performance b) Building Performance Standards may be more feasible at the local jurisdiction level than statewide	**6a) Convene a statewide meeting to develop a framework for Building Performance Standards** **6b) Local jurisdictions should initiate implementation of Building Performance Standards**
Incentives, Financing, and Voluntary Programs		
IOUs	Replacement program to Savings by Design (SBD) could help address: a) First cost barrier b) High operation and maintenance for some ZNE strategies c) IOU data tracking variations d) Actual energy use that exceeds modeled predictions. e) Lack of documented occupant benefits with specific measures	**7) As the new nonresidential custom program is scoped, in addition to previous SBD offerings, the IOUs should consider:** 7a) Providing financing 7b) Offering optional post-occupancy support 7c) Documenting predicted energy use and savings 7d) Using a partial "pay for performance" incentive structure 7e) Offering and incentive for an indoor environmental quality (IEQ) survey
	Incremental costs are low for ZNE and ultra-efficient buildings, and sales and rental premiums should provide high Return on Investment (ROI)	**8) Emphasize NEBs and high ROI to potential program participants** 8a) Emphasize NEBs to project teams 8b) Highlight high ROI, particularly for privately-owned buildings 8c) Consider providing a ZNE recognition program
Education and Training		
IOUs	a) Integrated design helps achieve ZNE and reduce cost b) Several trainings requested are already provided through Workforce Education and Training (WE&T)	**9a) Continue to provide training on integrated design** **9b) Use the upcoming WE&T Market Assessment to parse out actual training needs vs. participation challenges** • Identify opportunities to increase participation in trainings • Identify needs, audiences, and delivery methods for coursework that can build the business case for ZNE
CPUC (IOUs)	Mandated training would reach a much larger audience, but California governors have rejected continuing education requirements	**10) Convene a statewide forum to discuss continuing education requirements**

Long Term Research Needs		
CEC (IOUs)	Benchmarking was recently mandated for large buildings. Compliance software does not accurately capture some advanced strategies.	**11) Allow 3rd parties access to modeling (in addition to benchmarking) data, and improve accuracy of models** • Compare modeled and actual energy use. • IOUs can help prioritize modeling improvements by identifying common strategies in their custom programs
CPUC (CEC)	Statewide ZNE progress is not tracked.	**12) Track ZNE claims in a central registry**
IOUs	Actual energy use varies by operation and occupant behavior a) Facility operators are in good position to identify opportunities for improvement b) Most ZNE project teams track building performance	**13) Solicit "boots on the ground" perspectives to reduce actual energy use** 13a) Provide industry competition for strategies to improve operations and occupant behavior 13b) Ask ZNE contacts for methods to reduce occupant energy use
Building Technology Recommendations		
IOUs (CPUC and CEC)	Itron (2019) recently published a study that identified high priority technologies	**14)** IOU programs, codes and standards, and policies should **continue to encourage adoption of the high priority technologies**
CEC (IOUs)	• Data centers were not studied, because there is no data center prototype	**15) Improve tracking of building stock and EUI for data centers** • Use results as initial step to identify savings opportunities • Track data centers as a separate category in the next building stock or energy use survey

3 Introduction

This section introduces the purpose of the study and the role of ZNE in evolving state priorities and discusses study limitations.

3.1 Study Purpose

California set bold goals for zero net energy (ZNE) buildings, including a goal by the California Public Utilities Commission (CPUC) for all new commercial buildings, and 50% of existing commercial buildings, to be ZNE by 2030[2]. **The purpose of this study was to support the Statewide ZNE goal** by meeting several research objectives, including to:

- Leverage findings of past and current studies to identify knowledge gaps, to provide ZNE building characterizations by sector, and estimate the current and potential market size for ZNE and ultra-efficient buildings
- Identify drivers and barriers to the commercial ZNE market, understanding how these vary by sector, and identifying lessons learned from current ZNE and ultra-efficient buildings;
- Assess opportunities to further understand and develop the ZNE and ultra-efficient market and provide analysis and recommendations.
- The overall goal of the study was to identify progress towards California's ZNE goals and recommend actions for policy makers and the California investor owned utilities (IOUs) to increase the adoption of ZNE and ultra-efficient buildings.

3.2 Role of ZNE in Evolving State Priorities

The IOUs scoped the study in 2017 with an eye towards meeting the 2030 ZNE goals outlined in the 2008 Energy Efficiency Strategic Plan and then reinforced through the Integrated Energy Policy Report (IEPR) over the years, the latest being in 2016. Since then, while the state agencies (CPUC and California Energy Commission [CEC]) have continued to support ZNE goals, the State agencies have intensified their focus on GHG reduction goals, and the IOUs have increased focus on GHG and demand response (DR). The 2019 IEPR Scoping Order merges buildings energy efficiency and building decarbonization goals into one goal towards cleaning a clean economy.

Deep energy reductions and on-site renewables found in ZNE buildings play a critical role in meeting GHG goals. Getting to zero in commercial buildings involves a combination of optimizing building-level energy efficiency – including reducing (or eliminating) natural gas consumption in buildings, and offsetting building consumption with distributed energy resources (including site-based renewable energy), all of which reduces the overall carbon intensity of the grid. The following literature supports this:

- A recent study by E3 (2018) for the CEC reports that deep energy reductions remain critical because efficiency reduces overall costs for all of the other elements of a comprehensive decarbonization strategy.
- An article by American Council for an Energy Efficiency Economy (ACEEE) describes how many states are using energy efficiency to meet their greenhouse gas emissions reductions goals.[3]

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[2] CPUC, "California Energy Efficiency Strategic Plan", 2008, p. 31. Available at: https://www.cpuc.ca.gov/general.aspx?id=4125

[3] https://aceee.org/blog/2019/07/going-clean-how-energy-efficiency

- Several California policies have recognized the role of buildings in meeting GHG, as illustrated by Figure 11 in Section 6.3.4, which provides a timeline of California policies related to ZNE, including relevant GHG policies.

However, the simple efficiency loading order of the past (which always prioritized efficiency before renewable energy) may not be the most relevant for GHG reductions, especially as the grid decarbonizes with both building-level and utility-scale renewables. Carbon intensity of energy will continue to fluctuate depending on where the building is located and the carbon intensity of the grid at the time the energy is used. However, regardless of the loading order, energy efficiency continues to be a significant contributor to building decarbonization goals by both lowering building energy loads as well as reducing the size and therefore cost of any renewable energy and storage required to provide full decarbonization benefits.

Similar to GHG reductions, while this study did not investigate the role of ZNE on DR, a DR potential study describes energy efficiency as a load-modifying demand response measure – whereby an efficiency investment (if the timing of service remains unchanged) decreases the net load (LBNL 2017 – details provided in Section 13.1.7).

As described in the Recommendations section (Section 2.3), more investigations are necessary to understand the relationship between ZNE, GHG, and DR, and to help market actors understand how their building can be a good “grid citizen".

3.3 Study Limitations

The study includes the following limitations:

Bias in interview responses. While the TRC team reached out to hundreds of market actors with to code or beyond code experience to request interviews, we received a much higher response rate from market actors with ZNE or ultra-efficient building experience. Thus, the market actor feedback primarily reflects findings from those with ZNE or ultra-efficient building experience.

Market size estimates may under represent penetration of ZNE and ultra-efficient buildings. The starting point for the market size estimate is the NBI watch list, which uses multiple methods to identify ZNE and ultra-efficient buildings. However, it is possible that the watch list does not identify all buildings. This is particularly true for ultra-efficient buildings, in part because there is no broadly used definition for this category.

Most EUI estimates are based on modeling: The EUI analysis is based on modeled because modeled data was generally more available, although this report includes some measured results. In addition, the EUI analysis is based on previous technical feasibility studies. It was beyond the scope of this study to identify the market potential or economic potential of the measures assumed to achieve ZNE in these feasibility studies.

Analysis of ZNE on GHG and grid impacts out of scope: Although the state agencies have an increased focus on GHG reductions and the IOUs have increased interest in GHG reductions and demand response (DR), it was beyond the scope to include a quantitative analysis of how ZNE impacts GHG emissions or DR.

4 Methodology

The following section provides an overview of the data collection methods used in this study.

4.1 Literature Review

The TRC team leveraged a knowledge management resource library maintained by New Buildings Institute (NBI) that served as the foundation for the assimilation of existing resources and literature review for this California commercial ZNE market characterization. The library contains a variety of resource types including reports, articles, case studies, presentations, guides, definitions, articles, and white papers. It includes information on key technologies, including a growing set of information on renewable integration in the building sector. The team has tagged information with key words and organized by building type, resource type, and relevant geographic location for easy identification and sorting.

The first step in the literature review was for the TRC team to update the library with the latest ZNE studies and materials. This included both secondary research and outreach to the Project Coordination Group (PCG) for review and feedback on the proposed list of materials for review. Members of the PCG provided additional insights and added all of their suggestions for additional research and materials to the list.

The team organized studies and sources that were a part of this search-and-gather task into four broad categories: (1) ZNE buildings in California, (2) research studies and books on ZNE, (3) case studies, and (4) policy examples. They also organized the initial list of 263 resources in a spreadsheet that included information including title, author, document source, resource type, geographic location, building type (including whether it related to new construction or existing buildings) and keywords.

The next step in the research was to review the abstract for each of these 263 resources, with an eye toward key research objectives and questions that the team set out to answer with the literature review. Key research questions included: California market size, costs, benefits, barriers, non-energy benefits, lessons learned, energy targets, and definitions. Each of these research questions had a column in the spreadsheet. Researchers then ranked each of the resources for the value and insights it provided on the key research questions.

The TRC team was then able to prioritize the review based on the value of the resource to answer the research objectives and questions. This began by reviewing high value resources first, then moderate value to determine the extent to which they could answer the question. If the team did not feel the research had fully answered the question, they added a review of low-value resources and referred the topic to the larger team for inclusion in the stakeholder interviews. The Appendix provides a more complete analysis of this approach.

This process of organizing, sorting, reviewing, and summarizing relevant resources provided a strong foundation and summary of the latest thinking in ZNE and ultra-efficient commercial buildings.

4.2 Interviews with Commercial Building Market Actors

The goal of the TRC team was to interview a variety of market actors active in new commercial construction in California to understand decision making related to ZNE and ultra-efficient buildings. The overarching goals of this data collection effort were to understand:

- The primary drivers to pursue ZNE in the commercial building and retrofit markets
- The key barriers to achieving ZNE in new and existing commercial buildings
- The potential solutions to addressing existing barriers

The team relied on a variety of sources to identify market actors and we used multiple approaches to contact market actors. Figure 2. provides an overview of the approaches used and the corresponding population of each data source the team used.

Figure 2. Market Actor Disposition Rate by Source

Source	Approach	Number contacted	Number of Completes	Response Rate
IOUs' Energy Center trainees from PG&E, SDG&E and SoCalGas	IOUs emailed trainees requesting they contact the research team if interested in an interview	3,053	36	1%
IOUs' Savings by Design program participants	IOUs provided the research team contact information and research team emailed requesting an interview	4,300	19	0.4%
NBI training attendee	NBI provided research team contact information and research team emailed requesting an interview	196	4	2%
Selected contacts from the NBI email list	NBI emailed contacts to inform them to expect an email from the research team requesting an interview	7	2	29%
Design professionals who worked on known ZNE buildings	NBI or TRC provided research team contact information and research team emailed requesting an interview	595	8	1%
Internet search for commercial developers	Emailed identified contacts requesting an interview	44	0	0%
Market actors' snowball referrals	Emailed identified contacts requesting an interview	30	10	33%
Total		**8,225**	**80**	**1%**

The different approaches used helped to increase total response rate and ensure a mix of respondents – both by market actor type and experience with ZNE. Although some recruitment rates had low response rates, all but one (internet search for commercial developers) provided at least two interview completions.

The team contacted market actors up to five times to request an interview, usually through a combination of emails and phone calls. In total, the IOUs and TRC research team contacted approximately 8,225 market actors.

The team conducted the interviews between September 2018 and January 2019. Each interview lasted between 30 minutes and two hours. The team recorded all conversations to ensure accuracy of the notes and offered the market a copy of the report upon completion as incentive to complete the interview.

The team completed analyses in *Excel*. When relevant, the team analyzed data by the following differences:

- Respondent type: Whether they were technical staff like architects and engineers or an owner/developer.
- Project type: Whether the respondent specialized in new construction or major retrofits
- Respondent experience: If they have worked on a ZNE and ultra-efficient building or less efficient buildings.
- The TRC team developed an interview guide to focus on addressing data gaps that the literature review could not address. For some topics, the team collected information using both the literature

review and interviews to compare results – particularly if information from the literature was only available at the national level.

4.3 Reach Code Interview Methodology

The TRC team conducted interviews with planning and code officials in jurisdictions with reach codes to assess progress and strategies jurisdictions are undertaking to exceed commercial energy code requirements, and identify challenges and successes in developing, implementing, and enforcing these reach codes.

The TRC team first used the California Energy Commission (CEC) website to identify jurisdictions with approved reach codes. The TRC team reviewed the supporting documents for the approved and pending reach codes to identify staff associated with the reach codes and supporting analyses and contacted them for the interviews. Out of the seventeen approved reach codes and one pending, the TRC team interviewed staff from six cities and counties. In addition, the TRC team interviewed one consultant who has supported reach code development and analysis for over twenty jurisdictions and multiple code cycles.

The interviews covered the following topics:

- Scope development and measures included and considered
- Reach code approval and adoption
- Means of and challenges with enforcement
- Future reach codes
- Other findings and recommendations from jurisdictions

Appendix 13.1 provides more detail on methodology, including a summary table of the jurisdictions with reach codes.

4.4 Energy Use Intensity (EUI) Analysis

The team studied modeled and measured EUI data of both new construction and existing buildings. The goal was to compare EUI data of different building types for new construction and existing buildings – including those built to code and those that are ZNE or ultra-efficient, and to compare measured and modeled data.

To look at buildings built to code, the TRC team used prototype models of buildings that are in minimum compliance with the Title 24-2019 Standards based on TDV (since TDV is used by the CEC for evaluating compliance). Because the TRC team ran hourly simulation results, the TRC Team used site energy usage for each fuel type (electricity and natural gas) obtained from model outputs to directly convert from kWh and therms to kBtu/h which was used to calculate site EUI.

The team reviewed energy use targets from several data sources and evaluated them for inclusion in this study. Some of the studies and corresponding data are several years old. However, they are the most recent data available and still provide reliable estimates at a high, “ballpark” level of EUI. Figure 3. shows the primary data sources used for the EUI analysis.

Figure 3. Data Sources for EUI Analysis

Data Source	Modeled or Measured	Efficiency Level
ASHRAE – Advanced Energy Design Guide (2018)	Modeled	Tech Potential
ASHRAE – RP-1651 – Development of Maximum Technically Achievable Energy Targets for Commercial Buildings	Modeled	Tech Potential
Bonnema, Eric, et. al (NREL) – Technical Feasibility Study for Zero Energy K-12 Schools (2016)	Modeled	Tech Potential
Dean, Edward (PG&E) – Zero Net Energy Case Study Vol. 1-3 (2014-2018)	Modeled and Measured	ZNE
Griffith, Brent et. al (NREL)[4] – Assessment of Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector (2007)	Modeled	Tech Potential
NBI – California K-12 and Community College Zero Net Energy Retrofit Readiness Study (2017)	Modeled	ZNE
NBI – Getting to Zero Status Update (2019)	Measured (and Modeled in some cases)	ZNE, ZNE Emerging

For PV production, this analysis only assumed rooftop PV, developed by NORESCO. This analysis also reviewed the results of the Arup, “Technical Feasibility of Zero Net Energy Buildings in California” (2012). Because much of the Arup results included onsite PV generation (not just rooftop generation), which would vary significantly by the site, we did not include them in our analysis. The TRC team’s rooftop PV production should be similar to Arup’s rooftop PV.

Figure 4. shows the building types analyzed for EUI compared to CEC building types. Where possible, the study aligned with the building categories tracked by the CEC (described in section 6.1) as much as possible. This study also provides analysis for some categories that the figures further classify by use (e.g., education buildings into K-12 schools and colleges/ universities) or building size – such as small and large offices.

[4] The NREL technical potential study (Griffith 2007) has valuable insights on ZNE potential, but was excluded from this dataset, because PV energy could not be separated from the EUI targets by building type.

Figure 4. CEC Building Type Categories compared to Categories in EUI Analysis

California Energy Commission Building Type	Scope of EUI Analysis provided in Study	Building Size Assumed in Prototype for EUI Analysis (conditioned sf)
Education	Where possible, analysis provided separately for K-12 Schools and colleges/ universities	Small School: 24,413 Large School: 210,886
Office	Where possible, analysis provided separately based on size.	Small Office: 5,502 Medium Office: 53,628 Large Office: 498,589
Retail	Where possible, analysis provided separately for stand-alone retail and strip malls	Strip Mall: 9,375 Stand-Alone (Medium) Retail: 24,563 Large Retail: 240,000
Warehouse	Analysis provided for nonrefrigerated warehouse only. As shown in Figure 8, refrigerated warehouse has small footprint	Nonrefrigerated Warehouse: 49,495 *not conditioned
Hospitals and healthcare	Not analyzed. Some results pulled from Arup (2012) study	Not analyzed
Restaurants	Analysis provided for sit-down restaurants	Restaurant: 2,501
Food – i.e., facilities that sell food and/or liquor	Analysis not provided	Not analyzed
Miscellaneous: all other categories besides above	Analysis provided for high-rise multifamily buildings	High-rise Apartment: 93,632

When presenting results, the TRC team used an "apples to apples" approach as much as possible. Thus, the team compared *modeling* results for new construction buildings: code compliant with new construction ZNE and ultra-efficient, and vintage code compliant with ZNE and ultra-efficient retrofit buildings. Separately, the TRC team compared *measured* (i.e., actual energy) data for building stock with ZNE and ultra-efficient buildings. Consequently, analysis included:

- **New Construction Buildings – Modeled Results**: The team analyzed EUI by building type by taking models of Title 24-2019 compliant buildings and comparing modeled EUI results to EUI ranges found to be technically feasible to achieve ZNE from the above studies. Analysis aggregated results across climate zones. The team analyzed EUI results from efficiency separately from adding rooftop PV. In addition to the feasibility studies, the TRC team added results of modeled data for actual ZNE and ultra-efficient projects, both for modeled energy consumption and modeled net energy. The project-level results come from new construction projects completed in 2016 or later from the NBI Watchlist and PG&E ZNE Verification study.
- **Existing Buildings – Modeled Results:** The team used the same analysis approach for existing buildings as for new construction buildings. However, the analysis compared modeled EUIs of buildings constructed to vintage codes from 1980, 1990, and 2000 to modeled EUIs of retrofitted buildings that pursue deep retrofits.

- **Existing Buildings – Measured Results:** The team analyzed data of measured energy use of existing building stock from CBECS and CEUS with measured energy use of ZNE and ultra-efficient buildings from the NBI Watchlist and PG&E ZNE Verification Study. Their studies show analysis for offices and schools, since these were the two building types with sufficient data for comparison.

- **Modeled vs. Measured EUI for ZNE and Ultra-Efficient Buildings:** The TRC team compared modeled versus measured energy consumption, and net energy use, for the few ZNE and ultra-efficient buildings for which data are available.

4.5 Estimates of ZNE Market Size

4.5.1 Total Market Size

ZNE Building Market Size Estimate

While there is no central tracking of ZNE buildings by the State (TRC 2018), NBI has been tracking ZNE and ultra-efficient new construction and retrofit buildings since 2010 in the NBI ZNE Building Tracker tool. The team has this list of commercial buildings (including multifamily – which includes low-rise and high-rise) from multiple sources including from designers, owners, utility programs, private and public organizations, articles, e-news, research, and real estate professionals. At any time, owners and designers can also submit projects for inclusion in the list through a portal at https://newbuildings.org/project-registry/. In addition, each year NBI augments this list by issuing a formal call for projects through media releases, events, and direct communications with design teams and owners. The latest public call for proposals happened during the Fall of 2018.

During the annual update to the list, NBI collects project information including building name, location, size, and type. When the data are available, NBI will note when the project is new construction or a major retrofit, as well as predicted and measured energy consumption, on-site renewable energy production and net energy use.

4.5.2 Relative Market Size

Methodology & Assumptions

The TRC team analyzed market penetrations of ZNE, ultra-efficient and beyond code buildings by comparing relative construction areas to that of the total market. The team identified total construction area using CEC building stock forecasts (CEC 2015), which are based on the number of planned building permits. To obtain the number of ZNE and ultra-efficient buildings, the team used data from NBI, as described above.

To study beyond code buildings, the TRC team looked at buildings participating in voluntary programs designed for achieving high sustainability goals (detailed in Section 6.3.3). Of these programs, we assumed that a significant proportion would participate in LEED and SBD because both programs have high emphasis on energy performance. Therefore, this analysis studies LEED and SBD programs as the beyond code market.

Due to differences in available data, the team:

- Aligned program payment and certification dates with construction dates to overcome inconsistency in date information.

- Imputed square footage data based on average areas using data from the 2012 California Building Energy Consumption Survey for some building types.

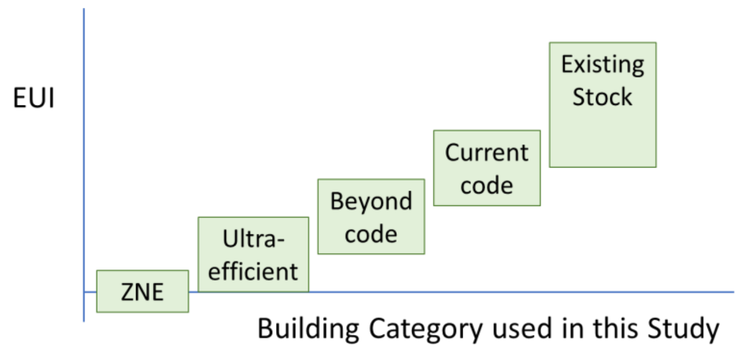
- Binned buildings into more general classifications to allow for comparisons between datasets.

The team also considered buildings that may belong to more than one category of ZNE, ultra-efficient, LEED or SBD. The analysis limited these buildings to one categorization to prevent overcounting. For more information on methodology and assumptions, see Appendix Section 13.5.

5 STUDY TERMINOLOGY

This section provides the definitions for key term as used in this document. Other studies may use these terms in different ways; the purpose of this section is to define them for the reader's clarity. Section 7.2 discusses other terms used in the market. Figure 5 provides an overview of the terms used in this study. This report provides a definition for each term (as used in this study) in the following subsections.

Figure 5 - Overview of Study Building Categories



5.1 ZNE and Ultra-Efficient Buildings

Broadly speaking, this study uses a ZNE building to refer to an energy efficient building where the energy production on site offsets the annual energy use of the building through renewable energy means, based on modeling or metering. As described below, there are several subcategories of ZNE. Because the number of ZNE buildings and market actors that have worked on those projects is relatively small, this study also investigated ultra-efficient buildings.

ZNE and Ultra-Efficient Buildings: This study uses the term "ZNE and ultra-efficient buildings" to collectively refer to all of the following types of buildings:

1. "**ZNE performance**": ZNE performance buildings have shown through measurements of actual energy use and renewable energy generation data that their annual energy use is equal to or less than their energy production. Measured energy refers to energy data that is based on any type of monitoring of actual energy usage such as energy usage data based on billing or metering data. "ZNE performance" projects are ZNE at the site and source levels (described below).
2. "**ZNE Emerging**": ZNE Emerging buildings have publicly stated a goal of reaching ZNE but have not yet demonstrated achievement of that goal. These buildings may be in the planning or design phase, under construction, or have been in operation for less than twelve months. Others may have been operating for at least a year, but their measured energy use data either has yet to achieve ZNE, or the data to document ZNE performance was not available.
3. "**Ultra-efficient**": Ultra-efficient buildings do not quite meet the ZNE specification for performance but are significantly more efficient than buildings that just meet building code requirements.

For these definitions, the terms include all energy end uses within the building (including process loads) but does not include electric vehicle (EV) charging or other end uses not within the confines of the building itself. Most findings in this report apply to all subcategories of ZNE and ultra-efficient buildings. In some instances – particularly for the market size estimates – the study will refer to one of these subcategories within the broader category of ZNE and ultra-efficient buildings.

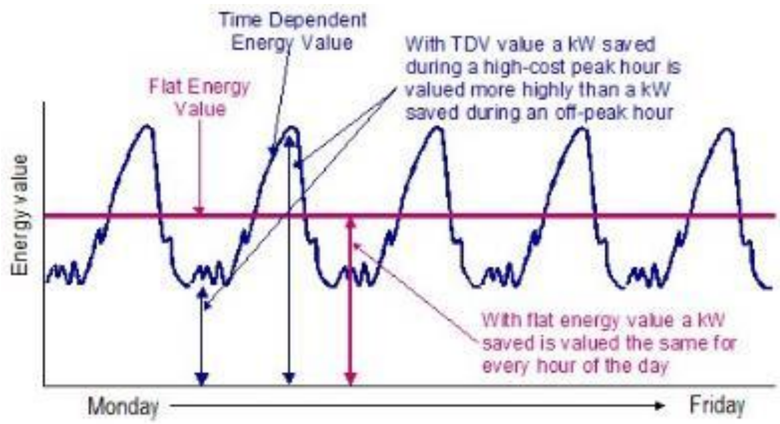
Within each of these three categories, there are additional subcategories based on the energy metric:

ZNE Site – A building designated as ZNE Site is a building that offsets its annual energy use with renewable energy generated on site, both expressed in terms of site kBtu (site energy).

ZNE Source – A building that offsets its annual energy use with renewable energy generated on site, based on a kBtu basis, that accounts for the on-site energy use, as well as energy required to extract and transport the raw fuel and losses associated with conversion, transmission, and distribution to the building.

ZNE TDV – A building that offsets its annual energy use with renewable energy generated on-site, based on a Time Dependent Valuation (TDV) metric. Under TDV, the study values energy on an hourly basis that reflects the actual cost of energy to the customers, to the utility system and to society. TDV is specific to California; values are calculated separately for the three primarily fuels used in buildings – electricity, natural gas, and propane – as well as for the 16 California climate zones. Figure 6. illustrates TDV compared to flat valuation of energy.

Figure 6. TDV Concept – "Flat" Valuation versus TDV for Electricity Use



There are other metrics used in the market, discussed in Section 7.2.

5.2 Beyond Code

Beyond code refers to buildings constructed to exceed building codes (Title 24) significantly (by at least 10%), but not as efficient as an ultra-efficient building.

This study categorizes Leadership in Energy and Environmental Design (LEED) buildings – a voluntary rating system described in Section 6.3.3, and Savings by Design (SBD) Whole Building projects[5] – which receive incentives from a CA IOU for exceeding Title 24 requirements by at least 10%, as beyond code.

In the interview guide, we categorized LEED Platinum as "ZNE and ultra-efficient", since many will likely be ultra-efficient. Some SBD projects may also be ultra-efficient. But for the market size estimates, we did not categorize any LEED or SBD projects, since we did not have EUI data or Title 24 compliance data to categorize them as such.

5.3 To Code and Existing Buildings

To code buildings are those recently constructed to just meet the requirements of the building code (Title 24) and appliance standards (Title 20 in California and federal appliance standards), but not exceed these significantly (by less than approximately 10%).

Existing stock are all buildings constructed in California to meet, without exceeding significantly, the requirements of the building code and their respective appliance standards.

[5] Based on SBD program requirements: https://www.savingsbydesign.com/wp-content/uploads/2018/08/2018_SBD-Handbook_Final_20180227.pdf

6 Overview of California Commercial Market

This section provides an overview of the California commercial buildings market, to provide a background and context for readers that are not familiar with some or all aspects of the general market. It introduces commercial building types and their relative share of the market, market actors and their role in commercial buildings, relevant codes and standards, and voluntary programs.

6.1 Types of Commercial Buildings and Relative Size in the Market

The commercial building sector includes various types of buildings. The figure below provides descriptions of building types according to CEC descriptions for forecasting purposes.

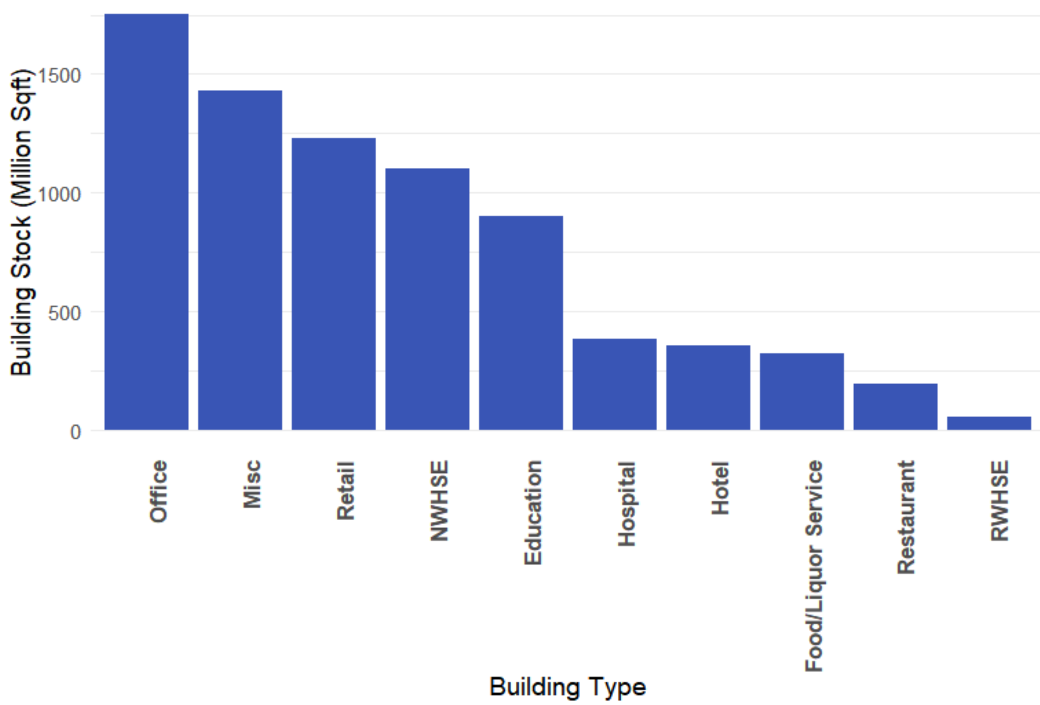
Figure 7. CEC Building Type Descriptions

Building Type	Description
Small office	Offices less than 30,000 square feet
Large office	Offices larger than 30,000 square feet
Restaurant	Any facility that serves food
Food	Any service facility that sells food or liquor
Non-refrigerated Warehouse	Non-refrigerated warehouses
Refrigerated Warehouse	Refrigerated warehouses
Schools	Schools K-12
College	Colleges, universities, community colleges
Hospital	Hospitals and other health-related facilities
Hotel/Motel	Hotels and Motels
Miscellaneous	All other space types that not fit in above categories

To give a sense of scale for each building type, Figure 8 shows the approximate square footage of existing stock in California by building type, based on building permit data from the California Energy Commission (CEC 2015[6]). As shown, offices, miscellaneous, retail, and nonrefrigerated warehouse (NWHSE) each comprise over 1 billion square feet. Education comprises approximately 900 million square feet. Food, hospitals, hotels, restaurants, and refrigerated warehouses (RWHSE) each comprise less than 500 million square feet.

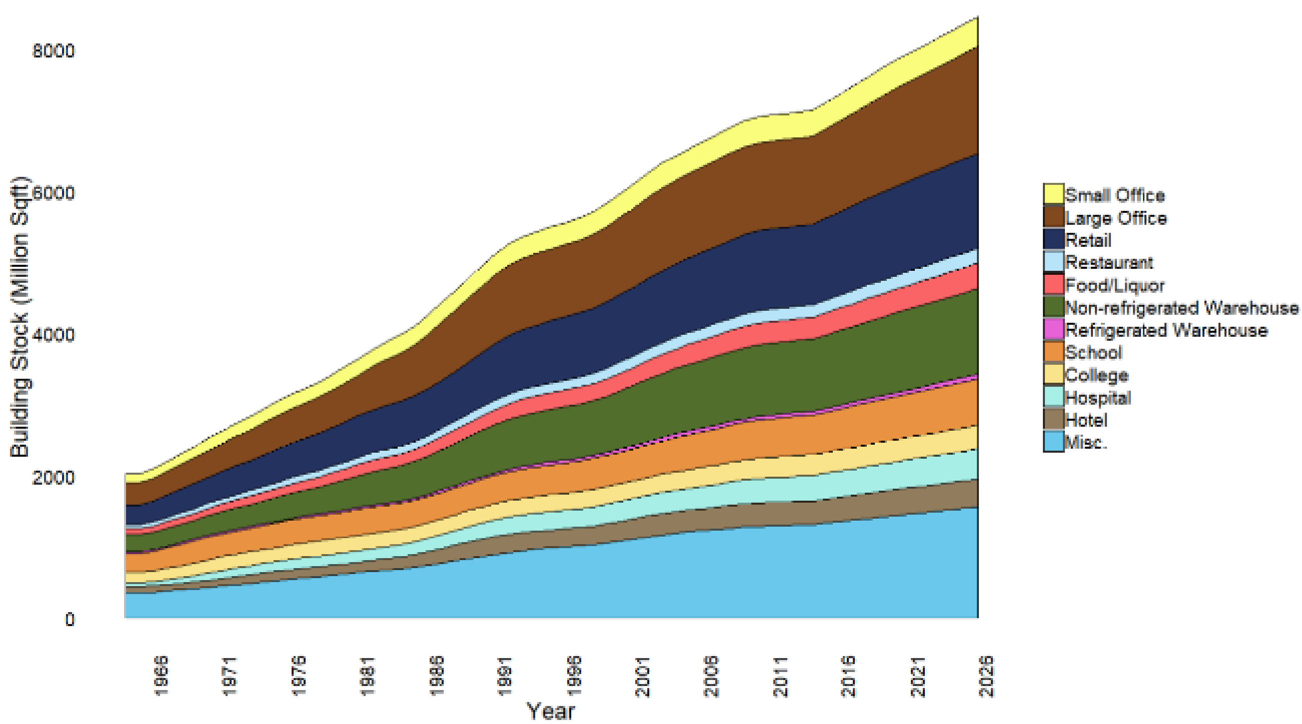
[6] CEC memo, "Floor Space Forecast", dated Nov. 11, 2015. The CEC develops a forecast of building permits and updates this estimate every 3 years, which includes reconciliating its forecasts of recent years with actual construction that occurred based on a combination of economic and demographic data, including building permit data. This dataset reflects building permit data up to 2014 and is forecasted for the following years.

Figure 8. Total Stock in 2019 by CEC Building Type



CEC forecasts through 2026 shown in Figure 9 predict that commercial building construction will follow these trends, with the greatest growth in additional square footage occurring in offices (and of those, primarily large offices), nonrefrigerated warehouses, retail, and education (CEC, 2015).

Figure 9. Total stock area from 1964 projected to 2026



The figures above show square footage – not energy use — by building type. The "energy footprint" of each building type depends both on its square footage and its EUI. Section 10.3 provides the TRC team's estimate of EUI analysis by building type for 2020 under two scenarios: code-compliant and for a ZNE / ultra-efficient scenario using maximum technical feasibility for energy efficiency.

6.2 Commercial Market Actors

Figure 10 describes commercial market actors and their typical role in a project.

Figure 10. Overview of Commercial Building Market Actors

Market Actor	Role
Developer(s)	Purchases land and develops the land for buildings. May build on the land or may sell to builders. Responsible for early decisions about what kind of building to construct and often oversees conceptual designs to gain community and government approvals for projects. Designs at this stage may or may not match what is ultimately constructed. Developer retains control over all aspects of construction if they are building or may pass on those responsibilities to others if they are only doing land purchase and development.
Contractor(s)	Typically, a General Contractor Is responsible for the overall construction of the project and coordination among different trades and vendors. There are several specialty contractors – structural, electrical, plumbing etc. – that work under the General Contractor. In some cases, the General Contractor also oversees the work on the design team including the Architect and engineers.
Building owner	For owner-occupied buildings, defines project requirements to which the building is built to meet their economic, functional and staff needs. For buildings intended to be occupied by entities other than the owner, sets the economic and functional parameters for the building design.
Architect	Works either under contract with the Developer, Building Owner or General Contractor and is responsible for planning, design of the building envelope as well as integration of work by other design team members including engineers (e.g. mechanical, electrical, plumbing, structural, acoustics, safety), interior designers and others. Architect also observes the construction of a building and provides required details for effective construction of the building. In a design-build scenario, Architects can also directly oversee building construction and play the role of both the Architect and General Contractor. Depending on the complexity of the project, there is often more than one Architect.
Engineer(s)	Designs and observes the construction of various building systems including structural, mechanical, electrical, and plumbing. Engineers also work with the Architect to evaluate impact of their systems on overall building design, loads and energy usage.
Facilities manager / operator	Operates and maintains building systems. These may be staff directly reporting to the building owner/occupant or are often third-party entities.
Facility energy manager	The facility manager may or may not provide energy management services to oversee and optimize building energy use. Sometimes a separate energy management firm may be hired for that purpose.
Occupant	Regularly occupies building. May provide input to owner's project requirements

6.3 Statewide Codes and Standards, Local Ordinances, Voluntary Programs, and Relevant Statewide Policy

This section provides a high-level overview of relevant codes and standards to California commercial buildings, a description of local ordinances, voluntary programs that many ZNE and ultra-efficient commercial buildings participate in, and California policy that relates to ZNE.

6.3.1 Codes and standards

Title 24 Building Efficiency Standards

Title 24 Building Efficiency Standards. California Building Energy Efficiency Standards Title 24 part 6 (commonly abbreviated as Title 24) provides energy efficiency requirements for new construction and retrofit buildings in the state. The CEC updates Title 24 on a three-year cycle. The most recently published version is Title 24-2019, which takes effect January 1, 2020. Projects comply with the version of Title 24 that was in effect at the time when they receive a permit. Projects can comply with Title 24 using either a prescriptive approach – which defines approaches and provides a set of trade-offs for some measures, or performance approach – in which the project team develops a simulation of energy use for the proposed building (“proposed”) compared to a building designed to minimum Title 24 requirements (“standard”) under CEC-approved software CBECC-Comm, to show the proposed building uses less than or equal to the total energy use of the standard building.

Title 24 regulates many end-uses, including heating, cooling, water heating, lighting and some process loads. However, Title 24 does not regulate all loads, such as some process loads.

Title 20 Appliance standards

California maintains Title 20 Appliance Efficiency Regulations, which sets efficiency requirements for specific appliances, including air conditioning equipment, refrigeration equipment, lighting products, water heating products, motors, fans, and more.

Commercial buildings must meet both Title 20 and Title 24 requirements. Using lighting as an example, Title 20 sets efficacy requirements (minimum lumens per watts) that individual lighting products must meet, while Title 24 set lighting power density requirements (maximum watts per square foot) which a building’s lighting system must meet.

Because project teams generally achieve ZNE through an integrated, whole building approach, this study focuses on requirements in Title 24.

6.3.2 Local Ordinances and Reach Codes

Reach codes or local ordinances are requirements set to exceed the statewide energy code. The ruling jurisdiction (e.g., a city or county) adopts a reach code, which the CEC must approve. All reach codes must be at least as stringent as the respective energy code and all the requirements defined in the reach code must be cost effective.

There are two types of reach codes – prescriptive and performance. The former mandates a specific measure or more while the latter requires overall building performance. The primary difference between these two types of reach codes is that the prescriptive targets particular energy conservation and sometimes renewable energy measures, but the performance approach evaluates the project and collection of measures as a whole as modeled in an approved modeling software.

6.3.3 Voluntary Programs

Voluntary programs offer an opportunity for owners and other project team members to distinguish their buildings from standard practice buildings.

IOU Nonresidential New Construction Program

The Savings By Design (SBD) program was the statewide nonresidential new construction energy efficiency program. The IOUs are in the process of sunsetting the SBD program and will replace it with a third-party-implemented program for nonresidential buildings. However, since the TRC Team used data from the SBD program for the market size analysis and as one population of interviewees, the SBD program is described here.

SBD applied to new construction and major renovations that involved a complete multi-system replacement, area reconstruction, or equipment installed to increase the capacity of existing systems due to existing or anticipated new load handling requirements[7]. The participating utilities included the four California IOUs and Los Angeles Department of Water and Power (LADWP). SBD offered a consistent approach that encourages energy-efficient building design and construction practices for new construction and to major renovations. It provided up-front design assistance and performance-based financial incentives. The program used the 2016 California Building Energy Efficiency Standards (Title 24, Part 6) as a reference baseline for comparison, providing financial incentives based on percent better than code.

Leadership in Energy and Environmental Design (LEED)

LEED is a green building rating system that provides a set of mandatory measures and voluntary credits for site, energy, indoor air quality, water, and materials. Projects must meet the mandatory pre-requisites and – based on the number of points earned through the voluntary credits – achieve a certain level of certification: Certified, Silver, Gold, and Platinum (in increasing order of points needed). The U.S. Green Building Council (USGBC) administers LEED and provides different rating systems for different building types. For example, LEED version 4 for Building Design and Construction applies to new construction (and major retrofits) for commercial buildings. USGBC updates the requirements for each rating system every few years.

Announced in 2017, the USGBC is piloting a new approach to reviewing LEED projects built in California. Eligible projects permitted under the 2016 California Building Code can utilize code compliance for a batch of Alternative Compliance Pathways (ACP) on LEED v4 projects[8]. In addition to the traditional certification levels (Certified, Silver, Gold, and Platinum), in 2018, USGBC developed “LEED Zero” to verify achievement of net zero goals. These include “LEED Zero Carbon*”:* operate with net zero carbon emissions over 12 months, and “LEED Zero Energy*”*: achieve a source energy use balance of zero over a period of 12 months. [9]

Living Building Challenge Zero Energy Certification (ILFI)

The ILFI Zero Energy Building (ZEB) Certification™ was created to allow projects to demonstrate ZNE performance, building a cohort of projects with the integrity of third-party performance certification[10].

School Sector Specific Programs

Some programs are specific schools, including the following described in this report:

- **Collaborative for High Performance Schools (CHPS).** CHPS is both a non-profit organization and a program. The CHPS program offers design criteria plus verification of high-performance school construction and operations[11]. As of 2017, 42 school districts in California had school board approved

[7] Savings By Design https://www.savingsbydesign.com/start-here/what-is-sbd/

[8] USGBC 2018 https://www.usgbc.org/articles/us-green-building-council-announces-leed-v4-and-calgreen-alignment-california-projects

[9] From USGBC resources, including LEED Zero Program Guide https://www.usgbc.org/sites/default/files/LEED_Zero_Program_Guide_190128_clean.pdf and the USGBC website: https://new.usgbc.org/leed-zero

[10] International Living Future Institute https://living-future.org/net-zero/certification/

[11] Collaborative for High Performance https://chps.net/

policies that require CHPS verification (or equivalent) for their facilities, which represents 24% of the schools in the state and 27% of student enrollment (NBI and Madison Engineering 2017).

- **Prop 39 and the Prop 39 Zero Net Energy School Retrofit Pilot Program.** Proposition 39 (Prop 39), the California Clean Energy Jobs Act of 2012, provided approximately $400 million per year to improve energy efficiency and increase the use of clean energy in existing public schools and community colleges. The adjunct three-year Prop 39 ZNE Schools Pilot allows California IOUs to support schools in retrofitting facilities to ZNE by leveraging Prop 39 funding. The Prop 39 ZNE Retrofit Pilot is establishing "proof of concept" to demonstrate the feasibility of ZNE retrofits in 13-18 schools and has developed case studies, offered workshops, webinars, and established a ZNE School Leadership recognition awards.

6.3.4 California Policy Related to ZNE

California is a global leader in the movement towards ZNE buildings. Figure 11 is a legislative timeline that highlights some of the major developments related to ZNE. As this timeline demonstrates, the goals and strategies for Statewide GHG reductions identify strategies in the building sector – including increased energy efficiency, ZNE, and building decarbonization, as important means of achieving GHG targets.

In addition to the policy noted in Figure 11, the State has revised some of the metrics used to track energy performance in buildings. For residential buildings, CEC has moved to an Energy Design Rating (EDR). Title 24-2019 provides the following definition of EDR[12]:

ENERGY DESIGN RATING (EDR) is a way to express the energy consumption of a building as a rating score index where a score of 100 represents the energy consumption of the building built to the specifications of the Residential Energy Services (RESNET) reference home characterization of the 2006 International Energy Conservation Code (IECC) with Title 24, Part 6 modeling assumptions, and a score of 0 (zero) represents a building that has zero net energy consumption. The EDR is calculated using Commission-approved compliance software as specified by the Alternative Calculation Method Approval Manual.

The CEC is developing a similar metric for commercial buildings.

[12] From Title 24-2019, Section 100.1 (Definitions and Rules of Construction).

Figure 11. Summary of California Policy Related to ZNE, Including Related GHG Policy

Year	Name	Summary
2006	Assembly Bill (AB) 32, the "Global Warming Solutions Act"	Calls for reducing the state's greenhouse gas (GHG) emissions levels to 1990 levels by 2020 (15% reduction from business as usual - BAU)
2008	AB 32 Scoping Plan (from California Air Resources Board)	Provides strategies the State will use to meet AB 32. It was updated in 2013-2014, and identifies green buildings as one strategy
2008	California's Long-Term Energy Efficiency Strategic Plan	The CPUC identifies four "Big Bold Energy Efficiency Strategies," two of which involve ZNE: all new residential construction in California will be ZNE by 2020, and all new construction commercial and half of existing commercial buildings will be ZNE by 2030.
2015	Governor Brown's Executive Order B-30-15	Adds a midterm goal of a 40% GHG reduction by 2030 and an overall goal of 80% reduction by 2050
2015	Governor Brown's "50-50-50 plan"	Calls to raise the renewable portfolio standard (RPS) to 50%, increase efficiency in existing buildings by 50%, and reduce petroleum usage by 50% by 2030
2015	Senate Bill (SB) 350, "Clean Energy and Pollution Reduction Act"	Passes with the RPS and efficiency goals, but not petroleum
2015	AB 802	Creates California's benchmarking program, requiring large commercial and multifamily projects to disclose annual energy use.
2016	Senate Bill (SB) 32	Codifies the goals set by Executive Order B-30-15 into law
2018	Integrated Energy Policy Report – IEPR	Recommends developing a plan to assess the feasibility of significantly reducing GHG emissions from buildings
2018	SB 100	Requires 100% fossil-fuel electricity by 2045
2018	Governor Brown signs into law SB 1477	Calls on the CPUC to develop, in consultation with the CEC, Building Initiative for Low-Emissions Development (BUILD) and Technology and Equipment for Clean Heating (TECH) programs aimed at reducing GHG emissions associated with buildings. Proposal for Building Decarbonization Pilots Draft TN-229015 Submitted 7/17/2019[13]
2018	AB 3232	Calls on the CEC, by 2021, to develop an assessment of the feasibility of reducing the GHG emissions of California's buildings by 40 percent below 1990 levels by 2030, in consultation with the CPUC
2019	CPUC voted to alter the "three-prong test" and call it "Fuel Substitution Test"	The three-prong test, effective since the 1990s, discouraged programs that substituted electricity for natural gas and required that each energy efficiency measure 1) reduce energy use, 2) benefit the environment and 3) be cost-effective. The new Fuel Substitution Test removes the requirement for cost-effectiveness at the measure level and imposes it at the portfolio level, and uses overall environmental benefits for source energy savings by capturing emissions reductions from electrification.

[13] https://efiling.energy.ca.gov/GetDocument.aspx?tn=229015&DocumentContentId=60393

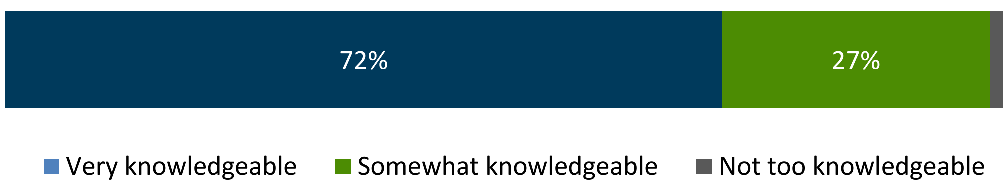
7 Market Actors' Perceptions of ZNE

The following section provides this study's findings on market actors' perceptions of ZNE and ultra-efficient buildings. The team drew these largely from the interviews but supported them with literature review findings when applicable. **Most of the interviewees had experience with ZNE and ultra-efficient buildings**, so these findings may not reflect the total population of California commercial building professionals.

7.1 Awareness and Interest in ZNE

Almost all of the interviewed market actors reported they were knowledgeable about ZNE and ultra-efficient buildings. Of the 78 interviewees, 72% reported they were very knowledgeable about ZNE design and construction practices and 27% stated they were somewhat knowledgeable. The interviewed market actors likely do not represent all commercial building market actors in California but those pushing the envelope for high-performance and ultra-efficient buildings.

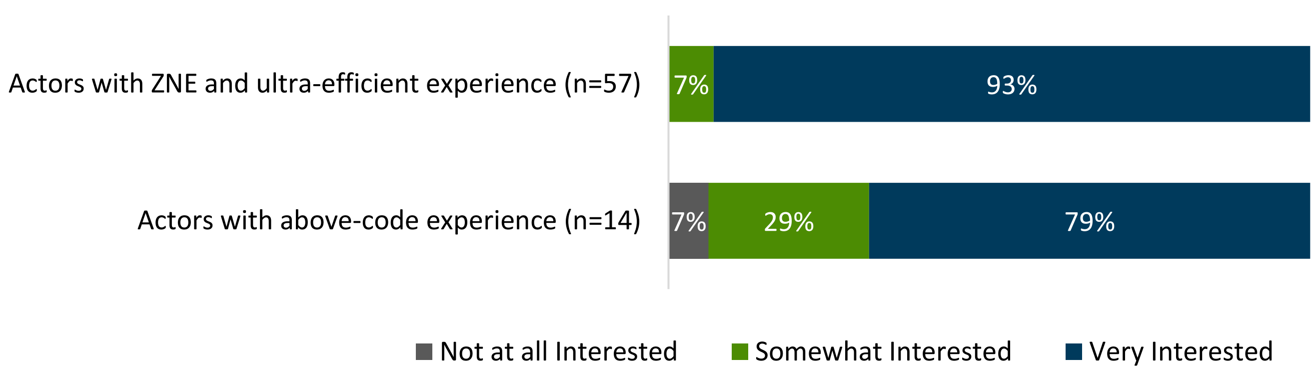
Figure 12. Respondent's Reported Knowledge of ZNE Design and Construction Practices (n=78)



Market actors reported they and their companies are highly interested in working on more ZNE and ultra-efficient commercial projects and expect this type of work to increase in the next five years (Figure 13). The most common reason they gave for being highly interested was that their firm specializes in this type of work and, because they have staff with expertise in high-performing buildings, they would welcome more of this type of work. Consistent with literature review findings, several market actors mentioned that state and local policies are pushing in this direction and the market actors want to be able to meet the expected demand. A handful mentioned interest in high-performing buildings for environmental reasons and because the occupant and owner benefit from high-performing buildings.

The market actors who were "somewhat interested" in doing ZNE and ultra-efficient work said that, in their experience, building owners are not willing to pay the price premiums for this type of work nor the required necessary system commissioning, and that they have not seen the market demand this type of work.

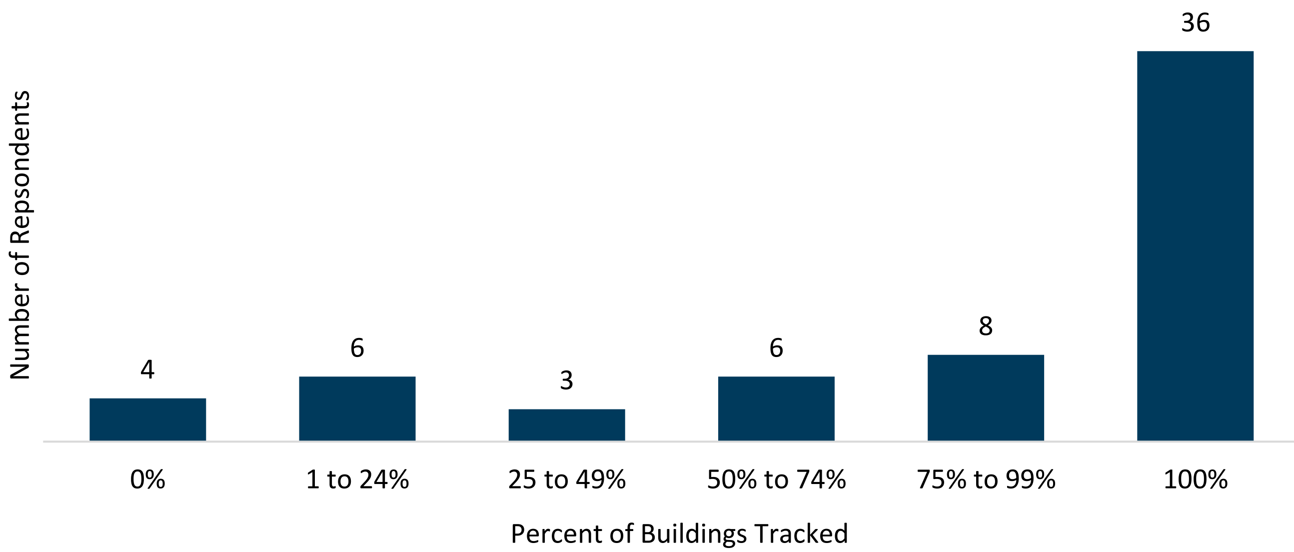
Figure 13. Company's Interest in Working on ZNE and Ultra-Efficient Commercial Building Projects Over the Next Five Years



Market actors reported that they commonly track their buildings; energy performance, and that tracking this post-construction was necessary to demonstrate the building is ZNE or ultra-efficient. Figure 14 shows that

70% of market actors (44 of 63) reported that at least three-quarters of their buildings have someone tracking the energy performance. Again, this finding may be specific to this group of market actors – almost all of whom have experience with ZNE or ultra-efficient buildings. The market actors viewed energy performance tracking as part and parcel with ZNE and ultra-efficient buildings. As an interviewed architect explained, "ZNE isn't ZNE unless you can track the data."

Figure 14. Percent of Buildings Energy Performance Tracked (n=63)



Many interviewed market actors reported tracking building performance by end-use, including HVAC systems and plug loads, which is necessary to troubleshoot in case the building is not performing to expectations and when performing retro-commissioning. The literature review findings substantiated the importance of system commissioning post-occupancy to the realization of energy savings and non-energy benefits. Both literature review and market actor interview results highlight the necessity of having facility managers trained on the system controls and energy management systems. The lack of necessary submetering infrastructure or a lack of professionals trained on the energy management system prevent proper tracking of building energy performance.

Market actors had future-looking, big-picture questions about the grid. At the close of the interview, the interviewer asked market actors if they had any questions; very few did. The questions they posed reflect deep experience and understanding of energy delivery and energy markets in California. They asked:

- How will the supply/demand duck curve change building energy analysis?
- How does California, with its duck-curve, go to 100% renewable energy without grid-level storage and without importing dirty energy from other states?
- What happens to the gas company as communities go all electric?

Many of these questions mirror questions that regulatory agencies, the Investor Owned Utilities, and policy-makers are asking.

7.2 Terms Used in Market

This section discusses definitions and other terms used in the market, and how those relate to study terminologies from the TRC team's literature review and interviews. While definitions vary, it is commonly agreed that ZNE buildings achieve their goal by first incorporating high levels of energy efficiency followed by the addition of onsite renewable energy. With that general guideline, other variations on the definition exist.

Most interviewees reported they use a site-based definition for ZNE. Nearly half of the interviewees (31 of 64) voluntarily mentioned that they preferred on-site generation for their ZNE and ultra-efficient buildings or had no experience with off-site renewables for their projects. Generally, the research suggests that ZNE Site is the most often mentioned metric used in the literature review, in case studies or by organizations serving project teams. Both Architecture 2030 (2018) and the American Institute of Architecture's 2030 Commitment[14] use a site-based definition. For owners and designer, site-based is easiest to track. However, some agencies prefer using a source-based metric. For example, Department of General Services (DGS) uses a source-based metric for its ZNE efforts. One advantage to a source-based metric is that there is generally a one-to-one correlation between source-based savings and GHG savings, while a site-based metric does not directly address decarbonization in a mixed-fuel building. However, the site-based and source-based EUI will be the same for an all-electric building.

The team mentions TDV only as an approach that the California Energy Commission uses to evaluate the cost-effectiveness of energy efficiency and demand response measures for Title 24. Only two market actors mentioned that California has its own ZNE Code definition that considers TDV. One just mentioned it and the other said that he wants the ZNE definition to be "zero net carbon on a time dependent basis."

Another variation on the ZNE definition is the clarification to whether a building is *designed* to be ZNE or is *performing* at ZNE. Again, this could be measured at either the site or source level. Sometimes a third party would measure this performance, in which case it would be "ZNE Performance Verified" (TRC 2018) The market actors viewed energy performance tracking as part and parcel with ZNE and ultra-efficient buildings. As an interviewed architect explained, "ZNE isn't ZNE unless you can track the data. Anyone who says they did a ZNE building and isn't tracking isn't doing a ZNE building. That's a big difference from LEED, which is all prescriptive and very little about performance."

Another type of boundary may focus ZNE objectives on a building, community, campus, district, or portfolio scale. Other terms used in the literature include the following:

- **ZNE Building**. An energy-efficient building that, over the course of a year, consumes an amount of energy less than or equal to the renewable energy generated onsite.
- **ZNE Portfolio**. An energy-efficient portfolio or group of buildings that together consume an amount of energy less than or equal to the renewable energy generated onsite on an annual basis. The buildings included in the portfolio may be located apart from each other.
- **ZNE Campus/District**. An energy-efficient campus or district comprised of multiple buildings that annually consumes an amount of energy less than or greater to the renewable energy generated on-site.
- **ZNE Community**. An energy-efficient community that annually consumes an amount of energy less than or greater to the renewable energy generated onsite.

It is also unclear whether renewable energy must be produced on-site or whether off-site renewable energy procurement is acceptable for a ZNE building. A small number of interview participants did not think that off-site renewables fit the spirit of ZNE. For example, one architect stated, "Depending upon how much of a purist you are, some people would argue that offsite renewables are not really ZNE." The Architecture 2030's Zero Code for California (Architecture 2030, 2018) allows for the purchase of off-site renewable energy consumption to offset what cannot be generated on the site in order to get the building to zero net carbon (see further discussion on ZNC below).

The greatest discrepancy in the interview results for the definition of ZNE related to the role of onsite combustion sources. Twelve percent (12%) of respondents (9 of 78) explicitly mentioned something about excluding natural gas when talking about the definition. An additional five mentioned something about zero net carbon or no fossil fuels. In other words, 18% (14 of 78) proactively mentioned a nuance in the definition

[14] https://www.aia.org/pages/203416-the-2030-commitment-what-to-expect

related to natural gas. Gas combustion is specifically prohibited from projects in the International Living Institute's Net Zero Energy certification program.

Transition from energy to carbon. For decades, energy savings alone dominated technical and policy work in California. However, California policy is rapidly evolving from ZNE to Zero Net Carbon (ZNC). An orientation towards zero carbon directly implies more than energy savings must be involved. To decarbonize a building is to remove greenhouse gas emissions from the building's energy use, achieved through making the building more efficient and integrating appliances powered by clean energy sources. It also involves factors associated with the carbon content of the grid at any time of day or day of the year depending on the primary fuel and/or renewable energy sources used at a particular location.

Architecture 2030 defines ZNC as a "building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually" (Architecture 2030). According to Architecture 2030, a carbon metric should account for site energy use, the fuel mix used for the energy generation (onsite and offsite), and seasonal and hourly variations based on location and the fuel mix for the grid at that particular location and time. This definition includes a preference for onsite renewable sources but allows for the procurement of energy from offsite and local renewable sources to offset building energy.

At the time of publication of this report, the State of California does not have an accepted definition for zero net carbon within California, though the California Energy Commission, California Air Resources Board, and California Public Utilities Commission are all working on developing carbon metrics that can be used towards zero carbon buildings.

7.3 Drivers and Barriers to ZNE

The following section provides more information on drivers and motivations to ZNE and ultra-efficient buildings. This section begins with a discussion of decision making for pursuing ZNE.

Nearly all interviewed market actors agreed (69 of 76; 91%) that the property owner is the person who most influences the decision about whether a commercial building will be ZNE or exceed the energy code. One-fifth of these respondents also voluntarily added that the design team is integral to the execution of the decision and the achievement of the performance goal. The literature review findings corroborate the importance of the design team in the realization of a ZNE building, especially when one of them acts a champion for the project. In fact, the TRC team found a couple ZNE buildings where design team members were the real influencers because they convinced the property owners to strive for a ZNE building. Interviewed market actors agreed that design team members can often guide the decision-making and named the architect as the second most influential actor in making the decision to go ZNE. For public entities, the property owner making the decision is often the City Council or City Manager at local governments and the Board of Trustees, President, or Chancellor for Universities, for example.

7.3.1 Drivers

Results from the literature review and market actor interviews indicate there are several key drivers for the market to construct ZNE and ultra-efficient buildings. These drivers include:

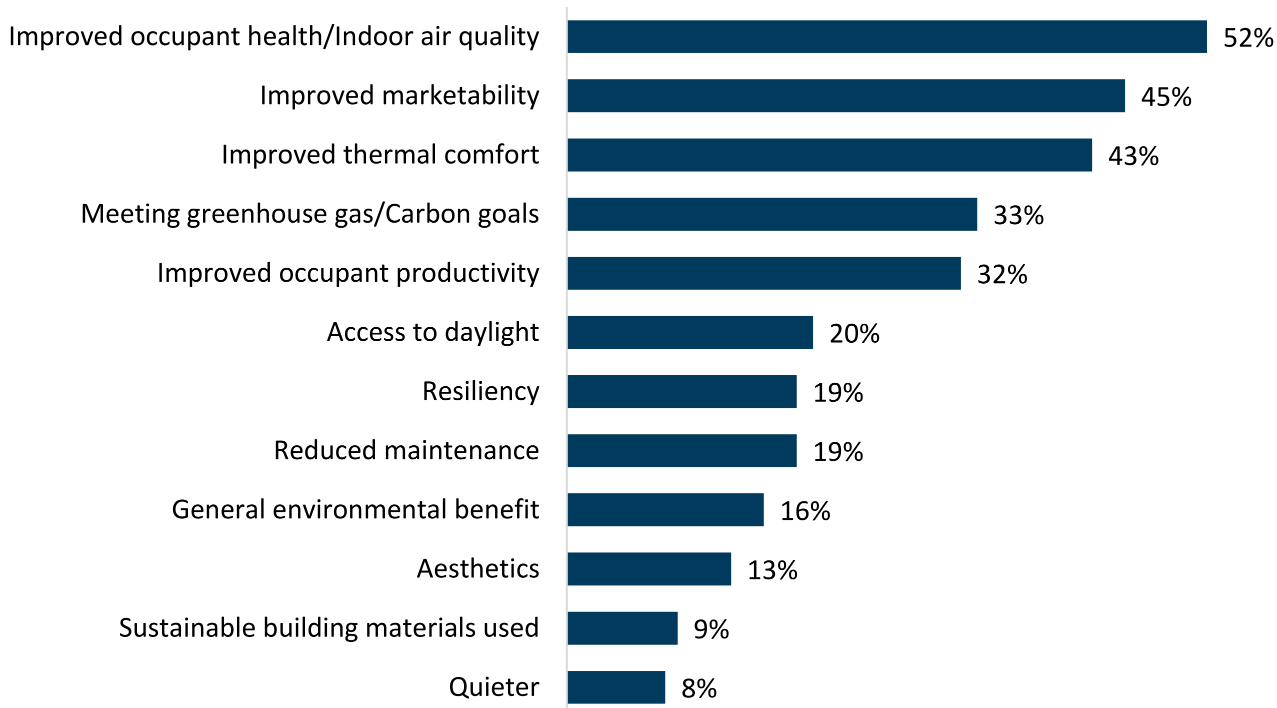
- Non-energy benefits to building owners and occupants
- Policies that support ZNE
- Organizational missions that value ZNE
- Long-term cost savings
- Design team leadership
- Incentive programs that support ZNE

We provide more detail on each these drivers below.

ZNE buildings offer non-energy benefits to building owners and occupants

Market actors reported that ZNE and ultra-efficient buildings have a variety of non-energy benefits associated with them, including an improved indoor environment (better thermal and acoustic comfort, improved air quality, and access to daylight) which, in turn, improves occupant productivity. Additionally, organizations that occupy ZNE or ultra-efficient buildings can market their commitment to the environment, attract green-minded tenants, and meet their carbon or GHG reduction goals. Figure 15 shows all the non-energy benefits of ZNE and ultra-efficient buildings market actors reported.

*Figure 15. Non-Energy Benefits of ZNE and Ultra-Efficient Buildings Reported by Market Actors (n=75) **



* Multiple response allowed

The literature review substantiated what market actors reported about non-energy benefits of ultra-efficient buildings and measures. For example, tighter seals on refrigerated display cases in grocery stores save energy and improve shopper comfort because less cold air is leaking into the aisles. Additionally, developers such as DPR Construction have reported that ZNE buildings attract tenants willing to lease at a higher value, lower long-term operating costs, and reduce tenant turnover.

Policies that support ZNE

California government agencies have enacted policies to operationalize ZNE goals set forth in the Plan. The literature review revealed that in 2008, California published the first Energy Efficiency Strategic Plan which established ambitious goals for the development of ZNE buildings (CPUC 2008, 2011). The Plan stated:

- All new residential construction will be zero net energy (ZNE) by 2020.
- All new commercial construction will be ZNE by 2030
- 50% of commercial buildings will be retrofit to ZNE by 2030

A few examples of the policies put in place that support the Plan are:

- California Executive Order B-18-12 requires that all new state buildings and major renovations designed after 2025 be ZNE.
- The University of California system is committed to achieving carbon neutrality for campus operations by 2025 for direct emissions and purchased energy.
- The San Francisco Unified School District developed sustainability goals including being carbon neutral by 2040.

Organizational missions that value environmental stewardship can lead to ZNE

An organizational environmental commitment is a strong driver for some private owners and owners are generally (although not always) the one that most influences the decision about whether a commercial building will be ZNE or exceed the energy code. The literature review showed that organizations such as Kaiser Permanente and Gunderson Health Systems embrace environmental stewardship and have taken actions to lower their carbon footprint and showcase that to their clients and customers. Because the property owner is most often the individual or organization that most influences the decision to pursue a ZNE design, according to market actor interviews, an owner with a sustainability ethos is currently critical to owners constructing a ZNE building.

The motivations that influence the decision to pursue a high-efficiency building varied. Some market actors said that non-energy benefits motivate non-profits and commercial entities who want to use the image of sustainability in their marketing, while energy bill savings are a driver for owner-occupied buildings and long-term ownership situations, including K-12 schools. Nearly one-third of market actors said that the motivations did not differ between building types or sectors (13 of 41; 32%).

Long-term cost savings associated with ZNE

Case studies found during the literature review demonstrated that ZNE buildings cost less to operate than standard code buildings. Several case studies show that ZNE buildings reduce operating expenses which can boost the bottom line and increase return on investment for owners and developers. For example, DPR Construction is a national general contractor and construction manager. After working on their first ZNE new construction project, Packard Foundation Headquarter, DPR made a commitment to confirm that ZNE retrofits were possible and establish a financial case for ZNE. Since then, DPR has opened four ZNE offices in San Francisco, San Jose, Phoenix and San Diego following a strict pro forma with acceptable financial returns.

ZNE Champion and Team Commitment

The literature review and the market actor interviews revealed that ZNE projects would not be possible without a champion and the commitment of the design and construction team. As noted above with DPR Construction (see Long-term cost savings associated with ZNE), some firms have a proven track record of success. They have positioned themselves as industry leaders, demonstrating not only proof of concept with ZNE commercial buildings, but also replicability. Additionally, the literature review found several cases of organizations constructing a ZNE building despite issuing RFPs for a non-ZNE new construction project. The organization selected a ZNE proposal because the design team demonstrated that a ZNE building was possible within a “standard building” budget. One-fifth of market actor interview respondents noted that the design team is integral to the execution of the decision and the achievement of the performance goal. The architect was named as the second most influential actor, after the building owner, in making the decision to go ZNE.

Incentive programs that support ZNE

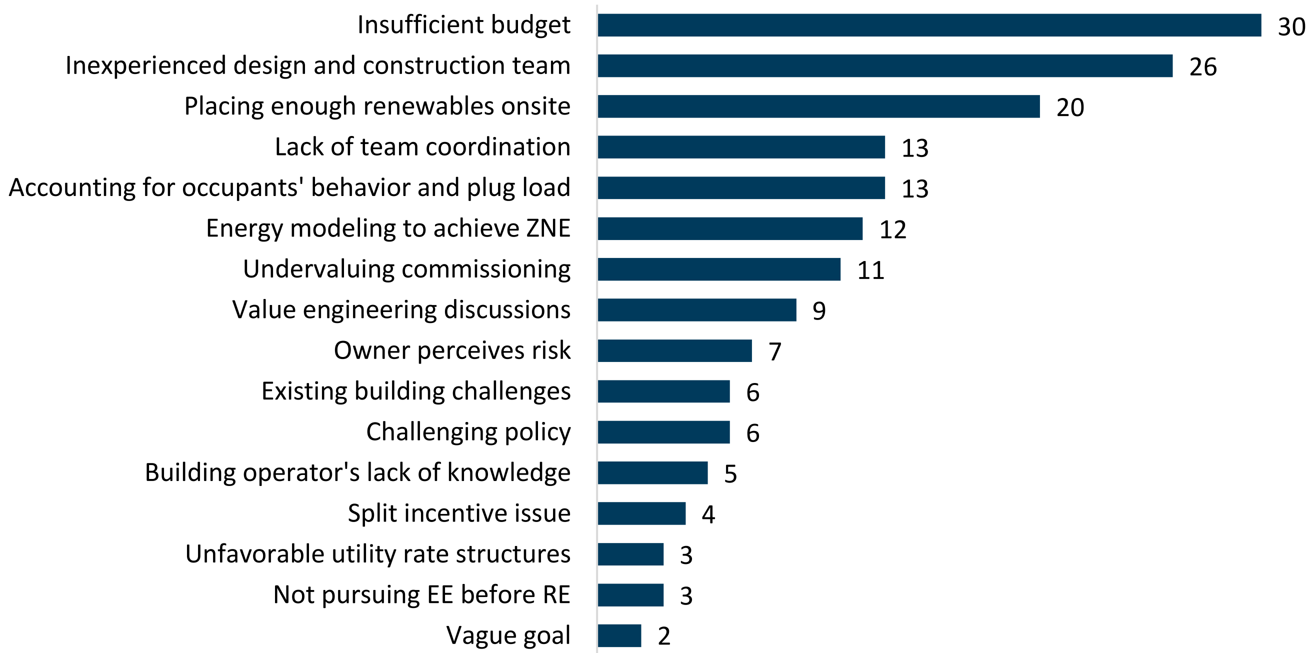
Energy efficiency incentive programs can sometimes be a driver of ZNE projects by providing additional funding to off-set some costs. The literature review found that several school districts in California, including some of the largest like Los Angeles and San Francisco, are moving forward with ZNE roadmaps and additional projects that incorporate deep energy efficiency, renewable energy systems, and electric bus integration because of incentive programs that support ZNE efforts.

7.3.2 Barriers

The California commercial building market and its market actors face barriers that may prevent or delay success in the transition to ZNE. Many of these barriers are consistent with well-documented barriers to energy efficiency, including: imperfect information, split incentives, externalities, and imperfect competition (Vaidyanathan 2013). In addition to these common barriers, ZNE commercial buildings face ZNE-specific barriers which the below section describes in more detail. The number that follows each challenge denotes the number of market actors that identified this as a barrier. For example, 30 market actors identified insufficient budget.

Figure 16 shows the barriers and challenges that market actors identified to ZNE and ultra-efficient buildings, with the numbers after the bar indicating the count of respondents indicating the issue as a challenge.

*Figure 16. Barriers and Challenges to ZNE Buildings (n=78) **



* Multiple responses allowed.

As shown in Figure 16, market actors identified insufficient budget, inexperienced design and construction team, and placing enough renewables onsite as challenges most often. The following subsections provide more detail on responses.

Cost concerns

- **Concerns with first incremental costs for ZNE and ultra-efficient buildings.** Building owners and professionals are concerned about the extra costs associated with going ZNE including energy modeling, integrating controls, and installing on-site renewable energy. Part of their concern is related to the difficulty in defining the bottom-line costs of ZNE buildings is challenging due to the wide variability of factors related to the design and construction of buildings. Several market actors corroborated this sentiment, saying that, in their experience, building owners were not willing to pay the price premiums for this type of work. Furthermore, there is great uncertainty about how much the normalized cost of a ZNE building varies. For instance, the literature review showed that ZNE buildings – offices and schools mostly - could cost as little as $175 per square foot to as much as $909 per square foot. Section 8 describes in greater detail market actors estimates of the incremental cost and what the literature review revealed about incremental costs. In addition, owners and developers may be reluctant to aim for a ZNE building because they find new technology risky or are unsure if they can sell or rent the finished building.

- **Value engineering discussions:** When the owner is focused on the ZNE goal and the budget is dwindling, the team will engage in value engineering to identify what project components they can cut to save money while maintaining the building's high performance. However, when this occurs, the team needs to make changes to the design and energy models; market actors reported that they will sometimes get pushback from the design team or energy modelers because they do not want to have to re-run their models. A project champion must ensure the most important energy efficiency items are not subject to value engineering. We discuss strategies to avoid value engineering more in section 9.1.

- **Insufficient budget:** More than one-third of the interviewed market actors (30 of 78) mentioned budget constraints as a challenge. The project budget may not always be large enough to account for the additional design team analysis to investigate ZNE or the various components needed to achieve a ZNE building. These components may include efficient mechanical and lighting systems, additional envelope and air tightness measures, and sufficient renewables to offset the building's energy load. Eight of the 30 market actors who mentioned budget as a barrier specifically said the budget for onsite renewables can be a challenge.

Lack of Awareness or Experience

The lack of awareness impacts all aspects of the commercial building market.

- **Inexperienced design and construction teams stick with what they know.** Engineers and contractors inexperienced with high performing buildings are often reluctant to work with new systems with which they are unfamiliar. Interviewed market actors described "entrenched attitudes" where the design teams specify familiar equipment and will push back or attach a price premium to their services if they must work with different equipment. One interviewed construction manager reported:

"The big reason why we don't see more ZNE buildings is that construction is an exceedingly complex and hassle-prone endeavor. ZNE strikes fear in the heart of everybody, especially contractors. If that fear is not dispelled, owners will see very big price tags from the construction industry. They need to cover themselves for unforeseens. That is the biggest reason that prevents the project from going ZNE. The owner sees the price tag and wants to eliminate some feature."

Another market actor said, "there is a lot of ignorance and stubbornness" and a third reported "the human factor is the biggest challenge at this point in time."

- **Lack of team coordination:** Weak coordination of the design and construction teams throughout the duration of the project can make it challenging to reach the energy goal. Market actors reported that it is essential to repeatedly communicate the owner's energy performance or labeling goal to the design, construction, and maintenance teams, so they can follow through with these goals. Ensuring everyone is on the same page and "rowing in the same direction," as one interviewee put it, makes them less likely to suggest eliminating components through value engineering and makes it more likely to realize the ZNE design in construction.

- **Vague goal:** When an owner says they want a green or sustainable building, but do not settle on a specific goal, it makes it more difficult to achieve the high-performance building because the design team is unsure of the goal. Market actors recommended deciding on a specific goal and making sure the design team is committed to it, so as not to eliminate that options that could have made a big difference on the way to ZNE. Section 9.1.3 (Strong Goals) discusses the importance of goal setting further.

Technological Challenges

The list of **early ZNE projects has made apparent that not all building types and locations will have access to enough onsite renewable energy to achieve zero** due to the available site solar budget**.** This may be because the building is located in a climate less favorable to ZNE or it may be because the building has a high energy use intensity (for example, hospitals or restaurants), due to shading of photovoltaics by trees or adjacent buildings, or because the building has many stories and not enough roof space to offset consumption with production. Other technological barriers include difficulties with energy modeling, convincing owners to pursue energy efficiency before renewable energy, siting renewables onsite, underestimation of the importance of system commissioning, and constraints in existing buildings. The following provides more detail:

- **Accounting for occupants' behavior and plug load in early energy models:** Planning for the types of appliances and equipment that will be plugged in and contribute to the building's energy load can be challenging to estimate and model. The energy modeler should consider whether they need to adjust the default inputs for occupancy periods and plug load to reflect what is expected during occupancy. Some market actors mentioned the need for occupant engagement so that the occupants' behavior does not appreciably contribute to the energy load.

- **Not pursuing energy efficiency before renewable energy:** A technological barrier that also has elements of lack of awareness is the appropriate balance between efficiency and renewables in ZNE and ultra-efficient buildings. A few market actors interviewed mentioned an educational challenge of convincing owners to pursue energy efficiency to the greatest extent they can before adding renewable energy. This is particularly important because of the challenge of placing enough renewable energy onsite to offset the building's energy load.

- **Placing enough renewables onsite:** Not all building types and locations will have access to enough onsite renewable energy to achieve ZNE due to the available site solar budget**.** Industrial buildings and high-rise buildings with little roof space relative to the conditioned space make it challenging to place enough renewables onsite to offset the building's energy load. Trees and adjacent buildings may shade PV panels, reducing their generative capacity. Sometimes PVs can be placed in parking lots or renewable wind energy can be used to supplement the building' energy generation. See section 9.2.1 (Renewable Energy) for more discussion on when renewables need to be placed offsite.

- **Undervaluing commissioning:** Some property owners undervalue system commissioning, yet it is necessary to ensure that the building performs according to the design parameters. Interviewees said it is important to allocate budget for commissioning and ensure the building operators have technical knowledge on controls. Complex systems with more controls have more potential points of failure, and trained commissioners are integral to maintaining optimal performance. Also, once people occupy the building post-construction, retro-commissioning may be warranted to adjust the system's performance and reduce energy usage.

- **Existing building challenges:** Technical challenges are more common in existing buildings than new construction projects. Market actors said there are "more constraints" and fewer things you can control with existing buildings, which increase risk and cost. If the building remains occupied during the renovation, it is a challenge to address each of the systems one by one without disrupting the building occupants too much.

Challenges Posed by Ordinances and other Regulations

Jurisdictional codes and regulations can hinder the unique needs of ZNE and ultra-efficient buildings. Some examples mentioned in interviews and documented in the literature review include:

- Historic building ordinances may prevent installation of solar PV panels or efficiency measures when they affect the historic aesthetics or character of the building

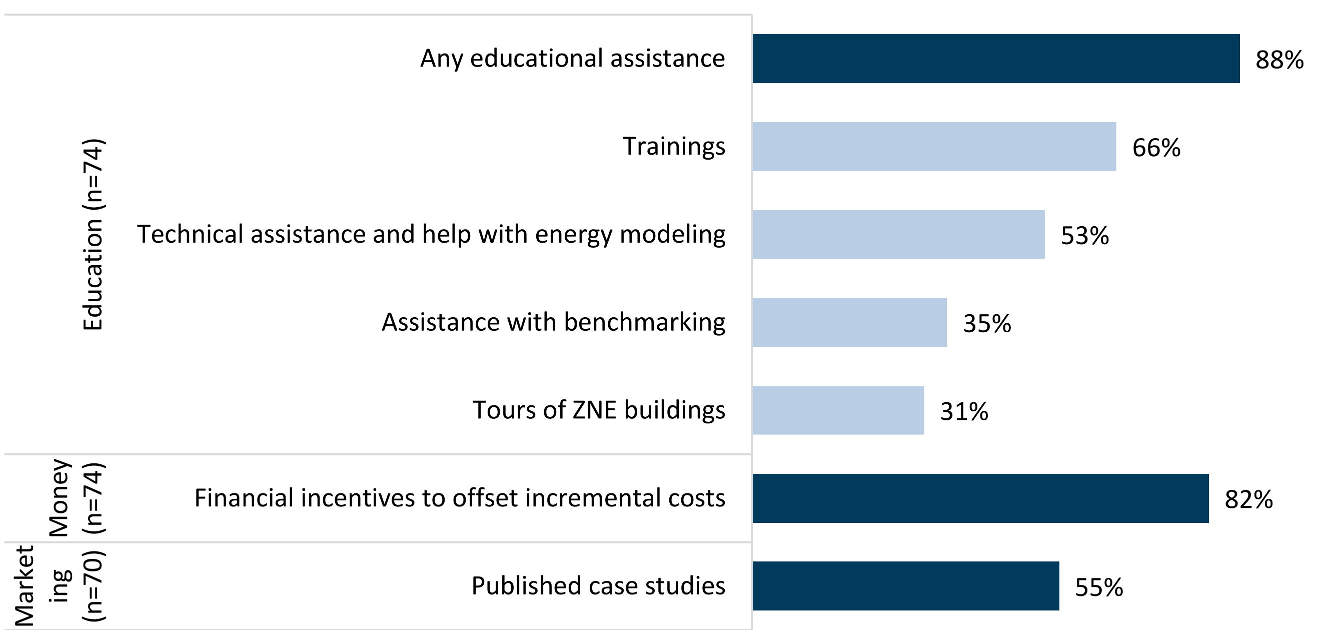
- Height limitations and roof ordinances can prevent installation of solar PV panels when the building is already at or close to the height limitation
- Tree ordinances can prevent removal of trees shading solar PV panels
- School design regulations prevent any equipment that would increase the weight of equipment on the roof without a review by the California Division of the State Architect (DSA), which can increase the timeline for solar PV installations and retrofits involving rooftop HVAC installations.
- Several utility rules and regulations pose challenges, including that time- of- use rate structure makes it more challenging to calculate return on investment, the grid intertie agreements can be complicated and require significant labor to complete, and net metering laws may affect the return on investment.

7.3.3 Assistance Suggested by Market Actors

The TRC team asked market actors for recommendations of assistance that would be useful to overcome challenges to ZNE. Figure 19. shows responses, with the dark blue bars grouping total responses by catgory, and the light blue bars showing specific respones.

Educational assistance related to ZNE was as important to respondents as financial incentives. Eighty-eight percent of respondents indicated receiving some type of educational assistance related to ZNE would be useful to their firm. Of those, most were interested in trainings or technical assistance and help with energy modeling. Fewer were interested in benchmarking assistance or tours of ZNE buildings. Most respondents (82%) indicated financial incentives would be helpful and about half (55%) indicated marketing support via published case studies would help staff at their firm. No significant differences were seen between owner and technical respondents, by ZNE experience, or by market actor type. Due to interview time constraints, the TRC team did not ask about prior training taken by each market actor.

Figure 17. Requested Assistance from Market Actors



8 Cost of ZNE and Valuation

Cost is the biggest consideration for market actors, as reflected in the interview results. It is challenging to incremental costs of ZNE and ultra-efficient buildings. Little data exists on the costs of construction – for both ZNE and ultra-efficient buildings, and for to-code buildings. In addition, project teams do not typically build one ZNE or ultra-efficient building, and the same building constructed to code next door. Costs also vary significantly by location, building type, and other factors. However, the TRC team was able to collect some incremental cost data, presented here. The TRC team also gathered estimates of the difference for operating and maintaining ZNE and ultra-efficient buildings compared with to-code buildings, and identified past studies that have shown increased valuation of beyond code buildings. This section provides these results.

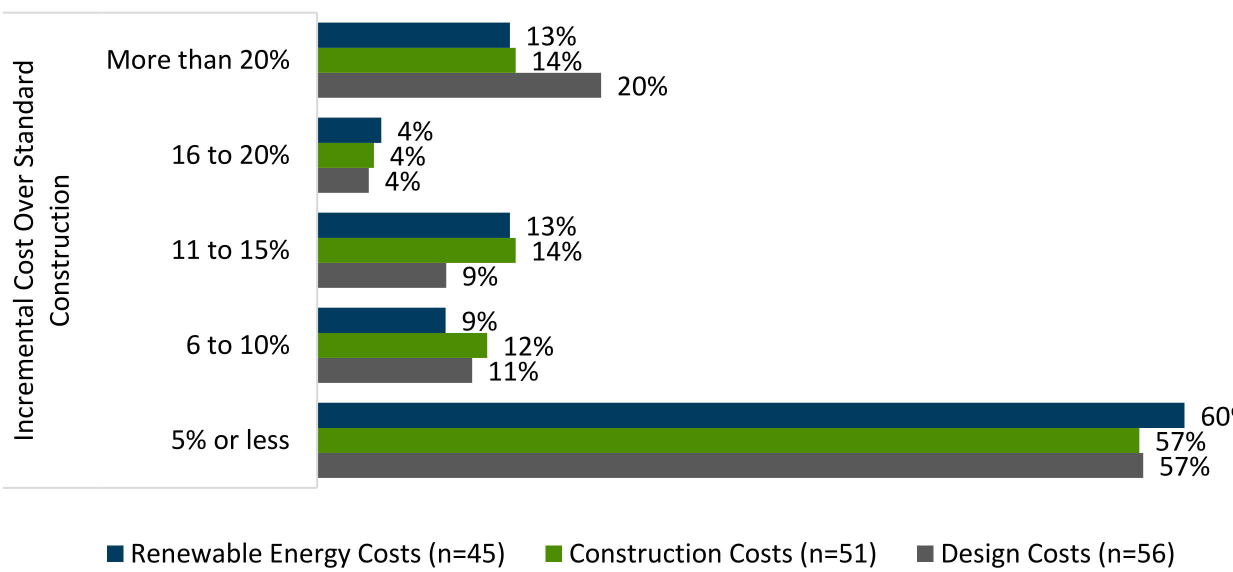
8.1 Incremental Cost Estimates

This section provides estimates of incremental costs. Section 9 discusses strategies to reduce incremental cost.

Overall, this study found that ZNE and ultra-efficient buildings typically requires a low to moderate incremental cost for design and construction.

Many market actors reported it is very challenging to estimate incremental cost to ZNE and ultra-efficient buildings. However, as shown in the figure below, **most interviewees estimated that achieving ZNE or ultra-efficient added five percent (5%) or less to the overall project cost compared to standard construction.** Their estimates were similar across the various elements of building ZNE and ultra-efficient projects, including the cost of on-site solar PV. Of those able to provide an estimate of the incremental costs of building ZNE and ultra-efficient, about three-fifths of respondents reported that the incremental cost of achieving ZNE or ultra-efficient was five percent or less for design, construction, and renewable energy. Responses did not vary significantly by whether the respondent had ZNE, ultra-efficient, or above code building experience nor by whether the respondent was a property owner/developer or on the design/construction team. Approximately one-third of respondents could not provide answers to the cost questions, and they are not included.

Figure 18. Incremental Cost Estimate of ZNE



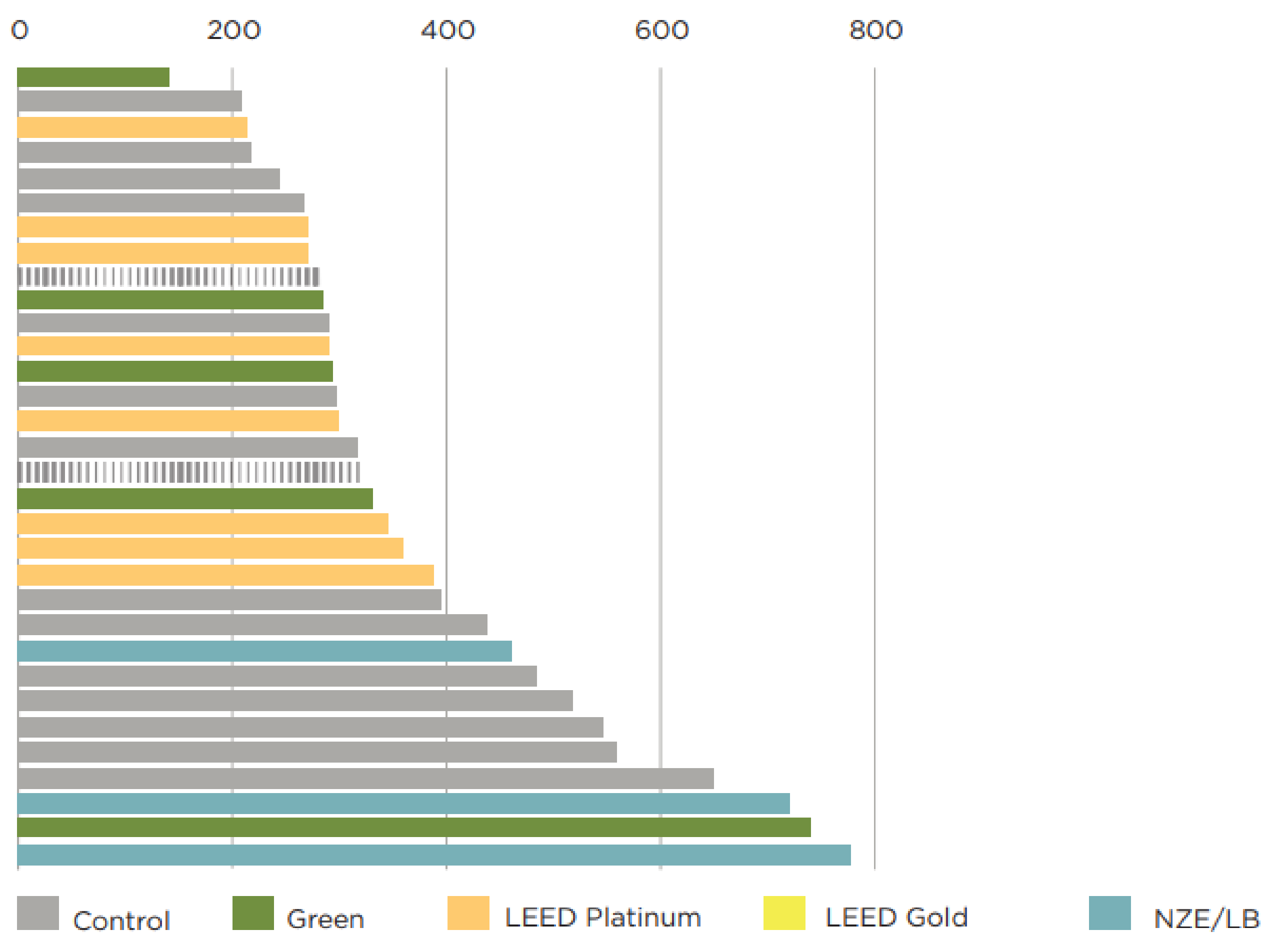
Literature shows that ZNE buildings have a low to moderate incremental cost. A 2013 study compared buildings built to "green" standards to comparable code or business-as-usual ("control") buildings (Lesniewski et al. 2013). The study clearly stated:

> "comparative cost studies tend to come up with a hard number or percentage increase for an answer. This can be misleading in that the audience tends to take that number as definitive and predictive. In

truth, the ultimate cost of sustainability on a given project will be particular to that project, and to that team and client."

The study investigated detailed information on 200 buildings and found sufficient cost data to support a detailed analysis on 88 buildings. It normalized for location, year built, and similar building types and program. The dataset included buildings distinguished as "green", LEED and ZNE via the International Living Future Institute (ILFI) Living Building Standard. The buildings studied included K-12 schools (eight), community centers (five), low-rise offices (five), and wet labs (three). While the data set is small, as shown in **Error! Reference source not found.**, the study found that buildings built to ZNE have been competitive with control-group buildings in the small sample set.

Figure 19. Cost Comparison ($ per square foot) of ZNE, LEED-Platinum, Green, and Standard Practice Buildings (Source: Lesniewski et al. 2013)



The Lesniewski (2013) study also looked at building cost compared to energy consumption. Again, the data set for this research is small. However, it indicates that buildings on the lower end of the EUI scale are not necessarily the most expensive buildings.

A report of ZNE buildings in the Washington DC area (ILFI et al. 2013) also mentioned that understanding costs for getting to zero are difficult to distinguish from overall project costs. This report concluded that there is an incremental cost to get to ZNE compared with LEED Platinum buildings. The 2013 study estimated an incremental cost for of offices of 8% for new construction ZNE and 16% for retrofit ZNE compared with Platinum. However, as described in the section 8.2, the study found the return on investment for the new office and other cases is estimated to be greater than 30%. Consequently, the reduced energy bills would more than outweigh this incremental cost.

A study of ZNE buildings in Vermont (Maclay Architects, 2015) compared ZNE and ZNE-ready designs to a code baseline design. For the open and closed offices, results indicate that ZNE buildings had an incremental cost of approximately 7% for ZNE-ready (just energy efficiency measures) and 14-16% for ZNE (cost of energy efficiency and PV)[15].

Figure 20 summarizes incremental cost findings for offices from the literature. It is important to note that none of these findings are specific to California.

Figure 20. Summary of Cost Findings for Offices from Literature Review

Study	Cost Finding
Lesniewski (2013) for low-rise office buildings across North America	Construction costs per square foot ranged[16] as: Code: $205-$650 (n=16) Green (AIA COTE Top Ten): $150-$740 (n=5) LEED Platinum: $210-$390 (n=8) ZNE or Living Buildings Challenge: $430-$875 (n=3) In general, ZNE is in higher range of standard costs, but within range of "standard" practice
ILFI et al. (2013) for offices buildings in Washington, DC	8% more for new construction and 16% more for retrofits compared with the baseline of LEED Platinum buildings in DC. (Based on the Lesniewski study, LEED Platinum does not have an incremental cost compared with code.)
Maclay Architects (2015) for office buildings in Vermont	7% for ZNE-ready, 14-16% for ZNE compared with code

In general, the literature reviewed here (which reflects national data or studies specific to Washington DC or Vermont) indicated *higher* incremental costs than what the California market actors reported in interviews conducted here. The differences may be because it costs less to reach ZNE in California due to the mild climate (lower heating and cooling needs), because California has a more stringent energy code[17] and the market may have more experience with ZNE than other areas of the United States, because these studies are old, and the costs for renewables continues to decrease or for other reasons.

The TRC team also identified absolute costs for ZNE and ultra-efficient buildings for a handful of California commercial buildings (See Figure 49 in Section 13.1.4). On a per square foot basis, the inflation-adjusted costs ranged from $183 to $1,030 per square foot. Because construction cost data for comparable buildings (to-code buildings constructed in the same area) was not available, the TRC team could not estimate incremental cost for these buildings. However, based on our industry experience, these cost estimates are within the range of reasonable for California commercial buildings.

The following subsections provide more detail on the design, construction, and renewable energy costs of ZNE and ultra-efficient buildings.

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[15] Incremental cost estimates were higher for the category "office and light manufacturing".

[16] Values are shown in the report as a graph. The TRC team estimated costs based on a visual inspection of the graphs.

[17] It was beyond the scope of this study to investigate the size of the U.S. market (outside of California) that adopts and enforces the latest version of ASHRAE Standard 90.1.

8.1.1 Incremental Design Costs and Energy Simulations

The majority of interviewees in this study (57%) reported that incremental design costs were 5% or less compared with standard construction. However, interviewees reported that design costs were slightly higher than the construction or renewable energy costs of ZNE and ultra-efficient buildings, and one-fifth of interviewees reported design costs were 20% or more. Interviewees reported the additional design costs largely come from the increased time it takes to do energy modeling beyond what Title 24 requires, additional communication between project team members, and additional investigations for project design options.

The literature did not break out costs for design specifically. The literature did identify energy modeling needs as greater for ZNE buildings but found this is a key strategy for reducing overall costs and energy consumption. Energy modeling in ZNE buildings is different from the documentation of design decisions for code compliance or a voluntary rating system like LEED. The case studies from the literature review reveal that in ZNE buildings, energy modeling is used as an iterative process to inform continual design refinement and optimization of the building to meet the within the cost allowance (Dean and Turnbull 2014, 2016 and 2018). This attention continues throughout construction, through value engineering and into construction and commissioning to evaluate how changes impact the anticipated energy performance.

8.1.2 Incremental Construction Costs

The majority of interviewees in this study (57%) reported that incremental construction costs were 5% or less compared with standard construction; the team split remaining respondents evenly in estimating construction costs were 6-10% higher, 11-15% higher, or more than 20% higher (11%, 14%, and 14% of respondents respectively). A few respondents noted that experience matters – i.e., after a contractor has done a couple ZNE projects, they learned their lessons and can now do ZNE for a similar price to standard construction. However, these contractors cost more. The literature did not break out costs for construction in a way that could be easily compared and analyzed.

8.1.3 Renewable Energy Costs

The majority of interviewees in this study (60%) reported that incremental costs for renewable energy was 5% or less compared with standard construction; most of the remaining respondents reported renewable energy costs were 11-15% or more than 20% compared with standard construction (13% each). Interviewees in this study reported that incremental renewable energy costs could add as little as zero percent – if they do a third-party PV – to as much as 70%, and costs can be particularly high if a new transformer must be added.

The literature illustrated a steady decrease in PV costs over time – a dramatic price drop of 67% from 2010 to Q1 2018 – mostly from 2010 to 2013, and a slight decrease of 2.6% from Q1 2017 to Q1 2018 (DOE 2018). This indicates the costs of PV may decline due to natural market forces.

8.2 Operation and Maintenance Cost Estimates

There is little doubt that ZNE and ultra-efficient buildings will have lower utility bills because of reduced energy use. However, this study found mixed results on whether ZNE and ultra-efficient buildings cost less to operate and maintain compared with standard practice buildings, because of possibly greater operational needs.

Interviewees were split into thirds for estimating that operation and maintenance would cost more, less, or about the same for a ZNE or ultra-efficient building compared with standard practice buildings.

- Seventeen respondents estimated that operating and maintaining a ZNE or ultra-efficient building would cost 14% more, on average, than a standard building. This additional cost results from the need to find qualified staff to run an ultra-efficient building, and operations staff need to pay more attention to operating, tuning, and retro-commissioning ZNE and ultra-efficient buildings.

- Fourteen respondents estimated that a ZNE or ultra-efficient building would reduce operations and maintenance costs by 31%, on average, because of the energy savings.
- Thirteen respondents reported no difference in operations and maintenance costs, because the energy savings offset any additional staff costs.

The literature supported that energy costs would be lower in a ZNE or ultra-efficient building, but that proper operation of a ZNE building is instrumental to ensuring that the building performs with low energy use.

In addition, scenario analysis conducted for commercial buildings in Washington DC (ILFI et al. 2013) found that – while the incremental cost for ZNE office retrofits compared to a code-built building (16%) was higher than for office new construction (8%), the ROI for retrofits was also higher for retrofits, since retrofits provide the opportunity of higher energy savings. Overall, the study found that when ZNEs are assessed on a lifecycle cost, they can financially outperform most standard buildings.

In addition, a meta study of above-code buildings supports the finding that energy savings are high. A study of over 175,000 commercial buildings in Los Angeles for 2005 to 2012 compared monthly energy consumption of above-code buildings (LEED, ENERGY STAR, and Better Buildings Challenge) with non-participating buildings and found average energy savings of 18 to 19% (Better Buildings and ENERGY STAR) to 30% (LEED)[18].

8.3 Valuation of ZNE, Ultra-Efficient, and Beyond Code Buildings

While data are sparse for ZNE and ultra-efficient buildings, studies have shown an increase in valuation for beyond code buildings. According to a DOE (2015) analysis of several meta studies[19], past studies that sampled thousands of commercial buildings nationwide found that – compared to non-rated buildings:

- LEED buildings have a 15-17% and ENERGY STAR have a 7-8% premium in rental rates over similar non-rated buildings.
- LEED buildings have a 16-18% and ENERGY STAR have a 10-11% higher occupancy rate than non-rated buildings.
- LEED buildings exhibit a 10-31% and ENERGY STAR buildings a 6-10% premium in sales prices.

Since the majority of market actors interviewed here reported that the incremental cost for ZNE and ultra-efficient buildings is 5% or less, if ZNE and ultra-efficient buildings have valuations at least as high as LEED and ENERGY STAR, payback for the incremental cost may be immediate or less than one year.

The TRC team explored the Costar data set to attempt to compare rent prices (per sq. ft) of ZNE and ultra-efficient offices with similar properties in their submarket – i.e., those in the same geographical location and class of office space. The TRC team could not draw any conclusions based on the comparison, in part because the ZNE or ultra-efficient buildings often had different rent structures (e.g., triple net) compared to the submarket rent (full service). However, one interesting finding was that **the fifteen ZNE and ultra-efficient office buildings in the Costar database were a mix of class A, B, and C spaces.** This indicates that the ZNE and ultra-efficient market is serving the high-end of the market (class A) as well as middle and lower ends (classes B and C respectively).

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[18] USGBC 2017 https://www.usgbc.org/articles/new-research-supports-business-case-leed

[19] DOE 2015 https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Energy%20Efficiency%20and%20Financial%20Performance_12_2015.pdf

9 APPROACHES TO ZNE

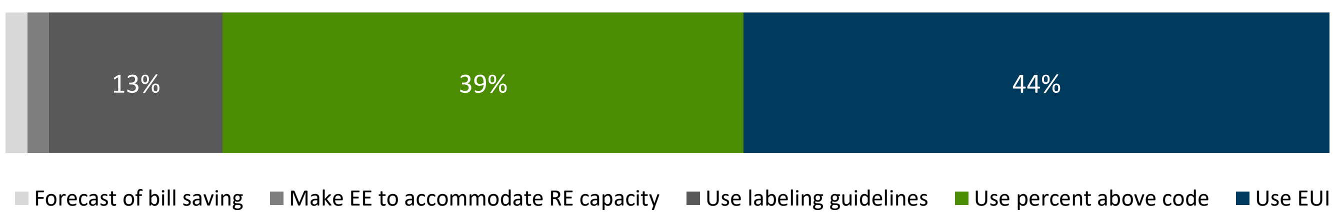
This section provides information on how buildings achieve ZNE and ultra-efficient buildings. The first subsection focuses on whole building practices (including team coordination) and energy efficiency strategies. Market actors indicated that many of these strategies can reduce incremental cost of building ZNE and ultra-efficient buildings. The second subsection focuses on distributed generation practices – including solar PV.

9.1 Approaches to ZNE and ultra-efficient buildings

The literature review and stakeholder interviews identified a number of key patterns and lessons learned associated with successful approaches in ZNE. The below section describes these in further detail.

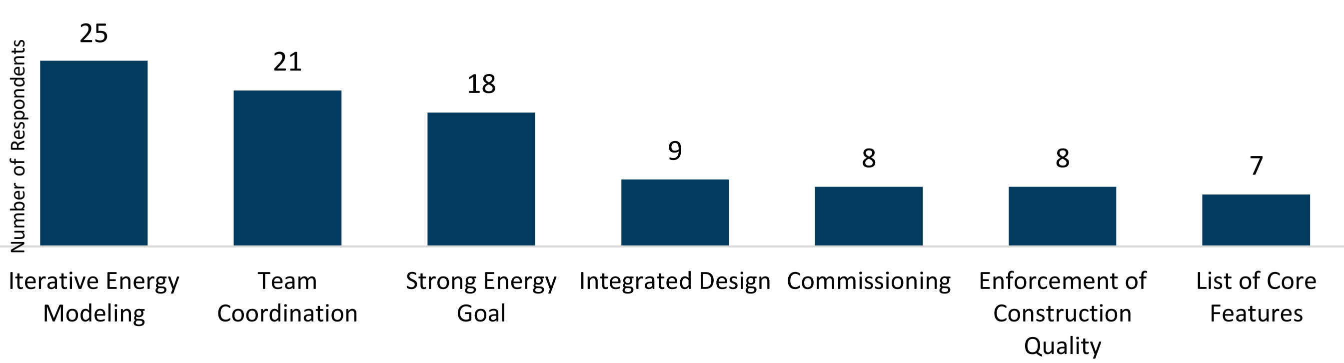
Most interviewed market actors establish clear efficiency and renewable energy goals for their projects during the conceptual design phase. Both market actors and the literature review findings indicate that establishing the energy goals early in the project is important to setting design team expectations and setting up to achieve the goal. Of the market actors who specified how they measured their energy efficiency goals (n=61), a bit less than half (44%) used an EUI value and two-fifths (39%) used a percent above code value. Far less (13%) reported using labeling (e.g. LEED) requirements or other techniques. As an example, the literature review found that the San Francisco Unified School District (SFUSD) uses a EUI goal across their portfolio.

Figure 21. Targets for ZNE Projects (n=61)



Market actors experienced with ZNE and ultra-efficient buildings learned a variety of approaches to ensure that energy goals are met in later stages of a project, particularly when value engineering comes into play. In particular, **they emphasized the importance of iterative energy modeling to test options and strong coordination among team members to align their efforts with the energy goal**, among others. We elaborate on these strategies and more, following Figure 22.

*Figure 22. Strategies to Ensure Energy Goals Are Met (n=68) **



* Multiple responses allowed.

9.1.1 Experienced Team, Iterative Energy Modeling, and Integrated Design

Both the interviews and literature review indicated that an experienced project team reduces costs of ZNE and ultra-efficient buildings. Multiple interviewees noted that construction ZNE or ultra-efficient buildings becomes less costly after the project team has constructed one or more.

The literature review found that the **early-design or pre-design stage was essential to producing a ZNE building**, something the market actors reinforced. A skilled energy modeler who can run scenarios to see how a decision affects the building's energy performance was one of the most important strategies interviewees mentioned to ensure their team meets its energy targets. The energy modeler can inform the decision-makers about the financial and energy implications of changing different building components and how they affect each other.

Along these lines, seven interviewees said that having a "basis of design" is another tool they use to meet energy targets. The literature review also found this to be important because it serves as the primary document that translates an owner's needs into a narrative that outlines specific building approaches such as building envelope, mechanical, electrical, plumbing, security systems, and building automation system. Interviewees said that having such a list to refer to is helpful when value engineering conversations arise, and frequently referencing the list helps remind the project team of the energy goals and keeps them on track. Although a basis of design is currently required in Title 24, the code requirement by itself may not be enough to address general market reluctance to do a proper "basis of design."

Market actor interviews indicated **that integrated design at the start of the project minimizes chances that any one system or design feature will be nominated for elimination** (9 of 68). To illustrate, the building's orientation and amount of glass influences the daylighting which influences the amount of lighting needed, which affects energy load, which affects PV sizing. Similarly, projects can invest in additional insulation, air sealing (i.e., reduced infiltration), and heat and energy recovery ventilators to enable downsizing and potentially simplifying mechanical systems. Changing any one component will necessarily affect other components. When team members understand that all the components have been modeled to be interactive, they will be less likely to suggest changes to any one of them. The review of case studies suggests that most, if not all, ZNE building teams start an integrated process early in design, and designers weave the building systems together in an integrated design process (Reeder 2016). Proper building-site orientation and passive systems result in reduced mechanical system size and smaller electric meters which can reduce first costs. The project team translated aggressive air infiltration reduction goals into construction practices to deliver a thermally tight envelope that reduces mechanical heating and cooling demands. They also integrated building systems with controls to operate only when necessary. These practices collectively reduce energy use and drive down first costs.

9.1.2 Team Coordination

The second most important strategy to meet energy targets reported by market actors, and a key lesson learned from the literature review, was having an internal champion to coordinate team members. The champion ensures team members understand the ZNE goal and that their activities stay aligned with that goal. In these situations, the team members offer design or equipment suggestions to cut costs while still maintaining energy efficiency and meeting the owner's goals. Having a core list or basis of design to refer to guides these conversations. One market actor summarized the team coordination necessary when cutting costs in the following way:

"You need to make sure that your energy modeler stays involved and shows the impact of any value engineering decisions and makes sure the team understands the key design features that really impact energy use and comfort. So, when there are value engineering conversations, the key items that make the building perform well stay in, while the extras like aesthetics might get cut."

9.1.3 Strong Goals

The literature review found, and a quarter of market actors (n=18) reported, that having a strong and immutable energy target or ZNE goal helps ensure they meet that goal once the building is constructed. Market actors said it is important to clearly define the goal as early as possible and continually refer to that goal. It is beneficial to ensure the team's efforts are aligned to the goal. Market actors mentioned that some companies' energy performance goals are so strong, the project team must meet them, including buildings on the University of California campuses, State of California buildings, local government buildings, and K-12 schools.

9.1.4 Construct as Designed

Interviewed market actors (n=8) also mentioned the importance of ensuring that project team constructs the building according to the original design intention in order to meet energy targets. Three of these respondents described the need for a quality assurance (QA) representative to be onsite during construction. One builder said they encourage property owners to allocate funds for onsite construction QA in order to catch installation errors that could cost the owner substantial money over the building's performance lifetime. Five market actors suggested the need for strong enforcement of performance requirements in contracts with vendors, ESCOs, or contractors to ensure their work achieves what they promised.

9.1.5 Commission to Perform Appropriately

Both the literature and eight interviewees reported that it is critical to commission energy-using systems to perform in accordance with the energy models. Although commissioning (Cx) is often used colloquially to refer to activities at the end of the project, it is technically a process that covers the entire project lifetime - from pre-design through post-construction, including development of the design team's Basis of Design[20]. Post-occupancy commissioning identifies and resolves any unexpected operational issues after move-in and can lead to cost savings and non-energy benefits. The interviewed market actors emphasized that having a knowledgeable and experienced commissioning agent or controls contractor helps ensure they meet energy targets. Ongoing monitoring of energy performance after the building has been occupied is critical to assessing the performance of the building and identifying opportunities for retro-commissioning.

One market actor said that, in their experience, "The commissioning process has been continuously under-valued and under-cut." A few market actors mentioned that budgeting for submetering infrastructure and connecting it to a building energy management system facilitates identification of system performance issues and optimal system commissioning. One engineer mentioned a case where a project budgeted for submetering infrastructure but did not budget an additional $10,000 for commissioning and networking of the submeters, which prevented them from executing measurement and verification.

9.1.6 Financing Sources Ensure Efficiency

Interviewees reported that tax credits, on-bill financing, and revolving green loans make it easier to afford ZNE and ultra-efficient commercial buildings, yet there are still barriers in traditional financing for existing buildings. In interviews, four market actors mentioned using Prop39 funds to support their public schools' projects. One market actor, whose company constructs high-rise multifamily buildings for low-income families, takes advantage of tax credits for California Tax Credit Allocation Committee. However, these funds are only available for public buildings. Two market actors noted challenges with obtaining financing for ZNE projects, due to a lack of comparable projects, and there is no motivation from bank's end to finance a project surpassing code. Another market actor said that it would be advantageous if "green bonds" -- a form of on-bill financing -- were available to commercial entities in the United States, as they are in some European countries. Green bonds pay for the cost of an energy efficiency or clean energy measure, and the property owner pays for the cost via

[20] https://www.wbdg.org/building-commissioning

their bill. As the entity who provided the loan gets repaid, they put money back into the fund, so it is available for another project. Some green bond programs exist in California but are used for local government buildings.

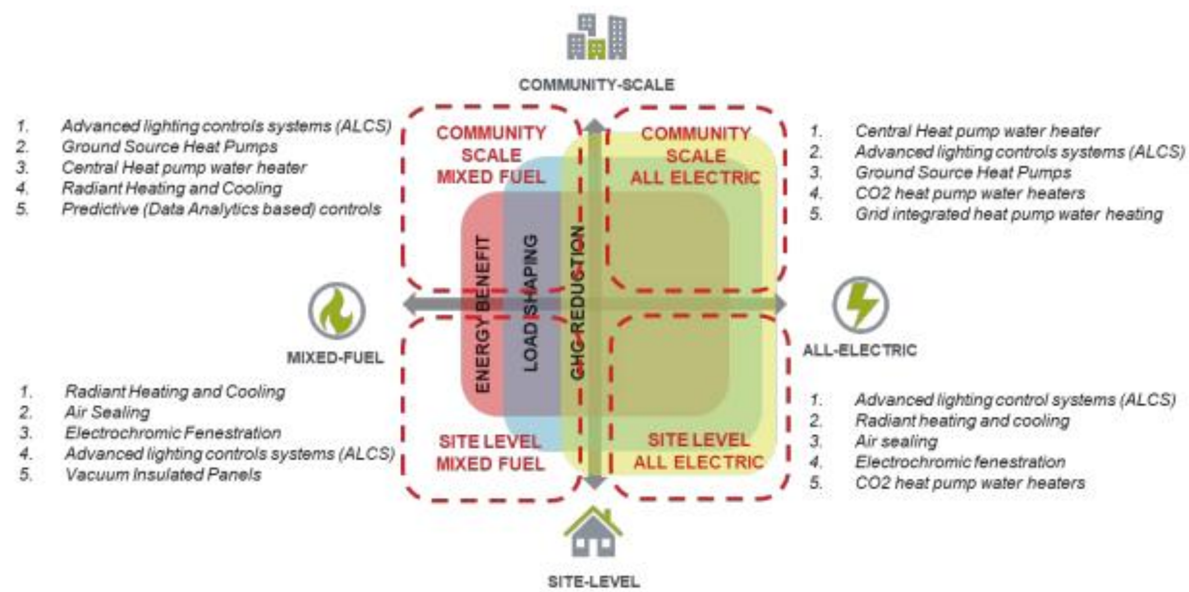
In addition, two interviewees noted that establishing an accurate budget early on in the design process was a strategy that minimizes value engineering later. One engineer said they recommend their clients include a "buffer" in the budget, so that they can afford the important energy efficiency and renewable energy measures if other construction costs exceed their estimates. A property owner reported using a similar strategy; at their firm, they keep the budget for the energy efficiency measures separate from the rest of the project so as to safely allocate and protect those funds any value engineering discussions.

Three interviewed market actors mentioned that the source of funds plays a role in ensuring that energy efficiency equipment is kept in a project. One interviewee mentioned that, in many cases, the owner relies on utility incentives to make the project financially feasible and eliminating the efficient system jeopardizes losing the incentives. One engineer mentioned that some non-profits fundraise to cover their construction costs, and those funds come with stipulations on the types of equipment they can be spent on.

9.1.7 Technical Approaches

As a market characterization, it was beyond the scope to investigate technical approaches for ZNE. However, Itron (2019) identified priority technologies for ZNE buildings under different scenarios – including community-scale and site level renewable energy, and mixed fuel and all electric buildings, presented in Figure 23.

Figure 23. ZNE Scenarios with Examples of High Priority Technologies (Source: Itron 2019)



9.2 Approaches to Distributed Generation

For most projects, distributed generation is onsite solar PV – including PV on the building roof or in other areas such as on covered parking. In some cases, the site may use other types of renewable energy (such as geothermal energy) or offsite renewable energy. This subsection also discusses electric vehicles (EVs) and battery storage, which can be used as decarbonization and DR strategies.

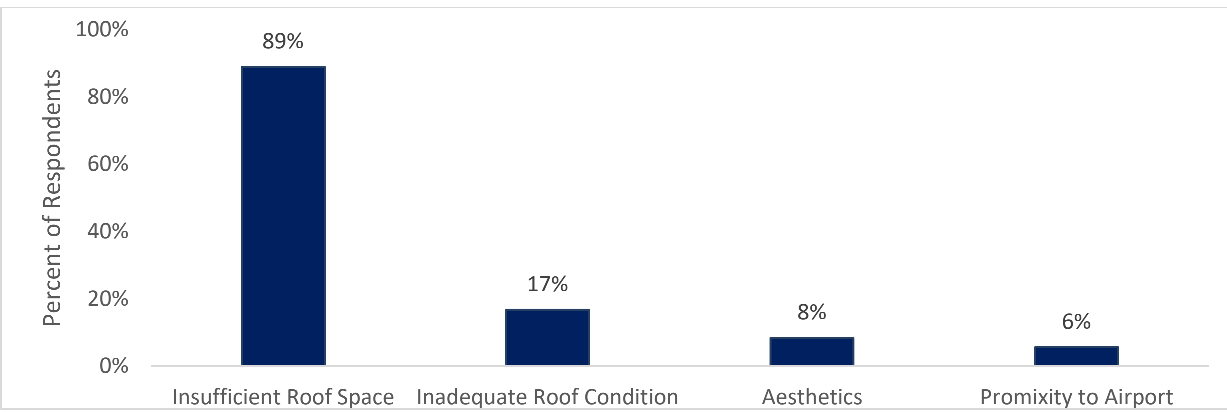
9.2.1 Renewable Energy

Respondents had mixed perspectives about on-site and off-site renewable energy generation, though many preferred to put them onsite to the greatest extent possible. Nearly half of the interviewees (31 of 64) voluntarily mentioned that they preferred on-site generation for their ZNE and ultra-efficient buildings or had no experience with off-site renewables for their projects. A small number did not think that off-site renewables fit the spirit of ZNE. For example, one architect stated, “Depending upon how much of a purist you are, some people would argue that offsite renewables is not really ZNE.”

About a quarter of interviewees mentioned viable strategies for off-site renewable energy generation and a few mentioned that the industry is trending toward more acceptance of off-site renewables. While utility tariffs can make off-site renewable generation more complicated, some market actors found net metering aggregation programs, community solar, and power purchase agreements (PPAs) to be advantageous ways of sourcing renewable energy from off-site.

Interviewed market actors noted that off-site renewable energy generation was most necessary in cases of tall, skinny buildings in dense urban environments or for buildings with intensive energy loads, such as laboratories. Figure 24 displays the main reasons why market actors would site renewables off-site. We elaborate on each of them following the figure. After that, we discuss challenges market actors have encountered when trying to place solar PV onsite.

*Figure 24. Reasons Why Renewables Placed Off-Site (n=64) **



* Multiple responses allowed.

Factors that would influence owners and design teams to consider siting renewables off-site included:

- **Roof space to place PV arrays sufficient to offset the building’s energy load.** Having sufficient roof space depended on the energy load of the building and whether other necessary equipment was on the roof (such as HVAC equipment). Nearby land or a parking lot provided attractive options for mounted PV arrays (31 of 64).
- **Roof condition including its age, structural integrity, and orientation.** The age of the roof factors into whether renewables are sited onsite or offsite; older roofs and roofs lacking in structural integrity favor placement off-site. The roof’s orientation and presence of trees shading the roof can also limit the viability of PV on the roof (6 of 64).
- **Aesthetics** can play a role in sourcing renewables from off-site. In some cases, the owner finds the PV panels unappealing and, in other cases, historic buildings are required to maintain an architectural style that can prohibit PV placement (3 of 64).
- **Proximity to an airport** necessitates Federal Aviation Administration (FAAs) compliance, which can limit onsite renewables. Respondents mentioned how PV can cause “glint and glare” that affects aircraft and FAA-imposed wind-sourced power system restrictions (2 of 64).

Reasons why respondents said it was important to maintain renewable energy generation onsite included the fact that “it feels more like ZNE” to the design team and owner, and that the visibility of PV on the building can carry “marketing cachet” which strengthens the building’s sustainability image.

A variety of challenges to incorporating PV panels onsite confronted market actors, including sufficient roof space, first cost, and complicated utility tariffs including Net Energy Metering (Figure 25). We elaborate on each challenge following the table.

*Figure 25. Market Actors' Challenges to Incorporating PV (n=57) **

Challenge	Number of Respondents
Insufficient unshaded roof space	39
High first cost	18
Complicated utility tariffs, NEM, and PPAs	9
Existing buildings not solar ready	7
Unfavorable local codes or permitting processes	6
Shoddy panel providers	4
Complex interconnection process to utility grid	2
Improper submetering	2

* Multiple responses allowed.

Respondents provided the following comments on these challenges.

- **Insufficient unshaded roof space:** As described above, there must be enough roof space to place sufficient PVs to offset the building's energy use. This becomes a challenge with tall, skinny buildings that have higher energy loads relative to the available roof space. Shading from trees and the presence of mechanical equipment can also limit viable roof space. Finally, other usage of the roof space can prohibit PVs; in one case, the building owner reportedly desired to have a rooftop patio, which prevented the inclusion of PV on the roof.

- **High first cost:** The upfront cost of the solar panels and their installation can be a challenge to incorporate into the budget for some building owners. If the panels will be in a parking lot, the trenching required to connect it escalates the cost. Two market actors added that government buildings cannot take advantage of the tax credits that private properties can, which can cover up to one-third of the cost.

- **Complicated utility tariffs, NEM, and PPAs:** Changing solar rate tariffs, time-of-use rates, and net energy metering billing arrangements complicates the economics of solar PV and can be difficult to explain to building owners. PPAs with third-parties are complex legal arrangements and can be administratively difficult to execute. PPAs can present challenges for property owners with a lot of bureaucracy, such as government entities and universities. One actor mentioned that third parties are not as inclined to serve small sites through a PPA because it is not cost-effective for them.

- **Existing buildings not solar ready:** Two primary conditions in existing buildings can make it difficult to incorporate PV: the roof's structural integrity to support the weight of the panels, particularly if the roof is older (~20 years old); and the existing electrical panels may need to be upgraded with a converter.

- **Unfavorable local codes or permitting processes:** Three market actors mentioned challenges related to local fire codes that restrict PV placements so that firefighters can access the roof. Other codes related to glint and glare near airports or aesthetics of panels on buildings.

- **Unreliable or unqualified panel providers:** A few market actors said it was important to carefully choose the panel provider. Two market actors reported experiences where the panel provider went bankrupt after they had supplied some panels, but not all. Integrating two manufacturer's panels added cost and complexity to the project. Another reported that the low-bid solar provider was able to deliver the right kW but not enough kWh. Finally, a fourth market actor reported that government contracts require union labor and few solar PV installers have labor in unions.

- **Complex interconnection into grid:** The interconnection process to connect the system to the utility grid is complex and caused project delays for two market actors. The challenge includes filling out the utility's application forms and agreements.

- **Improper submetering:** Submetering infrastructure is important to understand how much power the panels are producing and manufacturers design meters and their integration into building management systems in different ways. In one case the solar energy information was only going to "the cloud" and not the building's energy management network, which caused the building owner's IT department to carve a hole in the firewall to allow the building network to accept information from the PV network. Another market actor mentioned that some meters owned by the solar companies do not have consistent up-time, leading to gaps in data.

9.2.2 Electric Vehicle Charging Infrastructure

About half of market actors (11 of 24) said there were no challenges to incorporating EV infrastructure at their projects, while the other half (13 of 24) cited challenges. The main challenges relate to the electric load generated by the charging stations, their first cost, and how to implement their use (Figure 26).

Figure 26. Challenges to Incorporating EV Charging Infrastructure

Challenge	Number of Respondents (n=24) *
No challenges related to EV infrastructure	11
How to account for electric load	6
High first cost	5
Questions around implementation of service	4
Space constraints	2

* Multiple responses allowed.

Respondents provided the following comments:

- **No challenges related to installing EV charging infrastructure:** These market actors said that installing EV charging stations is becoming standard practice and a growing number of clients are requesting them. Two said that local codes or policies in their area require installation of EV chargers.

- **Accounting for increased electric load:** The added electrical load from charging stations needs to be considered when considering the electric load of the building and the amount of renewables needed to offset that load. For small buildings, the charging infrastructure load can be a significant amount, and for buildings with many EV-charging parking spaces, there can be a demand spike when all the EVs arrive and start charging. One market actor said that they exclude EV infrastructure from their ZNE projects because the EV charging load is difficult to predict and there are not reliable load assumptions to build into the modeling calculations.

- **High first cost:** The cost of the chargers alone can reach up to $2,000 each and then the owner incurs other installation costs, such as adding a separate electrical branch. Adding this electrical branch can require trenching which is expensive and disruptive if the parking lot is already in use. Further, existing buildings may not have sufficient power available for the charger, requiring an expensive infrastructure upgrade.

- **Questions around implementing the charging service:** Building owners had unanswered questions about how to implement the charging service. For example, should they just charge for the parking space, charge for the energy to charge the car, or both? Others had questions about their frequency of use, fearing there was not enough demand to justify their installation.

To avoid interview fatigue, the TRC team asked only limited questions related to EV charging. Future research should investigate drivers and barriers to EV charging more fully, including breaking out drivers and barriers to different charging scenarios (e.g., 120 vs. 240-volt charging), for different building types, and for buildings with and without onsite electricity generation.

- **Space constraints:** A few market actors mentioned that sometimes programs or policies require a minimum number of parking spaces to provide EV charging. This can be a challenge for sites that do not have a lot of parking spaces.

9.2.3 Battery Storage

As shown in the figure below, the two main challenges to incorporating batteries were their high first cost and a lack of space for them.

Figure 27. Challenges to Incorporating Batteries

Challenge	Number of Respondents (n=14) *
High first cost	10
Lack of space for battery	4
Unattractive rate structures	3

Market actors provided the following explanations:

- **High first cost**: Market actors said there has been some interest in including batteries on ZNE and ultra-efficient building projects, but they have not been able to overcome the first cost barrier. Two market actors added that the high first cost and lack of utility incentives for commercial storage makes it difficult to convince a building owner to include it.
- **Lack of space**: Market actors mentioned challenges related to locating the battery on-site, particularly for retrofits. One market actor mentioned that the electrical room needs to be three times as large to account for the battery infrastructure. Market actors said that batteries are often placed outside, and that if they were to be placed inside, it must be in conditioned space as they generate heat.
- **Unattractive rate structures**: Three market actors reported that the rate structures in California make batteries more attractive for selling energy to the grid than for increasing the amount of renewable energy used at the building. They reported the building's energy peak and the grid's peak are at different times, and the battery is discharged when the grid peaks and the building is unoccupied, and that the utilities are not yet offering attractive rate structures or the right incentives for commercial battery storage. (Note that - while these market actors identified the California Utilities for setting the rate structures, both the CPUC and Utilities play a role, since the IOUs propose a rate structure and CPUC approves that rate structure.)

9.3 Reach Code Adoption Status, Drivers, and Barriers

This section provides findings on the adoption status of reach codes and other city or county ordinances that impose commercial building energy efficiency (or renewable energy) requirements beyond statewide code as well as drivers and barriers to adoption of these reach codes.

In general, ZNE is not the target or goal of the reach codes that have been adopted to date. **Most active reach codes target specific measures such as lighting or cool roofs or require that the project's whole building performance exceeds code energy use requirements.** The TRC team learned that some jurisdictions may shift focus from directly reducing energy use to reducing carbon emissions in the future.

The following figure summarizes commercial energy reach codes or green building ordinances that include energy efficiency and sustainability measures (including LEED requirements) for jurisdictions in California. The TRC team identified energy reach codes based on CEC listings[21], and the green building ordinances based on a literature review. There may be additional green building ordinances not identified here.

Figure 28. Commercial Reach Codes or Green Building Ordinances in California

Jurisdiction	New Constr. (NC) or Retrofit	Ordinance Type	Requirement
Los Angeles	Both	Green Building	LEED Certified for projects > 50,000 sf
San Francisco	Both	Green Building	All municipal (muni) projects must be LEED Silver. NC and projects >25,0000 sf must be LEED Gold. Projects 5,000-25,000 sf must be LEED Certified.
San Jose	NC	Green Building	Projects >25,000 must be LEED Silver. Others must be LEED Certified.
San Diego	Both	Green Building	LEED Silver for projects > 5,000 sf.
Brisbane	Both	Green Building	Non-muni projects > 10,000 sf must be LEED Silver. Muni projects >5,000 sf must be LEED Silver.
Oakland	Both	Green Building	LEED Silver for projects valued >=$ 3 million
Calabasas	NC	Green Building	Projects >5,000 sf must be LEED Silver. Others must be LEED Certified.
West Hollywood	NC	Green Building	All new public buildings must be LEED Certified
Brisbane	NC	Energy Efficiency	Cool roof on NC multifamily and non-res
Chula Vista	NC	Energy Efficiency	Reduce outdoor lighting energy in NC non-res
Del Mar	NC	Energy Efficiency	Reduce lighting and/or mechanical energy by 5-10% above code
Fremont	NC	Energy Efficiency	Reduce outdoor lighting energy in NC non-res
Marin County	NC	Energy Efficiency	10% more efficient non-res and multifamily high rise above code or all-electric
Palo Alto	NC	Energy Efficiency or PV	10% more efficient without PV or 0% with >=5 kW PV
San Mateo	NC	Energy Efficiency and PV	Cool roof and PV on NC multifamily and non-res
Santa Monica	NC	Energy Efficiency	10% more efficient than code

Although more reach codes are pending, most of the currently approved jurisdictions are socially and environmentally progressive, affluent jurisdictions and are mostly coastal or in moderate climates.

[21] https://ww2.energy.ca.gov/title24/2016standards/ordinances/

The TRC team conducted interviews with planners and building officials to discuss drivers and challenges to reach codes, and upcoming trends. **Interviewees reported that drivers include municipal goals and increasing State requirements related to energy**, and that efforts from early adopter jurisdictions demonstrating viability. One jurisdiction reported that it would not have adopted its current reach code had another, larger jurisdiction not shared its cost effectiveness findings. **Most interviewees reported similar challenges, namely meeting cost effectiveness tests** and appropriately addressing the level of construction activity in the commercial sector. None of the interviewees recalled opposition except one who mentioned environmental advocates pressing for greater stringency. Notably all of the interviewees were in jurisdictions that updated past reach codes, rather than creating new reach codes this cycle. These successful adoptions indicate favorable attitudes, key support, and cost effectiveness.

The jurisdictions also face the same challenges surrounding cost effectiveness and enforcement. Cost effectiveness, while a valuable indicator of attainability, also constrains the scope of the reach codes. Jurisdictions with multiple climate zones or geography found varied cost effectiveness results for its territory. Some interviewees commented that their reach codes relaxed the required energy reduction since the updated state code (Title 24-2016) was so stringent that previous reach code iterations were no longer cost effective, e.g. now require 10% improvement beyond code compared to 15% in the previous reach code.

As shown in Figure 28, **the scope of most reach codes is limited to new construction**. None of the jurisdictions interviewed have reach codes for retrofit projects, and interviewees reported this is largely because retrofit analyses have not been shown to be cost effective. For the next cycle, some jurisdictions will revisit retrofit codes to see if costs and savings have changed. One jurisdiction reported they are considering providing a recommendation or a voluntary code for retrofits to side-step cost effectiveness hurdles. To encourage projects to pursue voluntary standards, one jurisdiction, City of San Francisco, requires LEED Silver for new commercial projects but offers priority plan review to projects seeking LEED Gold.

The TRC team asked about opposition to the reach codes and difficulty approving them. None of the interviewers were involved with their respective ordinances when they were initially introduced. They all agreed that continuing the reach codes is largely without controversy. Should new measures or requirements be added, such as EV, a few of the jurisdictions said they would develop those independently of the energy reach code to prevent delaying approval, assuming development of a new code will take much longer.

Several interviewees reported they are shifting to decarbonization goals. Although several jurisdictions are investigating and evaluating requirements to further reduce carbon emissions, they did not have a firm scope at the time of the interviews. Jurisdictions are considering electrification and evaluating fuel mixes for next cycle, but recognize full electrification is not cost-effective in all cases. A few interviewees discussed requirements for EV charging. They reported that it is still expensive, so requirements specify EV-readiness even though some advocates have pressed for more.

Although the interview guide included questions on enforcement of reach codes, the TRC team was not able to assess this issue, since the interviewees (who planners were generally and building officials – rather than inspectors) did not know with certainty the degree of enforcement and compliance. From the literature review, the TRC team learned the City of San Jose requires projects pay a deposit that the city returns if the project meets the city-mandated LEED standards after construction finishes to ensure compliance.

Regarding upcoming reach codes, seven cities are publicly discussing what they are planning to enact in the next few years; two of these cities currently have energy reach codes. As with the active reach codes, none of the jurisdictions are considering requiring ZNE. They are instead targeting carbon or greenhouse gas reductions; a few cities are debating a ban on natural gas infrastructure in new buildings. Another city is considering carbon-based requirements for existing buildings, signifying a potential requirement for retrofits.

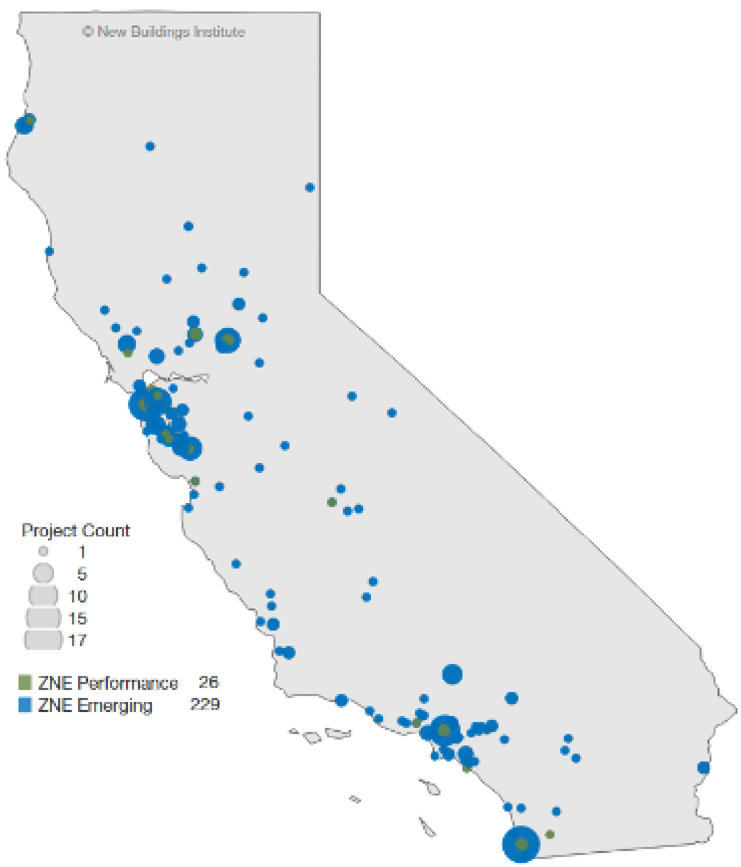
10 ZNE Market Size and Energy Characteristics

This section provides analysis of ZNE and ultra-efficient buildings – including their market size and how this compares with total construction, trends in building type and location, and trends over time. Because the ZNE and ultra-efficient building market is still relatively small, this section also includes market size analysis of beyond-code buildings. This section also provides EUI estimates for ZNE and ultra-efficient buildings compared with code-compliant and shows the combinations of strategies (aggressive energy efficiency, rooftop solar, onsite solar, and/or community solar or other off-site renewable energy) needed for each building type to achieve ZNE.

10.1 Market Size and Trends in ZNE and Ultra-Efficient Buildings

California leads the country in the number of building projects that are ZNE verified and emerging with 45% of all ZNE buildings in North America. As of March 2019, California has 255 known commercial buildings that are either verified (26) as ZNE or emerging (229) toward that ZNE target. Figure 29 shows ZNE buildings spread across California. Every California climate zone (CZ) has at least one a ZNE performance verified or emerging project. The Bay Area (CZ 3) and Los Angeles (CZ 8/9) have clusters of activity with 51 and 39 buildings, respectively. ZNE-performance verified buildings are located primarily in climate zones 3, 4 and 12.

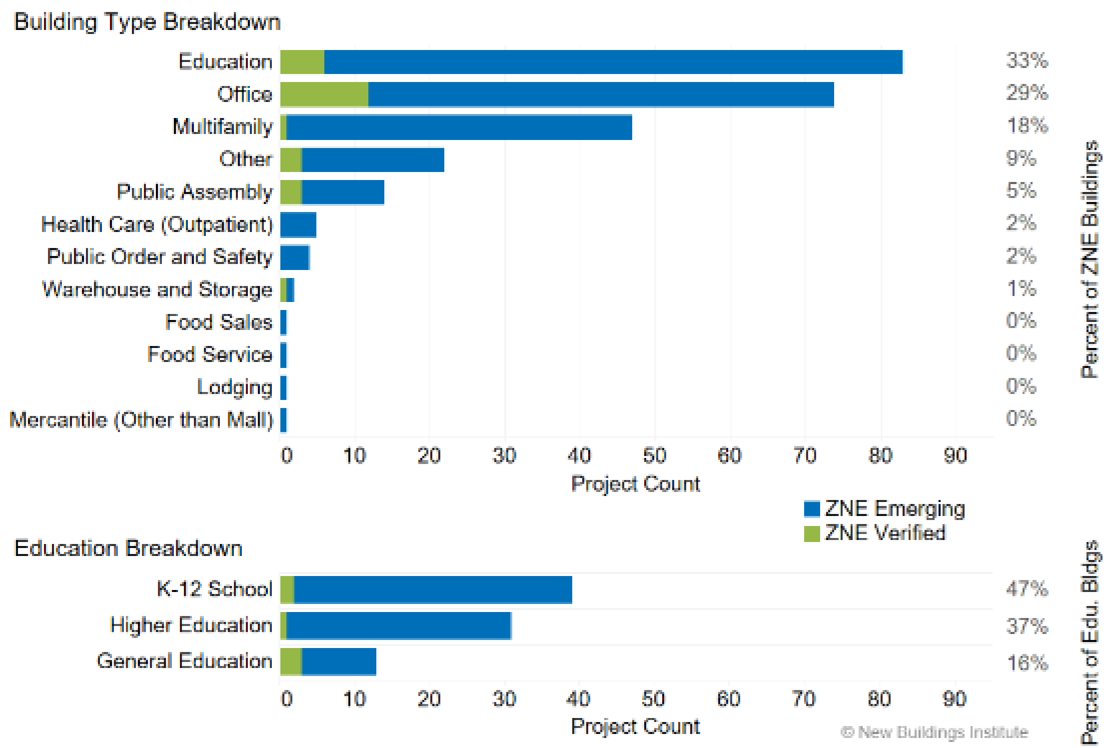
Figure 29. Map of ZNE Buildings in California



California has seen growth in ZNE projects, particularly since 2010. Public buildings continue to display leadership, advancing the growing ZNE market. According to the list of ZNE performance and emerging buildings, the growth trends for both public and private sectors by number of ZNE performance and emerging buildings are very similar, as shown in the following figure indicating diverse growth. Outside of California, the public and private sectors are also growing at a similar rate.

Figure 30 shows a detailed breakdown of the ZNE buildings in California by building type. Education, offices, and multifamily together account for 80% of ZNE buildings. A third of ZNE buildings are educational facilities. Among the educational facilities, nearly half are K-12 schools, which may be a result of strategic efforts to advance ZNE school retrofits through California's Proposition 39 ZNE Retrofit Pilot Project. Education is not only the largest category, but also the earliest adopter of ZNE in California. Note that multifamily includes both low-rise and high-rise, and most ZNE projects are low-rise. (To date, the TRC team is not aware of any high-rise multifamily ZNE Performance projects.)

Figure 30. ZNE building types in California

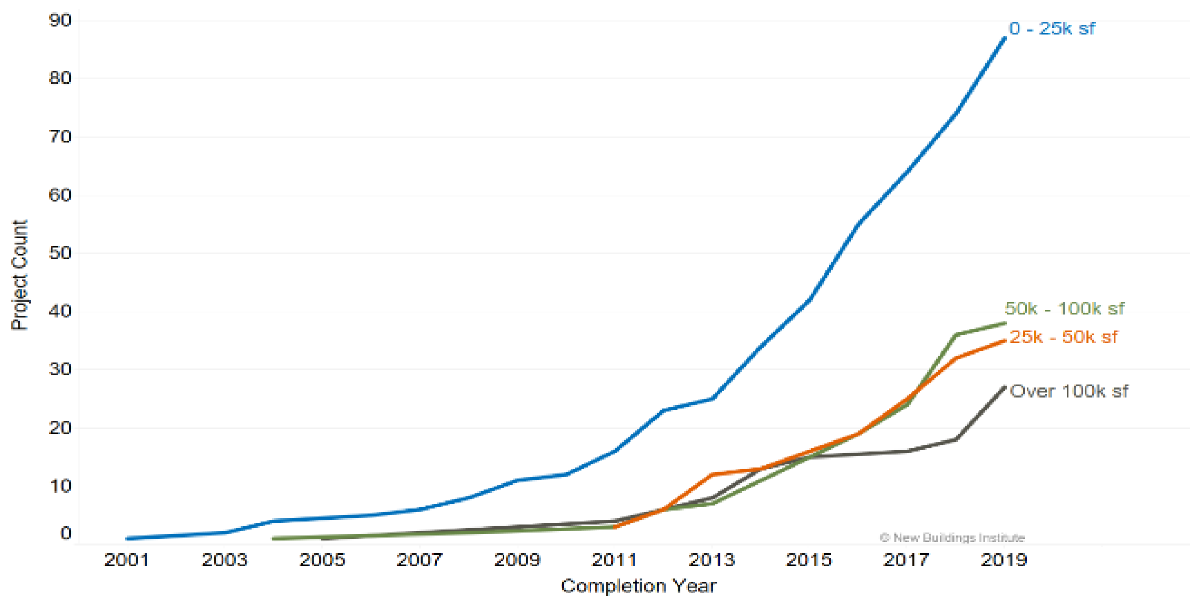


The CPUC's K-12 and Community College Retrofit Readiness Study (NBI 2017) provided recommendations to accelerate market transformation in ZNE retrofits in the education sector. Since that research has been published, more districts across the state are getting to zero with policies to establish district wide policies for schools (for example in Carlsbad, CA where the School Board reviewed and discussed a proposed District-wide Solar Energy, Battery Storage, and Sustainability projects[22]). Policies like these will likely fuel continued increased market growth in ZNE in the education sector across California.

Designers are targeting ZNE in buildings of all sizes. The first ZNE buildings were primarily small demonstration scale, in the 0-25k square foot (sf) range. As seen in Figure 31, beginning around 2012, larger buildings began to join the market and contributed to the rapid growth of the overall ZNE building stock in California. Currently, ZNE buildings are widely distributed among various building sizes.

[22] Carlsbad Unified School District 2019 https://cusd-ca.schoolloop.com/pf4/cms2/news_themed_display?id=1550574224131

Figure 31. ZNE Market Growth by Project Size



Based on the TRC team's review of ZNE performance projects, **most commercial projects built to date in California have been one or two stories. However, projects outside of California illustrate that taller ZNE projects can be achieved**, including in colder climates, such as the Bullitt Center in Seattle, WA[23], the Joyce Centre for Partnership & Innovation in Ontario, Canada[24], and the Unisphere project in Silver Spring, MD[25].

Existing buildings are also pursuing ZNE. **Over a quarter of California's emerging ZNE projects are existing buildings retrofitted to be ZNE.** (See Figure 96 in the Appendix.) In most cases, existing moderately efficient buildings are able to upgrade their lighting and HVAC equipment retro-commission other systems in order to reach the low-energy use needed to reach ZNE performance. The TRC Team was not able to gather detailed data on whether the existing projects achieved ZNE through "gut rehab" or "retrofit." However, NBI reports some projects in the "Proposition 39 ZNE Pilot Program" were "retrofit" rather than "gut rehab" projects, indicating at least some "retrofit" projects for existing buildings.

10.2 Relative Size of the ZNE, Ultra-efficient, and Beyond Code Market

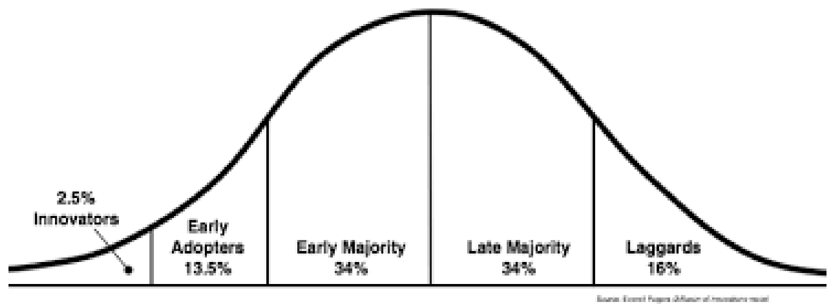
This section presents the relative size of ZNE buildings compared to the total California commercial buildings market. Analysis also shows the penetration of beyond code buildings, since these indicate market interest in exceeding code requirements. As shown in the Rogers diffusion of innovation curve (Rogers 1962), diffusion of a new technology begins with innovators (initial 2.5% of adopters), then moves to early adopters (next 13.5%), then early majority (next 34%) and then moves to late majority and laggards.

[23] http://www.bullittcenter.org/

[24] https://www.mohawkcollege.ca/donors-and-supporters/mohawk-momentum-our-causes/joyce-centre-for-partnership-innovation

[25] http://www.utunisphere.com/

Figure 32. Rogers Diffusion of Innovation for New Technology



10.2.1 Relative Market Share by Building Type

This section shows the relative size of the ZNE and beyond code buildings compared to new construction – referred to here as buildings built between 2016 and 2018, and total building stock.

ZNE building penetration is in the innovators stage for the new construction market, with the highest penetration in the Education and Office building sectors. Figure 33 below shows relative market shares of ZNE and beyond code buildings of newly constructed buildings. Each year there was construction of ZNE office and education buildings, but no ZNE restaurants or retail buildings. Additionally, the study also only found ZNE buildings for one year each in the recent market for hospitals, hotels, and warehouses. For education buildings, in which ZNE buildings had the highest penetration, market share represented 1.5% of the new construction market (averaged across 2016 to 2018) and appears to be increasing penetration over time.

Figure 33. New Construction Market – ZNE and Beyond Code

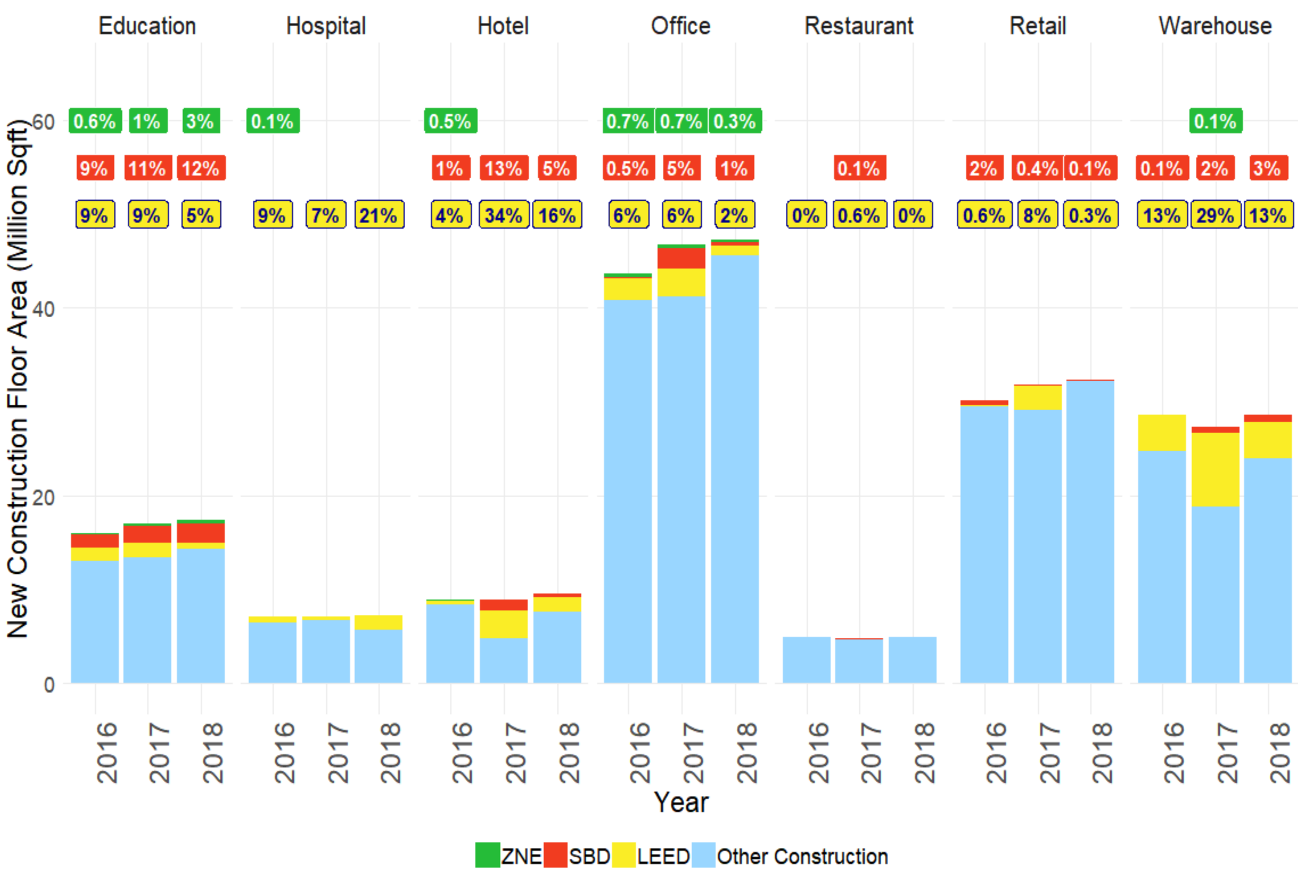


Figure 34 shows average market penetration of ZNE and beyond code buildings compared to the total new construction market, averaged across 2016 to 2018. The three-year averages are more reliable than the yearly comparison; because there was not construction completion date data available in the LEED or SBD datasets, using certification dates (LEED) and project payment dates (SBD) may have caused some misalignment in calculating relative market share for each year. As shown, across the seven building types analyzed, ZNE buildings comprised about 0.4% of the new construction market (averaged across 2016 to 2018).

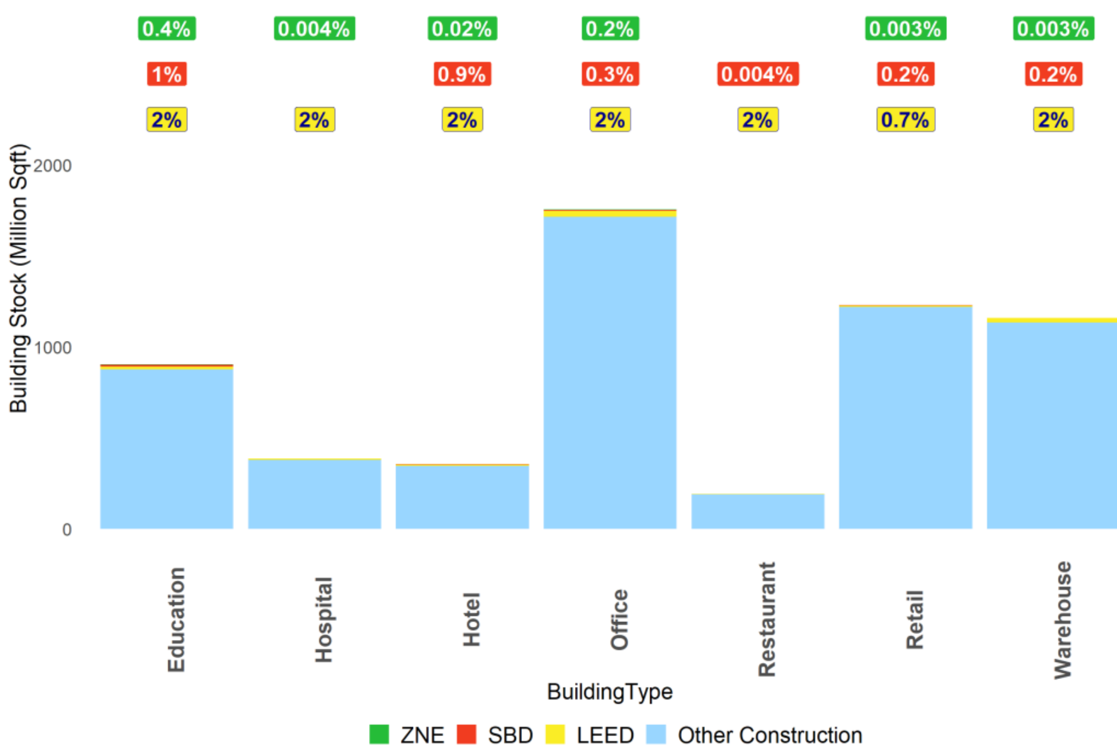
Figure 34. Average Penetration of New Construction Market – ZNE & Beyond Code

Building Type	Education	Hospital	Hotel	Office	Restaurant	Retail	Warehouse	Average
ZNE	1.5%	0.04%	0.2%	0.6%	0%	0%	0.04%	**0.4%**
Beyond Code	18%	12%	24%	7%	0.2%	4%	20%	**11%**

In comparison, the beyond code market had much higher penetration for new construction buildings, with an average penetration of 11%. **For the beyond code buildings, education, hotel, and warehouse buildings had the highest relative market shares and are in the early majority stage of adoption**[26].

Figure 35 compared ZNE and beyond code buildings relative to total stock, by building type. **For total existing buildings, ZNE building penetration comprises 0.1% or less.** Similar to new construction, the highest penetration of ZNE among total stock is in education and offices. ZNE buildings are mostly ZNE Emerging buildings. Beyond code building penetration is also relatively small, comprising 2% for most building types. LEED buildings comprise about 1-2% of the market while SBD penetration is generally less than 1%. This analysis considered LEED buildings certified under the New Construction category, which is comprised of both newly constructed buildings and major renovations.

Figure 35. Market Penetration of ZNE and Beyond Code Buildings Compared to Total Stock



[26] Based on the high penetration estimates of Beyond Code buildings for warehouses, hotels, and education buildings, the TRC team checked large project areas using Google Earth where possible. In almost all cases, the values seemed reasonable, although the TRC team adjusted a few square footage values based on Google Earth.

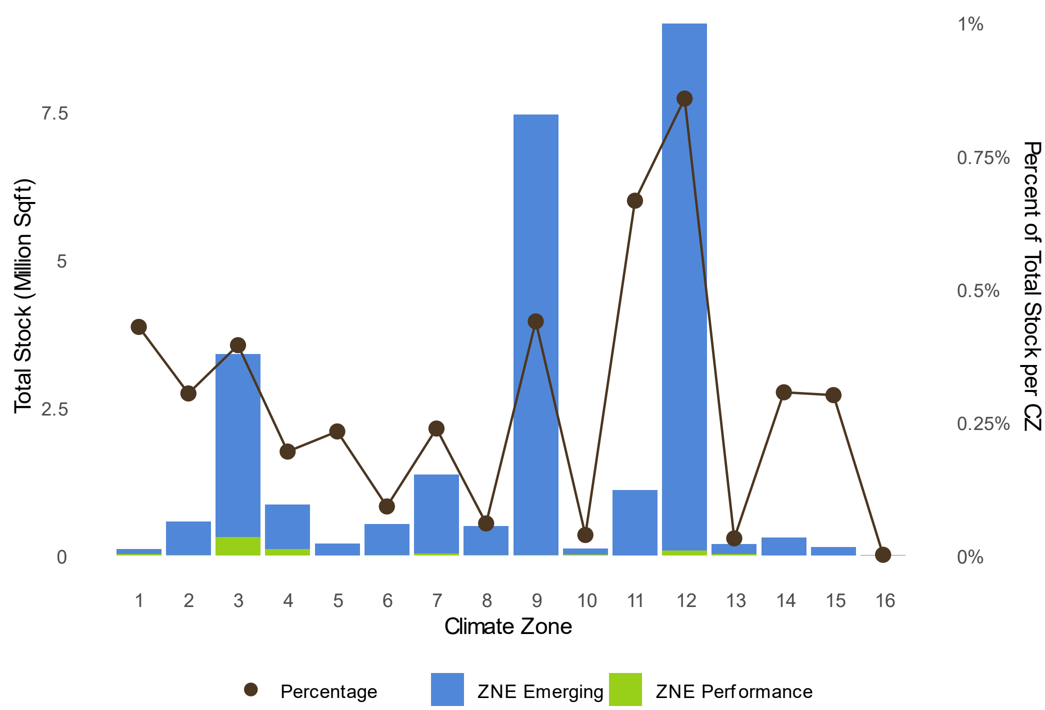
10.2.2 Relative Market Share by Climate Zone

Figure 36 shows penetration of ZNE buildings by climate zone – both on an absolute basis (left y-axis) and as a percent of total projected building stock for each climate zone in 2019 (right y-axis). This analysis does not include beyond code buildings, because address information was not available for all buildings.

The Sacramento / Stockton area (Climate Zone 12) stands out as both the highest square footage of ZNE construction and highest fraction of ZNE area compared to total stock (almost 1%). This may be in part because the California Department of General Services (DGS) has required all of their new construction commercial projects to be ZNE, and DGS have many projects in Sacramento. Large areas of ZNE buildings can be expected in climate zones 3, 9 and 12, which include cities with high populations such as San Francisco (CZ 3), Los Angeles (CZ 9), and Sacramento (CZ 12). However due to larger overall construction in these climate zones, climate zones 3 and 9 do not have the highest relative penetrations as well. Climate zone 12 shows to have both higher absolute and relative penetration, while climate 11 has low absolute penetration but high relative penetration. Climate zone 11 lies right above climate 12 and includes moderately large cities such as Roseville and Chico.

All climate zones had at least one ZNE building. Note that the ZNE building area in climate zone 16 is very small making this appear to be zero.

Figure 36. Square Footage and Percentage of ZNE Buildings by Climate Zone



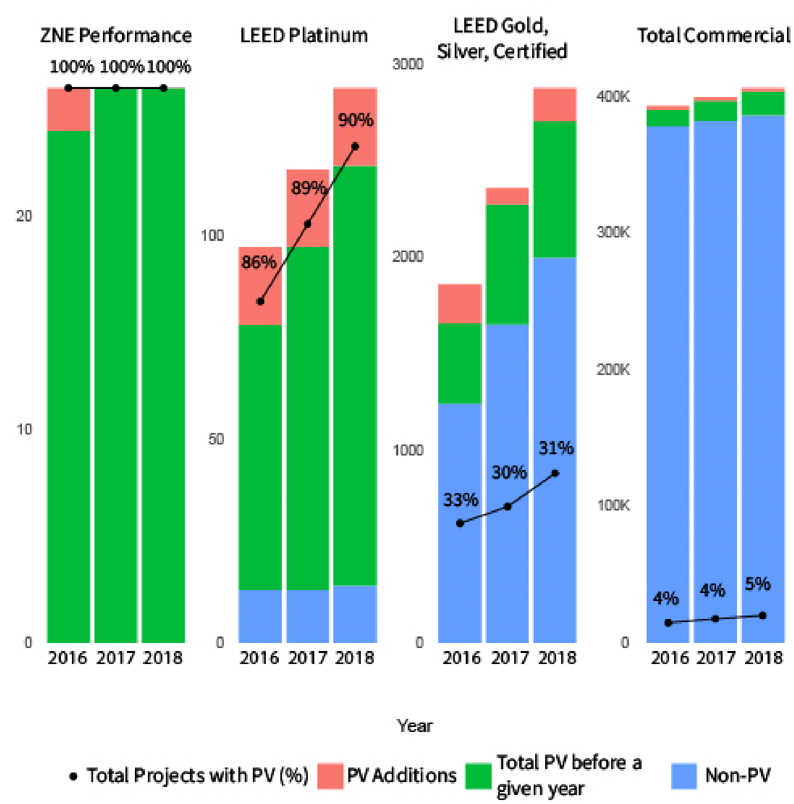
10.2.3 Penetration of PV & Renewable Systems

Since renewable systems – primarily solar PV to date – are an important component of ZNE buildings, the TRC team investigated PV system adoption in California commercial buildings. Figure 37 shows PV penetration for ZNE, LEED and total commercial buildings in California. As expected, all ZNE Performance projects used renewable systems to reach ZNE. This analysis assumed that LEED certified buildings had renewable systems based on whether the certified building had renewable credit points obtainable through either on-site or off-site renewables. Because renewable credit points can only be obtained by downloading information for each LEED project, the TRC team reviewed a sample of LEED projects (65 Gold, Silver and Certified projects out of 1716 total projects in 2016-2018 yielding a standard error in ratio estimate between 7% and 14% per year, 47

Platinum projects out of a total 78 projects certified before 2016 yielding a standard error of 3% and 53 projects Gold, Silver and Certified projects out of 1159 certified projects before 2016 yielding a standard error of about 6%). The team obtained the number of PV projects for all other California commercial building stock from the Currently Interconnected Data Set on the California Distributed Generation Statistics website[27]. Section 13.5.4 details methodology.

Use of Solar PV is growing and has entered the early adoption phase for the total commercial building market in California. In 2016, 4% of the total commercial market had solar PV, which increased to 5% in 2018. About a third of LEED Gold, Silver or Certified buildings had on-site or off-site renewables and the majority of LEED Platinum buildings had on-site or off-site renewables. While this indicates strong progress, there is still considerable opportunity for solar PV adoption, since the overwhelming majority of commercial buildings do not have PV and the majority of beyond code buildings do not have PV as well. For LEED projects, the USGBC database tracks all renewable systems, rather than PV separately, so it is possible that some of the LEED projects have a different type of renewable system installed than PV.

Figure 37. PV Projects in ZNE, LEED and Total Commercial Buildings



10.3 EUI Analysis

This section provides EUI analysis to illustrate opportunities and challenges for different building types, and for certain categories of buildings. The TRC team primarily developed EUI estimates based on modeling of building prototypes, although this analysis also provides models of actual ZNE and ultra-efficient projects where available and provides EUI from energy monitoring where data are available. All EUI data presents estimates of all loads, including assumed values for plug loads in the modeling results. The TRC team notes that monitoring studies at the circuit level would provide more accurate assumptions of plug loads for different commercial buildings types

[27] CPUC (2019), California Distributed Generation Statistics https://www.californiadgstats.ca.gov/charts/

in California. Also, this analysis only accounts for modeled energy use and solar PV production at the building level. The figures in this section also excludes energy use from the site – such as exterior lighting -- and excludes renewable energy production that could be generated at on-site, as this will vary tremendously depending on the site conditions, and off-site distributed energy generation, such as community solar. This analysis references on-site solar and community solar when discussing additional opportunities to meet ZNE for certain building types.

10.3.1 Modeled EUI analysis for New Construction

Figure 38 shows energy consumption estimates based on modeling for new construction buildings built to Title 24-2019 code (will take effect January 1, 2020) and for buildings built to achieve maximum efficiency based on ZNE modeling studies shown in the Methodology section (see Figure 3.). Figure 38 shows the series:

- “T24-2019 Eff” as an abbreviation of “Title 24-2019 Efficiency”. This is the EUI reached by prototype buildings with efficiencies that just meet (but do not exceed) Title 24-2019.
- “ZNE NC Eff Target” as an abbreviation of “ZNE New Construction Efficiency Target: This is the lowest modeled EUI used to reach ZNE in the studies that the TRC team reviewed. This is intended to represent an aggressive EUI target.
- “Max. NC Eff Feasibility” as an abbreviation of “Maximum New Construction Efficiency Feasibility”. This is the highest modeled EUI used to reach ZNE in the studies reviewed and is intended to represent a less aggressive EUI target.
- “Modeled Site EUI” are modeled EUI (based on efficiency only) for ZNE and ultra-efficient projects. This series differs from “ZNE NC Eff Target” and “Max NC Eff Feasibility” because the latter two series are based on hypothetical buildings, whereas the “Modeled Site EUI” series is for actual projects.

The results in the figure below do not include the impact of solar PV, which is in a separate graph. These results are also limited to modeling results only; measured results are in Section 10.3.3.

Figure 38. Modeled EUI Targets across CA Building Climate Zones

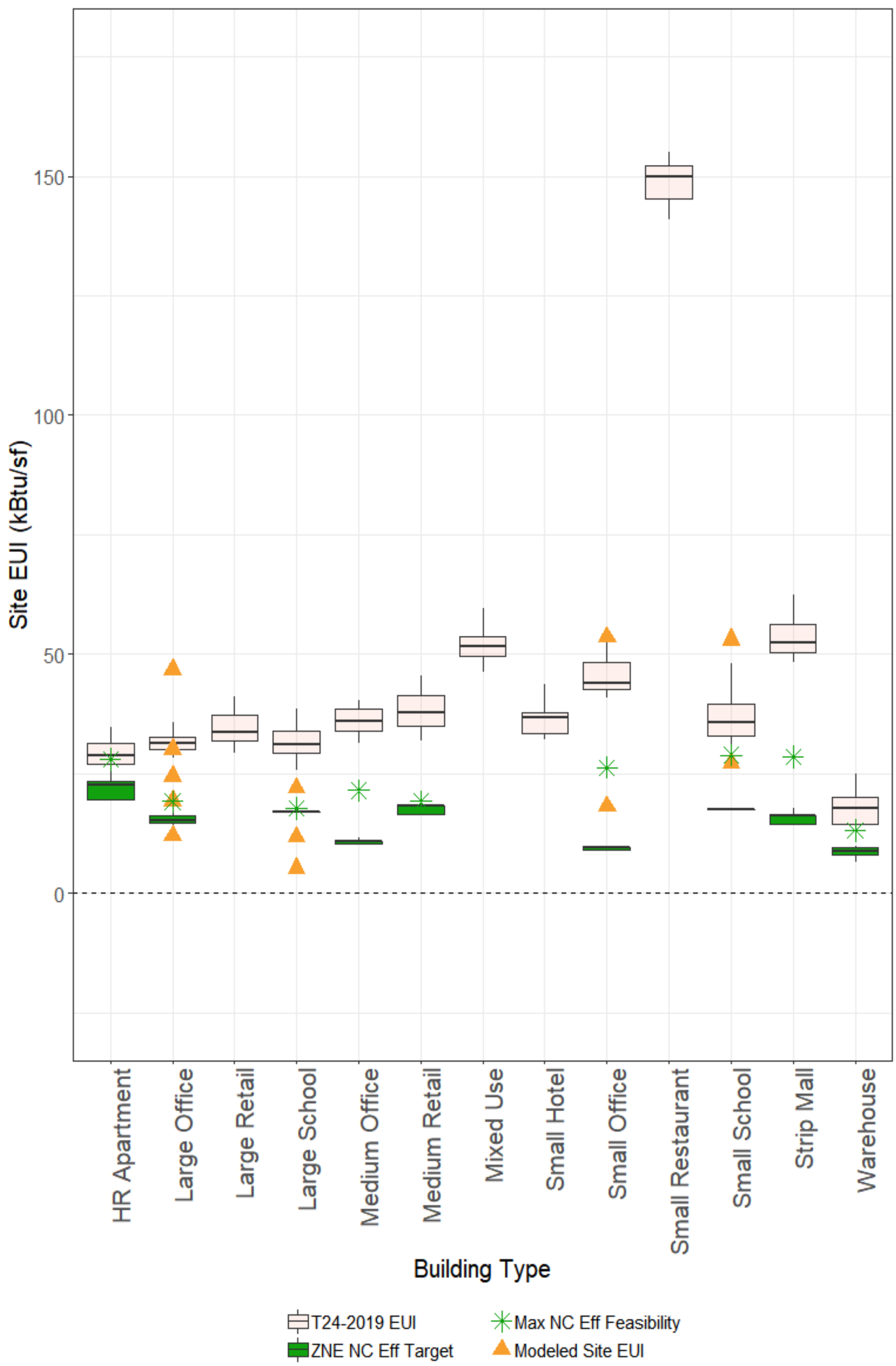
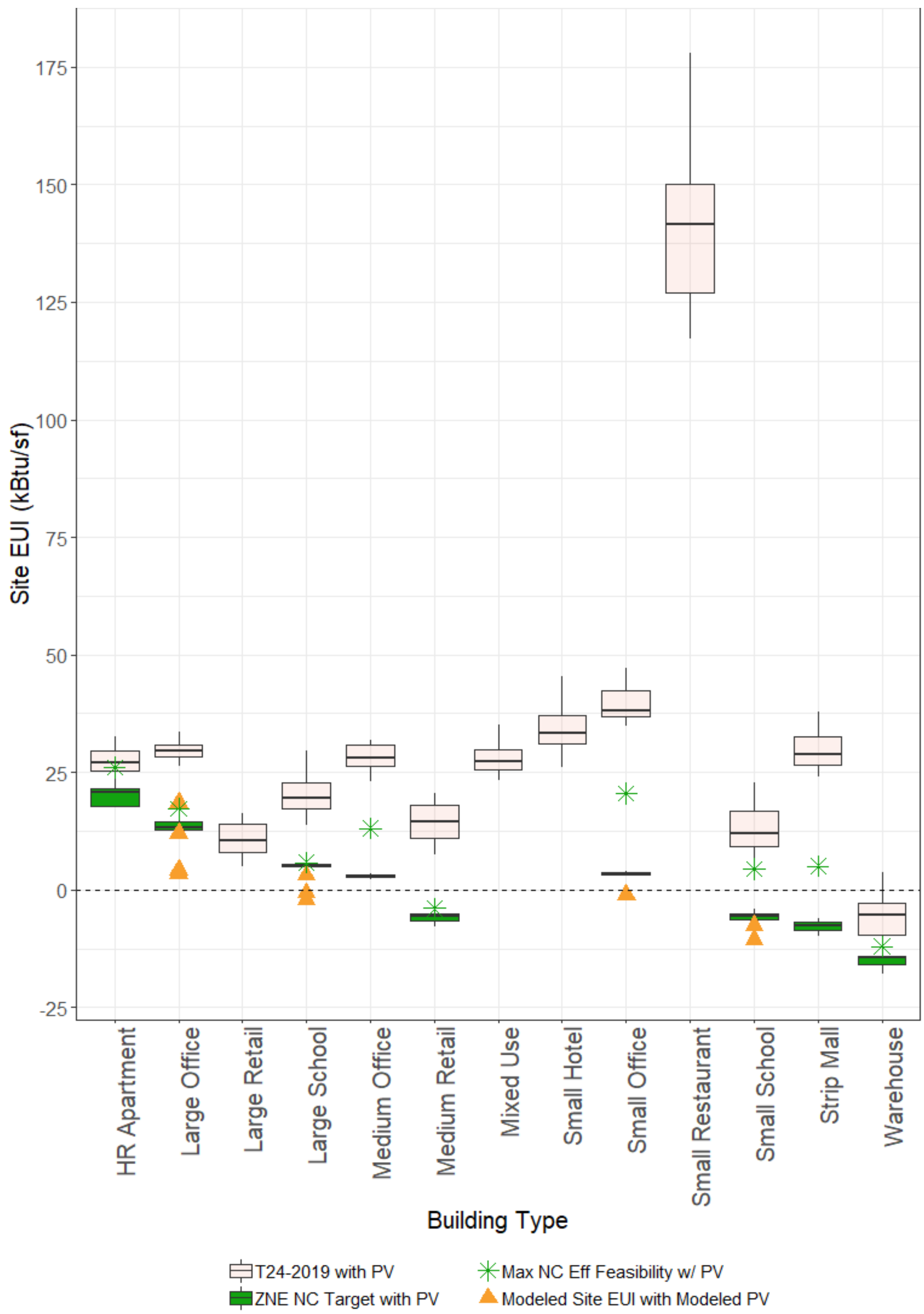


Figure 39 presents the same data series, but with solar PV included to estimate modeled net EUI. As expected, the EUIs of all data points drop. For several building types results from the efficiency feasibility studies and for many ZNE-project specific results drop into the zero or near zero EUI range.

Figure 39. Modeled EUI Targets across CA Building Climate Zones with PV



Results indicate large EUI savings from the addition of rooftop PV to Title-24-2019 buildings – particularly for warehouse, retail (including strip malls), and schools. Since these are generally assumed to be single-story or low-rise buildings, there is a high ratio of rooftop area to conditioned floor area.

Results for new construction indicate large energy savings opportunities compared with Title 24-2019. On average, ZNE target EUIs are 20%-80% better than Title 24-2019 code. For T24-2019 compliant buildings, most building types (warehouses and restaurants excluded) have an EUI between 30 and 55 kBTU/sf. Results of the statewide ZNE modeling studies (the "ZNE NC target" and "Max Targeted 2030" studies) indicate that – after installing maximum efficiency measures – most building types have an EUI between 10 and 25 kBTU/sf. Offices, schools, and retail showed high savings opportunity compared to Title 24-2019. There is less energy savings between Title 24-2019 compliant and ZNE buildings for high-rise apartments - in part because of high contribution of plug loads; and warehouses – because energy consumption is already low for T24-2019[28].

Restaurants have the highest EUI by far of building types analyzed, due to the additional loads of food preparation, cleaning/ sanitation, and refrigeration, and long operating hours that increase heating, cooling, and lighting energy[29]. The ZNE studies reviewed did not estimate EUIs under maximum efficiency measures for large retail, mixed use, restaurant, and small hotel, and it was beyond our scope to develop these estimates.

Results of the site-specific models – i.e., models constructed for actual projects, generally support the high-level modeling studies. In some cases, the site-specific models have a lower modeled consumption than the high-level modeling studies, while in some cases the site-specific models have a higher modeled consumption.

Based on modeling, ZNE is currently feasible through aggressive energy efficiency and rooftop PV for small schools, small offices, large schools, and some high-rise apartment buildings, and (based on engineering estimates) warehouses. These buildings have low enough loads and a high enough rooftop to conditioned area ratio that ZNE is feasible using aggressive efficiency and rooftop PV. For high-rise apartments, feasibility of ZNE using aggressive efficiency and rooftop PV depends on the dimensions of the building.

Modeling indicates that large office and some high-rise apartment buildings would require aggressive efficiency rooftop solar, and onsite solar or some community solar to achieve ZNE. Rooftop solar will generally not be sufficient to meet the needs of these building types, because of a low ratio of rooftop space (for PV) to floor area. These illustrate that in urban areas, due to lack of space for on-site renewable energy, project teams should explore options for offsite renewable energy including those recommended by the Architecture 2030 Zero Code for California (Architecture 2030, 2018), such as community solar, renewable energy tariffs, or bundled Renewable Energy Certificates (RECs). Recommendation 4c in Section 11 describes these strategies.

Modeling indicates that ZNE cannot be achieved through aggressive efficiency and rooftop PV for hospitals (not shown), hotels, and restaurants, and these building types would need a large amount of onsite renewables or community solar because of large process loads and (for hospitals and hotels) a low ratio of rooftop space (for PV) to conditioned floor area. Also load profile for some buildings challenging to grid because operate in evening. Highlights needs to address all (more) loads – including process loads and plug load.

10.3.2 Modeled EUI Analysis for Existing Stock and ZNE Retrofits

Figure 40 shows similar analysis based on modeling for existing buildings and shows the following series:

- "1980 Base", "1990 Base", and "2000 Base" represent code-compliant buildings built to vintage codes.
- "EB Eff Target" is an abbreviation for "Existing Buildings Efficiency Target". The team did not identify modeling results for aggressive retrofit projects such as gut rehabilitations that might yield ZNE projects, so instead used results of a modeling study of moderate retrofits.
- "Modeled Site EUI" shows modeling results for actual ZNE projects that were substantial retrofits.

As with the graphs for new construction, Figure 40 includes energy consumption data only (solar PV is shown in a later graph), and the results below reflect modeling results only.

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[28] Most energy use in nonrefrigerated warehouses is lighting, and Title 24-2019 has fairly stringent lighting power density requirements.

[29] U.S. Environmental Protection Agency 2010 https://www.energystar.gov/ia/business/small_business/restaurants_guide.pdf

Figure 40. Vintage Comparison by Building Type across CA Building Climate Zones

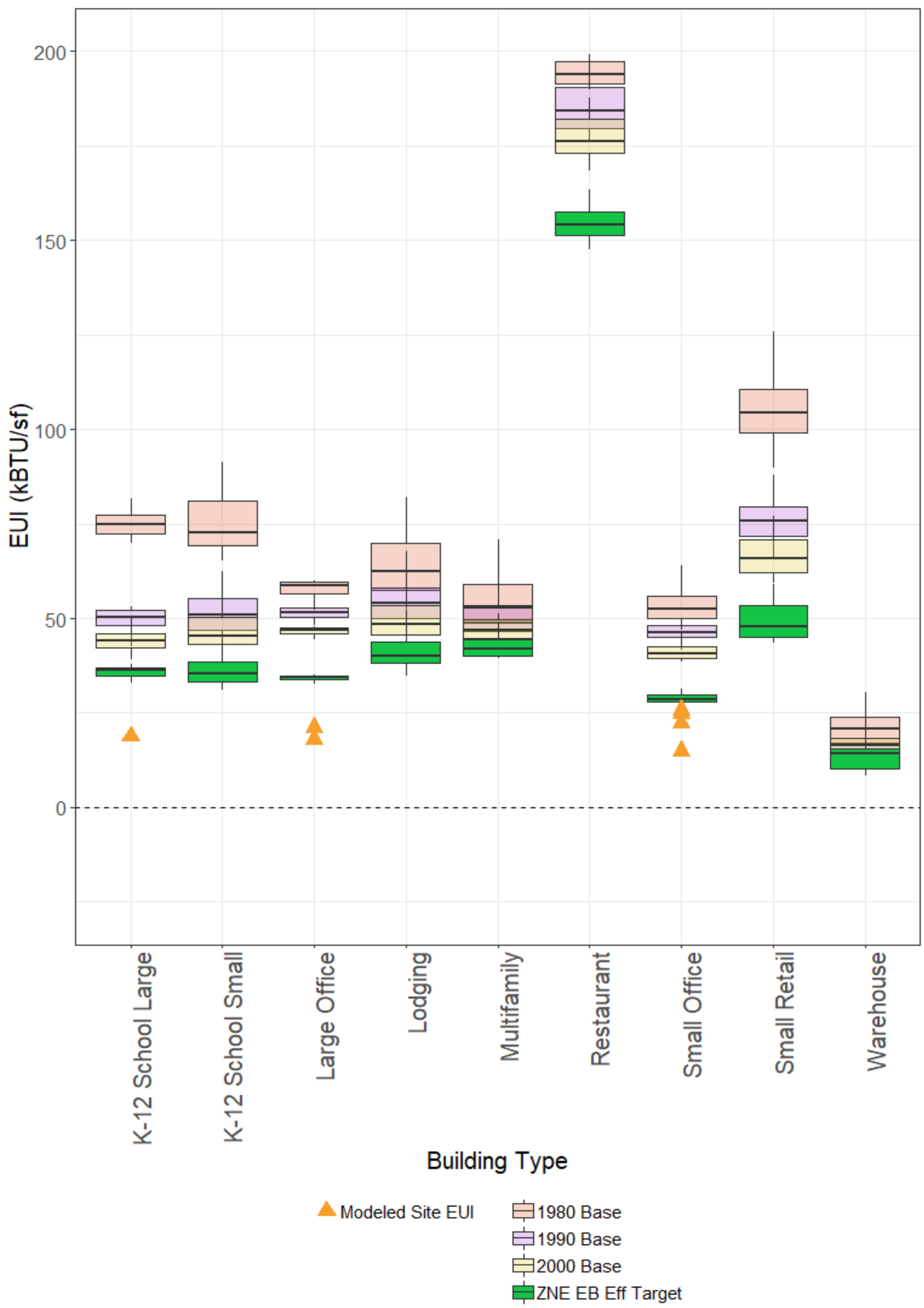
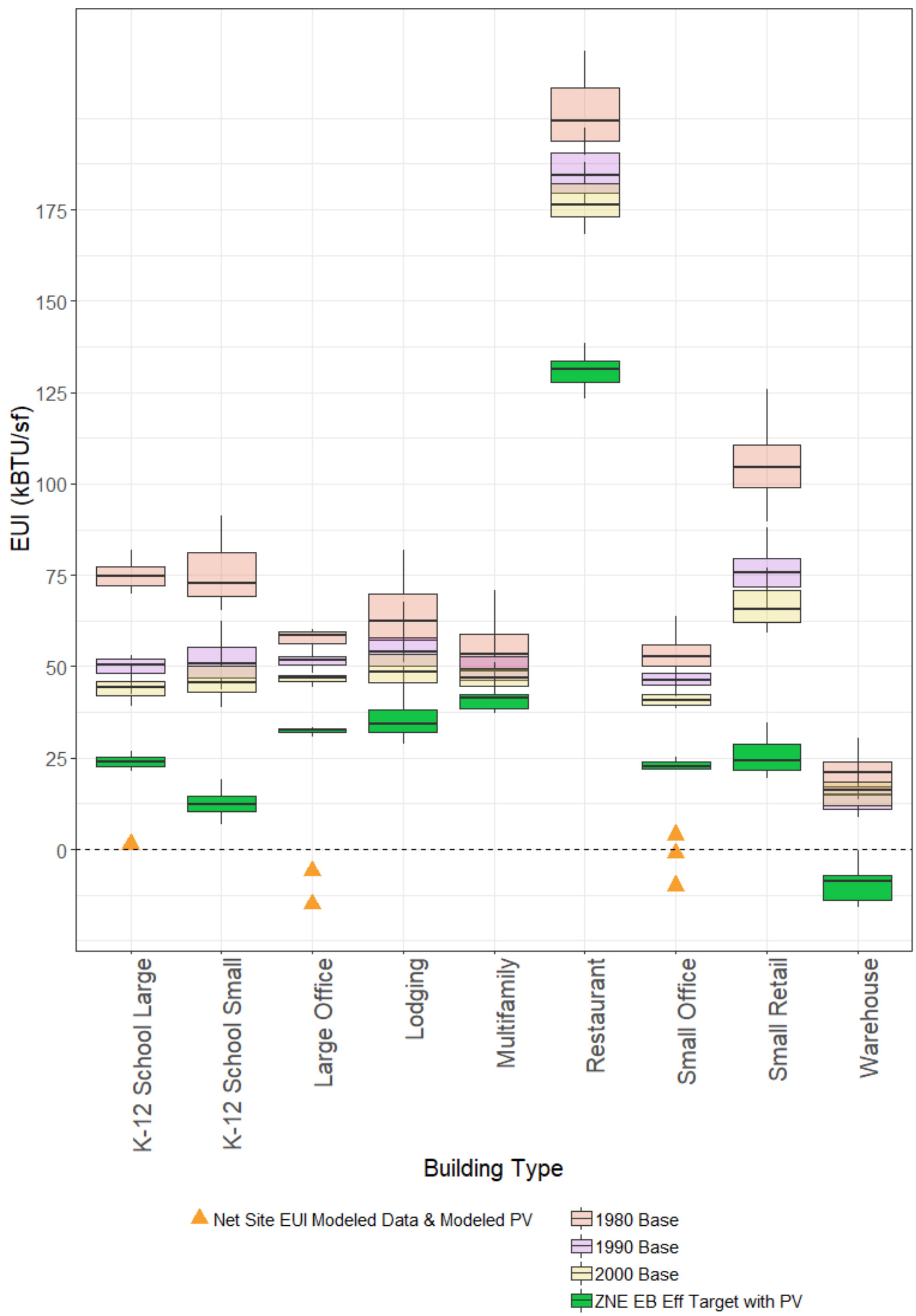


Figure 41 shows results for existing buildings with solar PV included for net EUI estimates. This analysis added solar PV to the modeled retrofits ("EB Efficiency Target" series) and project-level results of ZNE and ultra-efficient projects (the "Modeled Site EUI" series). This analysis does not show the impact of PV on vintage code buildings, since the preferred loading order is to install efficiency measures before adding PV, but the EUI of vintage code buildings are shown for comparison.

Figure 41. Vintage Comparison by Building Type across CA Building Climate Zones with PV



Results illustrate the success of codes to reduce energy use. With the exception of warehouses and restaurants, the modeled EUI for vintage codes (1980 through 2000) generally use 40 to 110 kBTU/sf compared with the Title 24-2019 modeled EUI: 30 and 55 kBTU/sf.

The study of maximum efficiency for retrofits (shown as the series "Retrofit Efficiency Target") shows there is significant energy savings potential for compared with vintage code, particularly for offices. The energy savings potential was lower for some other building types compared with new construction. However, this is likely an underestimate of savings potential – largely due to assumed limits in significant retrofits to the building envelope in the feasibility study, since the site-level modeling for ZNE retrofit projects shows energy consumption *below* the maximum efficiency EUI. In addition, as described in the next section, measured energy use shows ZNE retrofit buildings can use a fraction of energy compared with similar buildings of that type.

Overall, the modeled results for ZNE retrofit projects illustrate that existing buildings can achieve an EUI in the same ballpark as new construction. While the ILFI study (2013) found the cost to a conduct a retrofit is more expensive than for new construction, that study also found higher energy savings for retrofits. The EUI analysis here supports this, exhibiting larger energy savings between vintage code buildings and ZNE retrofit projects than between Title 24-2019 buildings and ZNE new construction.

The modeled results for ZNE retrofit projects indicate the ability of large schools, **and large and small offices, to achieve ZNE retrofits through aggressive efficiency, rooftop PV, and some onsite solar**. **Warehouses, small schools, and small retail should also be able to achieve ZNE retrofits** using the same approach (and possibly less solar. This is because the feasibility study shows warehouse EUI below zero and shows the EUI for small school and small retail as similar to or below the EUI of building types that have achieved ZNE retrofits (offices and large schools). If small schools and small retail have a similar ratio of rooftop to conditioned floor area as offices and large schools, they should also be able to achieve ZNE retrofits.

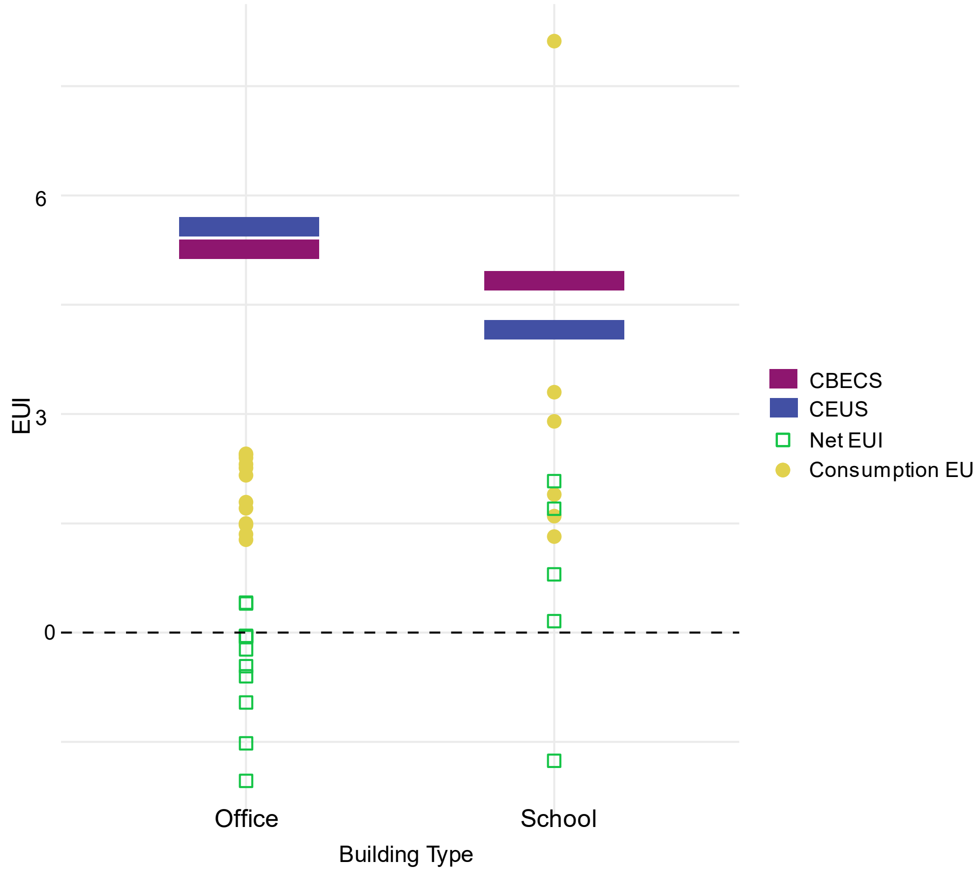
10.3.3 Measured EUI analysis

Figure 42 has the following series, all of which collected measured energy use:

- "CBECS" for data from the California Building Energy Consumption Study (2012), and "CEUS" for data from the Commercial End Use Saturation survey (2006), both of which represent the existing stock.
- "Consumption EUI" shows EUI based on efficiency only (no PV) of retrofitted ZNE and ultra-efficient projects, and "Net EUI" shows EUI for the same projects including PV.

This figure only includes ZNE and ultra-efficient retrofit projects for an "apples to apples" comparison, since most new construction ZNE and ultra-efficient projects were constructed after the majority of the building stock in the CBECS and CEUS data sets.

Figure 42. Measured EUI of Offices & Schools for Existing Stock vs. ZNE Retrofits



While there are only a few ZNE retrofit and ultra-efficient retrofit projects with measured data, **these example ZNE and ultra-efficient retrofit projects show significant measured energy savings compared with building stock**. On average, the ZNE and ultra-efficient retrofits had average energy use that was 62% less than the building stock average data (CBECS/CEUS) for offices, and 35% less than average schools. The measured data also shows that ZNE is possible for small offices and that can accommodate significant renovations. The ZNE retrofitted small schools also came very close to zero net EUI. Overall, the monitoring data support the findings from modeling – showing that office and school retrofits can result in achieving ZNE or near ZNE performance.

10.3.4 Measured and Modeled EUI Comparison

The TRC team also analyzed the performance of modeled data in comparison to measured data, by comparing modeled with measured data of ZNE projects (both ZNE Performance and Emerging where data was available) and ultra-efficient buildings.

Figure 43 shows a scatter plot comparing measured and modeled consumption EUI. Compared to the line indicating where modeled energy consumption is equivalent to measured consumption (“Modeled = Measured Consumption”), many buildings fall along or close to this line. In general, about half of the projects were measured to perform within 25-30% of the modeled EUI. However, several outliers exist both above and below the line. The best fit line for the data (measured = 0.74 x modeled + 10.1 with high significance of p-value < 0.01, indicating there is less than a 1% chance that the correlation described in the equation above is due to chance) appears to indicate that measured energy exceeds modeled energy for projects with low EUI, and modeled energy exceeds measured for projects with high EUI. However, this is largely driven by a few outliers and is not a reliable finding. **Overall, the comparison indicates that across all ZNE projects, the modeled energy consumption correlates with measured energy consumption, but results may not be consistent for each project.**

Figure 43. Measured vs. Modeled Consumption EUI for ZNE & Ultra-Efficient Buildings

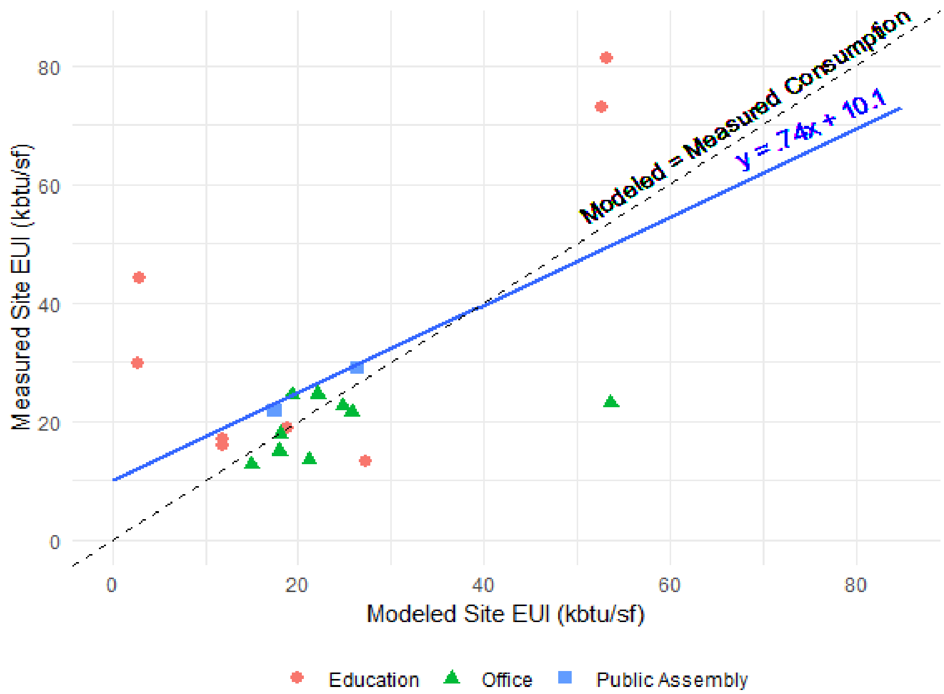


Fig 43 shows *net* modeled versus measured EUI, so includes both efficiency and solar PV. Overall, the data looks scattered with modeled net EUI ranging from -40 to 3 kBTU/sf and measured net EUI ranging from -21 to 21 kBtu/sf. While the TRC team found a strong correlation between modeled and measured energy *consumption*, the TRC team did not find a correlation between modeled and measured *net* EUI. This may indicate more discrepancies between modeled and measured results for solar PV generation. In addition, the net EUI comparison is more complex since it includes both consumption and solar PV generation, so there are more factors that must align to achieve a correlation.

While there was not statistical correlation between net modeled and net measured EUI, almost all projects modeled as ZNE or ultra-efficient also had low net EUI based on measured data. Section 13.5.5 in the Appendix provides more detail. **Overall, this comparison indicates there is considerable variability (no strong correlation) between modeled and measured net EUI, but most projects modeled as ZNE or ultra-efficient also had very low measured EUI.**

10.3.5 EUI Conclusions by Building Type

Figure 44 presents the EUI estimates and a summary of efficiency measures and solar PV needed to reach ZNE for each commercial building type in California. The figure includes EUI estimates of existing buildings (based on models of vintage codes), newly constructed buildings (based on models of T24-2019 compliant prototypes), ZNE retrofits (based on models of retrofitted ZNE and ultra-efficient projects), and ZNE new construction (based on models of maximum feasibility studies using prototypes), and ZNE. These data show the EUI status of the stock (existing and under construction) and what the EUI could potentially be (ZNE retrofits and ZNE new construction). Some building types were Not Analyzed (NA). This figure only discusses solar PV, but other types of distributed generation could be used. Building types are listed in descending order of ZNE feasibility.

Figure 44. Summary of EUI Estimates, and Efficiency and Solar Needed for ZNE by Building Type

Building Type	Vintage Code EUI (kBTU/sf from modeling)	T24-2019 EUI (kBTU/sf from modeling range of 25th to 75th percentile)	ZNE Retrofits Net EUI (kBTU/sf from modeling of ZNE retrofit projects)	ZNE New Const. Net EUI (kBTU/sf from modeling in feasibility studies)	Feasibility Finding
Warehouse (Nonrefr.)	12 to 24	14.4-20.0	NA	-14.1 to -15.9	T24-2019 efficiency + rooftop PV
Retail	62 to 110.6 (Small Retail)	50.3 to 56.2 (Strip Mall)	NA	-8.6 to -6.8	Efficiency levels between maximum feasible and Title 24-2019 efficiency + rooftop PV
Small School	43.1 to 81.2	32.7 to 39.8	NA	-6.4 to -5.2	
Small Office	39.5 to 55.9	42.7 to 48.3	-16.5 to 3.8	3.2 to 3.7	Maximum feasible efficiency, rooftop PV and small amount of onsite PV
Large School	42.1 to 77.5	29.2 to 34	1.4	5 to 5.6	
Large Office	46 to 59.7	30.2 to 32.6	-17.5 to 2.3	12.8 to 14.6	
High-rise Multifamily	44.7 to 58.9	27 to 31.4	NA	17.8 to 21.6	Maximum feasible efficiency, some reductions to loads, rooftop PV, and moderate onsite PV
Hotel	NA	33.4 to 37.8 (Small Hotel)	NA	NA	
Hospital	NA	NA	NA	NA	Maximum feasible efficiency, significant reductions to process loads, rooftop PV, and large onsite PV
Restaurant	173 to 208.2	145.5 to 153.6 (Small Restaurant)	NA	NA	

Decreasing ZNE Feasibility

The results of this analysis generally align with the findings from Arup (2012), which used modeling to investigate the feasibility of ZNE. Arup (2012) found that for most buildings excluding large offices, high-rise multifamily apartments, hotels, restaurants, and hospitals, it would be technically feasible to reach ZNE by 2020. Section 13.1.7 provides more details from the Arup (2012) study.

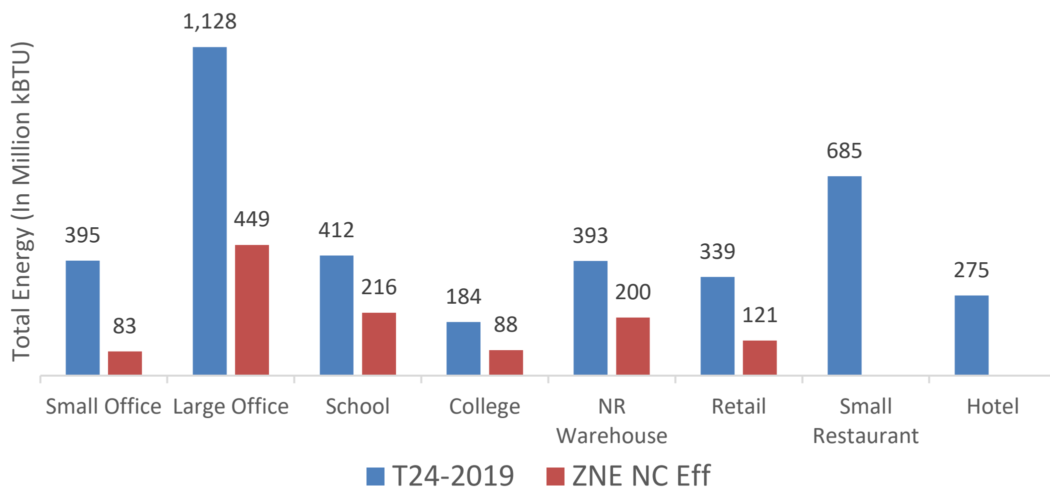
The TRC team developed Figure 45, which compares estimated energy usages by all buildings forecasted to be constructed in the CEC Construction Forecast. The analysis presents the two cases of:

1. All newly constructed buildings being Title 24-2019 compliant, shown as "T24-2019", and
2. All newly constructed buildings being built with maximum feasible efficiencies: shown as "ZNE NC Eff"

To calculate total energy usage, the team multiplied the construction floor area (forecast for 2020) by the modeled EUI from the Title 24-2019 prototypes (for scenario 1) and from studies included as the "ZNE New Construction Efficiency Target" (for scenario 2). The TRC team did not have a maximum efficiency scenario for small restaurants or hotels, so the figure only shows the Title 24-2019 scenario for those building types.

As shown, Title 24-2019 compliant large offices and small restaurants are projected to use the largest amounts of total energy. Small offices, schools, non-refrigerated warehouses, and retail sectors have similar energy usage under Title 24-2019. **Small offices and retail could reduce energy use by more than half, while schools and non-refrigerated warehouses could reduce energy use by approximately half through aggressive efficiency**.

Figure 45. Forecasted Energy Usage by Building Type for 2020 under Code-Compliant and Ultra-Efficient Scenarios



11 Conclusions and Recommendations

11.1 Conclusions

The results of this study indicate a mix of encouraging findings (“achievements”) and challenges (“outstanding issues”) for meeting the California statewide ZNE goals. The study found high excitement about ZNE from most market actors interviewed, almost all of whom had experience and success with ZNE or ultra-efficient buildings. However, only 1% of market actors responded to interview requests, perhaps indicating a lack of interest, knowledge, or prioritization for ZNE within the broad market. While there is a growing California ZNE and ultra-efficient market with strong diversity in climates, size, types, and ownership, they comprise approximately 0.4% of new construction and 0.1% of existing buildings. When considering only ZNE Performance buildings (i.e., those with metered results supporting the ZNC claim), the penetration is even lower. Thus, ZNE remains in the innovator stage and there are various outstanding issues related to feasibility and market adoption to achieve the 2030 goals. Several of these challenges are expected, given cost effectiveness constraints governing new Title 24 requirements, reach codes, and IOU programs. The findings show how market momentum combined with regulatory pushes are moving buildings towards ZNE, but at a slow pace.

This section provides conclusions by topic area, followed by recommendations, with the intent of assisting programs and policies to accelerate ZNE adoption.

11.1.1 ZNE Technical Feasibility

Achievements:

ZNE is technically feasible for many building types using efficiency and onsite solar PV. Nonrefrigerated warehouses can achieve ZNE through Title 24-2019 efficiency and rooftop PV. Retail buildings, small offices and small schools can achieve ZNE through efficiency measures only moderately more efficient than Title 24-2019 requirements and rooftop PV. Large offices and large schools can achieve ZNE by exceeding T24-2019 efficiency requirements and including rooftop PV and small levels of onsite solar (e.g., covered parking). These results are based on feasibility studies, and project-level results for ZNE and ultra-efficient buildings generally support these findings and often indicate that projects can achieve lower EUI than technical feasibility findings. Also, while ZNE feasibility results are based on modeling, metering results indicate that many types of new construction buildings have achieved ZNE or ultra-low energy use. While there are more ZNE modeling results available for new construction, a K-12 schools study found that retrofitted schools can achieve ZNE or near ZNE, and several existing office buildings have achieved ZNE or near ZNE through aggressive retrofits and onsite solar PV.

Outstanding Issues:

Some building types have high EUI even under Title24-2019 requirements, including hospitals, restaurants, and hotels. While these buildings have a relatively small amount of square footage compared to total commercial buildings, they have a significant energy footprint due to their high EUI. Urban high-rise projects with a low ratio of rooftop area to floor area also pose a challenge due to reduced rooftop and onsite solar PV opportunities.

Additionally, while prospects are good for ZNE for new construction for almost all building types, they are highly problematic for existing buildings if the metric of success is only based on payback from energy bills. Because greenhouse gas emissions from existing buildings dwarf those of new construction, it becomes even more critical to meet the state's goal of achieving ZNE in 50% of existing commercial buildings (in addition to 100% of new construction) by 2030 as the state intensifies its focus on greenhouse gas reduction.

11.1.2 Market Interest

Achievements:

Market actors interviewed here had positive experiences with ZNE and ultra-efficient buildings, expect their activity with these building types to increase, and are highly interested in working on more of them. Some sectors have embraced ZNE, such as those with long-term ownership of buildings (e.g., schools, universities, government buildings) and those with mission-driven policies to reduce GHG emissions. Beyond code buildings (analyzed here as those that participated in SBD or LEED) have strong market penetration in the new construction market at 11%, and solar PV adoption is increasing and has reached 5% (among total stock30) as of 2018. Both indicate that a significant portion of the market has an interest in exceeding code requirements.

Outstanding Issues:

There is a very low penetration of ZNE projects in market: approximately 0.4%. This indicates that the general market is not yet embracing ZNE, including for building types where it is easy to achieve ZNE (e.g., warehouses, small schools). The greater penetration of beyond code buildings indicates that the general market is less willing to reach ZNE than “beyond code”.

11.1.3 Drivers and Barriers

Achievements:

Market actors identified many drivers to ZNE and ultra-efficient buildings, including utility bill (cost) savings, energy and carbon emission reductions, and many non-energy benefits. These include improved occupant health, comfort, and indoor air quality; improved marketability of the buildings; attainment of greenhouse gas reduction goals; and reduced maintenance. For building types such as offices, some of these non-energy benefits lead to increased productivity and reduced sick days, which can far exceed cost savings from energy reductions alone. Most market actors interviewed reported that many barriers are solvable by education.

Outstanding Issues:

Market actors identified several barriers to ZNE, including insufficient budget, market actors’ inexperience with ZNE, inability to place enough renewables onsite, lack of team coordination, high plug loads and unpredictable occupant behavior, energy modeling challenges, and undervalued commissioning.

11.1.4 Cost Considerations

Achievements:

The incremental cost of ZNE will vary depending on several factors, including building type (which affects building load), building and site dimensions (which affects area available for solar PV), and location, which makes estimating incremental cost difficult. However, the majority of market actors interviewed here (57%) – most of whom had experience designing or constructing ZNE and ultra-efficient buildings – estimated that incremental cost of ZNE and ultra-efficient buildings is less than or equal to 5% compared with code-compliant buildings. Based on the literature, this should translate into a high return on investment (ROI). Although there are no ZNE valuation studies available, studies have found that LEED buildings have a 10-31% premium in sales price and 15-17% premium in rental rates compared to similar non-rated buildings.

Outstanding Issues:

Approximately 20% of market actors interviewed here estimated the incremental cost for ZNE and ultra-efficient buildings is at least 20% compared to code-compliant. Based on the EUI analysis, both the low incremental cost estimate noted above in “Achievements” (less than or equal to 5%, as estimated by 57% of interviewees) and the high incremental cost estimate (at least 20%, as estimated by 20% of interviewees) can be accurate, depending on building type. As another challenge, market actors were split in their estimates of how operation and maintenance costs of ZNE and ultra-efficient buildings compared to code-compliant, with one-third

[30] The data set available from CPUC does not track PV installations separately for new construction versus existing buildings.

reporting lower, one-third reporting higher, and one-third reporting about the same. Thus, while energy bills may be lower for ZNE and ultra-efficient buildings, these cost savings may be reduced to increased maintenance or operation needs. Also, the combined findings that 1. the majority of market actors interviewed here estimated incremental cost as 5% or less, 2. LEED buildings have a sale and rental premium higher than 10%, but 3. penetration of ZNE is less than 1%, indicates that market actors may have a higher perceived cost of ZNE, they may not believe the ROI estimates, or that market actors have other concerns delaying ZNE adoption.

11.1.5 Policies

Achievements:

Several jurisdictions have adopted reach codes or green ordinances to require buildings to exceed energy code requirements, and the number of reach codes is increasing. In addition to reach codes, jurisdictions and agencies can impose additional requirements for publicly-owned buildings. For example, DGS requires ZNE for new construction commercial buildings. The state of California – and several entities within it – have requirements for certain building types to exceed code, such as California Executive Order B-18-12 requiring state buildings and major renovations beginning design after October 2017 to be constructed as ZNE facilities. University of California's Carbon Neutrality Initiative commits the university system to achieving carbon neutrality for campus operations by 2025 for direct emissions and purchased energy.

Outstanding Issues:

Jurisdictions' reach codes do not require ZNE but instead impose moderate energy efficiency or renewable energy requirements. Most reach codes limit their scope to new construction buildings and exclude retrofits.

11.2 Recommendations

Meeting ZNE goals will require various types of actions. This section provides recommendations by topic, with related recommendations grouped under a single number (e.g., Recommendation 4a, 4b, 4c, etc.).

11.2.1 Immediate Research Needs

The TRC team identifies the following recommendations that the IOUs and CEC should pursue as soon as possible, because the outcomes would support various other recommendations related to codes and standards, incentive programs, and other topics.

1 ***Recommendation 1: Revisit ZNE goals to meet GHG emissions and demand response needs. IOUs lead, CPUC support***

Justification

The IOUs scoped this study in 2017 and in the years since, the State agencies have intensified their focus on GHG reduction, and the IOUs have increased focus on GHG and demand response (DR). It was beyond this study's scope to investigate the impact of ZNE on GHG or DR. There is generally an overlap between achieving ZNE and reducing GHG emissions and demand, but some ZNE strategies will have a larger impact than others on GHG and demand (and a few may have no impact at all). While the State has always prioritized energy efficiency over renewable energy to achieve ZNE, that loading order may not be ideal for achieving GHG and DR goals. A shift from TDV to a time dependent source (as recommended by Architecture 2030, or similar metric that addresses emission components) helps address GHG objectives and align GHG and ZNE goals. However, GHG reductions and decarbonization should be pursued on a least cost basis, and market actors interviewed here showed that energy efficient technologies and strategies (including low cost solutions such as proper orientation and passive systems) are critical to reducing costs for ZNE and ultra-efficient buildings. California policy should emphasize the need for low EUI footprints, and this emphasis should flow through to the building design community.

Implementation Strategy

The IOUs should consider conducting a study to revisit ZNE goals in light of GHG and DR objectives. The study should investigate different options for achieving ZNE in prototype buildings and their impact on GHG and demand. The research should include scenarios with different efficiency measures, renewable strategies (including rooftop, site-based, and community scale PV, and other renewables), and load management strategies (e.g., integrated DR or batteries) to estimate GHG and DR impacts. In some scenarios, ZNE may not be achieved, but the package of measures may perform well in terms of GHG and DR. Based on results, this study should identify a new loading order to qualitatively prioritize efficiency, renewables, and load management by building type and (if possible) by location (to account for local grid constraints) to best meet GHG and DR goals.

2 ***Recommendation 2**: Monetize non-energy benefits (NEBs) of ZNE and ultra-efficient buildings. CPUC lead, IOUs support*

Justification

While each program does not need to be cost effective, each IOU's portfolio as a whole must be cost-effective from a Total Resources Cost standpoint (excluding Codes and Standards), and codes and standards proposals must show cost-effectiveness based on net present value of TDV savings. The requirement for cost effectiveness is well-founded, since it ensures that code changes do not unduly burden the market and that IOU programs spend ratepayer dollars responsibly. However, this requirement poses a major challenge towards meeting the State's ZNE goals since it limits the scope and severity of code changes and the magnitude of incentive payments. To date, these cost effectiveness calculations are based on energy savings, but non-energy benefits (NEBs) can be significant. For example, a study found that office workers performed better on cognitive function tests in buildings with enhanced ventilation rates, equivalent to roughly $6,500 per employee per year in increased productivity[31]. Residential studies have also shown that the household and societal benefits from reduced cold-related and heat-related stress can be in the hundreds of dollars per household (E4thefuture, 2016). In addition, GHG reduction provides societal benefits, and strategies for ZNE can provide benefits such as resiliency and grid harmonization. If nonresidential NEBs from a minimum number of measures can be quantified and included in the cost effectiveness calculation, many strategies may become cost effective. The CPUC has allowed non-energy benefits to be included in the cost effectiveness tests for low-income programs (Morgenstern, 2015). In addition, the CEC has allowed for valuation of NEBs in the Prop 39 program, although this is limited to 5% (CEC 2019), which may underestimate their value.

Implementation Strategy

The CPUC should consider conducting an investigation of NEBs for nonresidential ZNE, ultra-efficient, and beyond code buildings with the goal of investigating which NEBs to include in cost-effectiveness calculations. As a first step, the CPUC should review NEBs research to date, including research from other states[32] and consider which types of NEBs (participant, utility, and/or societal) could be counted for which tests, and any findings that correlate NEBs to specific measures or packages of measures. This initial effort will likely underestimate NEBs

[31] https://resources.wellcertified.com/articles/workplace-meet-well-enhancing-the-employee-experience-through-healthy-buildings/

[32] As example studies of commercial and industrial NEBs, the Northeast Energy Efficiency Partnership (NEEP) has published a study: https://neep.org/sites/default/files/resources/NEI%20Final%20Report%20for%20NH%206.2.17.pdf and the Massachusetts Program Administrators contracted an investigation: http://ma-eeac.org/wordpress/wp-content/uploads/Massachusetts-Program-Administrators_Commercial-Industrial-Non-Energy-Impacts-Study.pdf

but help adjust the outcome of cost effectiveness calculations. Once more information on NEBs has been collected – such as through occupant surveys recommended below, or project-specific data related to a specific technology or strategy, the IOUs could provide data so that the CPUC could expand the list of NEBs or expand the measures that contribute to NEBs.

3 ***Recommendation 3: Shift away from percent better than code and move to an Energy Design Rating (EDR)-type reporting. CEC lead, IOUs support***

Justification

For Title 24 compliance and most beyond-code programs, such as LEED and SBD, project teams compare modeled savings for their building using a "percent better than" an energy code baseline (e.g., better than Title 24-2016), which changes over time and with the characteristics of the projects. Moreover, a Title 24 code baseline does not address unregulated loads, including plug loads, commercial refrigeration, and some processes. While many researchers have suggested tracking EUI instead of percent above Title 24, the CEC recently developed an Energy Design Rating (EDR) for residential buildings. EDR is a whole building metric used for both modeled (design) and measured (performance) energy use that compares the building's EUI to a fixed baseline that is a comparably sized building. (Section 6.3.4 provides the CEC's full definition of EDR.) Eley (2011) argues that a fixed performance baseline would enable comparison of efficiency levels across code cycles and among building types, set and measure progress toward policy goals, score efficiency standards such as energy codes, and give a score to aggregated building stock. Another benefit of an EDR-type metric over EUI is that EDR does not penalize small buildings. CEC is developing a similar metric for commercial buildings, and the IOUs are supporting them – including a study to investigate baselines using ASHRAE Standard 90.1 Appendix BM.

Implementation Strategy

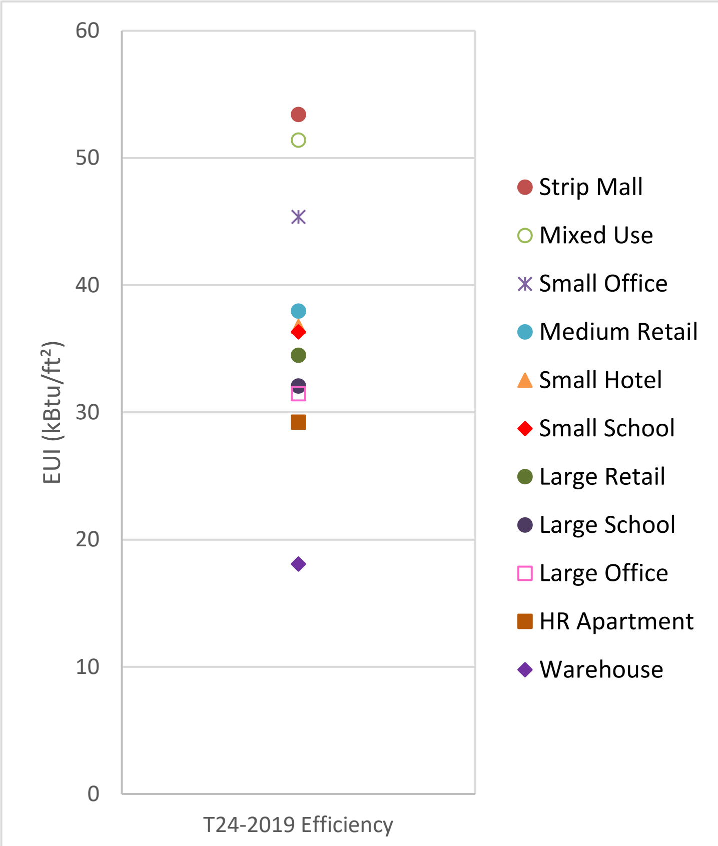
The IOUs should continue to support CEC in its development of a fixed performance metric, by helping to identify the baseline systems for each building type. Within each building type, TRC team's analysis found relatively little variation (based on modeling) by climate zone, which indicates that the performance-level metric could be simple (a few climate zones, rather than all 16 in California) for each building type. Once the CEC finalizes the EDR-type metric for commercial buildings, the CEC and IOUs should shift to using this metric for Title 24 reporting, incentive programs, and other tracking.

11.2.2 Codes and Standards Recommendations

The TRC team directs the following recommendations to the CEC, the agency that develops Title 20 and Title 24 regulations and solar provisions, as well as Statewide Utility Codes and Standards Enhancement (CASE) team that provides recommendations to CEC for Title 20 and Title 24 proposals.

Figure 46 shows the average EUI across climate zones for Title 24-2019 buildings based on analysis of this study. The figure excludes restaurants (so as not to compress the y-axis), but this analysis modeled their Title 24-2019 EUI as 151 kBTU/sf.

Figure 46. Modeled EUI under Title 24-2019 Efficiency



There are various efforts underway to investigate opportunities for identifying EUI reductions for California nonresidential buildings, including various codes and standards efforts, and we note a few examples here: The CEC – supported by the Statewide Utilities CASE team – proposes specific updates to Title 24 each code-adoption cycle, for a variety of measures and performance-based approaches, and the IOU Code Readiness team investigates opportunities to pave the way for additional savings in future cycles. The Architecture 2030 ZERO code provides a model building ordinance (so could function as a reach code). The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) provides ZNE design guides for some types of nonresidential buildings[33], and NBI has developed a prescriptive new construction guide for high performance buildings; these resources are national but could be adapted for California. The CEC and IOUs should continue to leverage these investigations as they consider the following recommendations.

4 ***Recommendation 4: Enhance Codes and Standards requirements. CEC lead, IOU support (through Statewide Utility CASE Team efforts)***

4a ***Recommendation 4a: Accelerate the net energy reduction each code cycle.***

Justification

The current trajectory based on past Title 24 cycles is an approximate 3% TDV EUI reduction with each cycle of Title 24 (Contoyannis 2018). Contoyannis (2018) and Arent (2016) recommended greater reductions in energy savings from requiring trade-offs within the prescriptive path of Title 24.

Implementation Strategy

[33] Currently available for schools: https://www.ashrae.org/about/news/2018/new-advanced-energy-design-guide-available-to-help-k-12-schools-achieve-zero-energy and for offices: https://www.ashrae.org/about/news/2019/new-advanced-energy-design-guide-available-to-achieve-zero-energy-office-buildings

As recommended by past researchers, the CEC (supported by the Statewide Utility CASE team) should consider requiring deeper energy savings through greater prescriptive trade-offs. Additionally, the CEC and CASE team should consider leveraging existing studies that have developed prescriptive packages for ZNE and ultra-efficient buildings to inform designers on approaches to reach ZNE or ultra-efficient buildings, including the ASHRAE ZNE Design Guides. As recommended by Paliaga (2016), the IOUs should consider recommending bundles of measures – i.e., optimal packages and performance targets rather than isolated measures.

4b ***Recommendation 4b: Investigate opportunities to bring more loads under T24 or Title 20.***

Justification

Several building types have high EUIs, including hospitals, hotels, and restaurants, in part due to loads that are not regulated by Title 24 or Title 20. Our analysis predicted restaurants to use the 2nd highest energy (after large office buildings) for newly constructed buildings. Chase (2012) found that one half or great of all energy loads are outside the scope of Title 24 regulations in some building types, some due to federal pre-emption. Plug loads also pose a challenge, and Higa (2014) noted the need to address several structural limitations in Title 24, including enabling measures for addressing plug loads and appliance energy use and developing building-type specific code requirements..

Implementation Strategy

Title 24 and Title 20 CASE studies should continue to investigate opportunities to regulate these loads to reduce EUIs in these typically high-energy using buildings. In particular, the CEC and CASE team should investigate opportunities to regulate plug loads, commercial refrigeration equipment (currently regulated by a federal regulation), elevators, and process loads (such as those in data centers and hospitals). The IOUs could also develop project case studies for these building types that highlight successful strategies for reducing their energy use. In the short term, an EDR-type metric will help address whole building energy outcomes, because it captures (although does not regulate) all loads. A long-term option for addressing unregulated loads is to shift to outcome-based codes, discussed further in section 11.2.3. In addressing the federal pre-emption challenge, one strategy used by other states is ”optional packages” (Higa 2016), under which one or more options that include equipment compliant with the minimum federal efficiency standards but is combined with other package options such as low power density lighting or solar PV. This allows for building-specific alternatives that achieve equivalent additional energy savings while maintaining the minimum federal HVAC standards.

4c ***Recommendation 4c: In addition to efficiency measures, add requirements for renewable energy and load management, with flexibility to address needs of the project and site.***

Justification

While increasing, only 5% of commercial buildings have solar PV. Title 24-2019 requires new construction residential buildings to have solar PV, but not commercial. There are several barriers and opportunities for commercial buildings, including:

- At the policy level, a primary barrier is uncertainty over how to model solar PV for commercial buildings and a lack of modeling metric (equivalent to the residential EDR).

- Market actors interviewed here discussed lack of roof space and shading as the main barriers to solar PV (ahead of cost) and the literature review found that structural issues - e.g., additional loads to the roof, can be a challenge for adding rooftop solar PV.
- The continued addition of utility-scale and distributed solar to the grid has heightened demand challenges, with net electricity needs declining in the afternoon and increasing in the evening.

Implementation Strategy

New construction commercial buildings should be required to install onsite renewable energy, with flexibility for renewable energy options and additional requirements or trade-offs for load management and/or offsite renewables where onsite renewables are infeasible. Alternatively, requirements could use a tiered approach with different solar PV thresholds depending on the potential solar PV production of the building that accounts for shading, and other rooftop space constraints such as HVAC equipment.

Providing additional requirements or allow trade-offs for demand-response technologies, such as battery storage, would shift loads to non-peak times or possibly when the carbon intensity of the grid is lower. Ideally, the results of Recommendation 1 (revised loading order by building type and geographic area) could inform preferences and trade-offs for efficiency, renewable energy, and demand-response technologies. The CEC and CASE team could also consider imposing greater renewable energy requirements on suburban and rural projects – since these generally have more opportunity for rooftop or site-based PV, but typically higher transportation-associated GHG emissions.

The CEC - supported by the Statewide CASE team and in discussions with CPUC - should develop similar requirements for commercial buildings as they have for residential and investigate renewable energy credits (RECS). Similar to Title 24-2019 Section 10-115 (for residential buildings), the language for commercial buildings should:

- Require a direct line from the project to the community solar project.
- Require for a power purchase agreement (PPA) or other documentation showing that a part of that production is assigned to this project to avoid "double-dipping" from multiple projects.
- Require proof that the community system will serve the project for at least 20 year, in alignment with the Title 24-2019 Section 10-115 requirement for duration.
- Regulate the use of green tariffs (i.e., utility-scale or community choice aggregated 100% renewable energy) to meet requirements, including contractual requirements for committing to this green tariff long-term. Because CPUC oversees tariffs, the CEC should solicit their input when drafting these requirements.
- As proposed by Architecture 2030 (2018), provide procurement factors (i.e., multipliers) so that onsite or community renewable generation has a higher weighting than RECS, since it is less desirable. Related to the duration topic above, the multiplier could be higher if projects can prove long-term commitment to the community system.
- Designate an enforcement agency to verify the above components and potentially creating a central registry to track RECS to avoid “double-dipping.”

11.2.3 Reach Code and Local Ordinance Recommendations

As of 2019, at least 16 jurisdictions across the state have active energy and green building codes for targeted measures or general energy reduction beyond code. The recommendations below are directed to jurisdictions, with support from the IOU programs supporting reach codes.

5 Recommendation 5: Enhance Reach Codes and local ordinances. Local jurisdictions lead, IOUs support

5a Recommendation 5a: For jurisdictions with existing reach codes, consider updating the existing requirement separately from developing new requirements.

Justification

CEC requires that jurisdictions update reach codes every three years under the new version of Title 24 part 6. Some jurisdictions have expanded the scopes of reach codes over the code cycles. Several interviewees reported they will separate a new proposal into its own reach code or fold it into a green building code as opposed to trying to adopt one reach code with multiple elements, since new requirements can be more contested and take more time for adoption than renewing measures.

Implementation Strategy

While stakeholders discuss the scope and details of new reach code requirements, jurisdictions should renew existing reach codes in a separate proposed ordinance. This helps ensure the pre-existing standard will be renewed and clarifies at least some reach code aspects for the market.

5b Recommendation 5b: Impose enforcement mechanisms to help ensure that the intended outcomes are achieved.

Justification

For projects that must meet LEED standards, the City of San Jose requires that projects pay a deposit that the city returns if the project meets the LEED standards after construction. This deposit can help ensure a project will complete LEED requirements and not default after permit approval. San Francisco requires LEED Silver for new commercial projects but offers priority plan review for LEED Gold projects.

Implementation Strategy

A jurisdiction could require projects to pay a deposit that will be returned if the project meets reach code requirements, as verified after project construction. Other opportunities are issuing a temporary certificate of occupancy until a project meets its goals, a tax or utility fee structure that becomes more favorable once the building shows compliance, or requirements for audits or retro-commissioning if projects do not meet performance goals.

5c Recommendation 5c: Establish voluntary standards to encourage deeper energy savings and reach retrofit projects.

Justification

Cost effectiveness limits the scopes of reach codes. Jurisdictions cannot mandate ZNE, and in many cases exclude retrofits from reach codes, because analyses do not show cost effectiveness. To sidestep these issues, some jurisdictions develop voluntary standards to target deeper energy savings or to include existing building retrofits, and some impose stricter requirements for public buildings. For example, DGS requires ZNE for new construction for their commercial buildings. Jurisdictions can lead by example and impose stricter requirements for city projects, or could use these strategies to encourage electrification.

Implementation Strategy

Jurisdictions could develop voluntary standards to target ZNE more explicitly and include requirements for existing buildings. The IOUs' Local Government Partnerships have supported some of these efforts and should continue to provide support and technical services. Partnering with IOU programs where possible, jurisdictions could also offer technical assistance or design charettes.

5d ***Recommendation 5d: Encourage participation in voluntary standards through density bonuses, tax incentives, and permit fee rebates.***

Justification

Participation in voluntary standards may be limited if project teams see no benefits.

Implementation Strategy

Jurisdictions should considerable several strategies to help make the voluntary standards more attainable and compelling. These include floor area ratio (FAR) bonuses, which allow projects to exceed the jurisdiction's maximum gross floor area for a typical building given the lot size; bonus density increases; tax incentives; and permit fee rebates, in which a percent of permit fees are rebated at project completion if it meets the voluntary standards (NBI 2018).

6 ***Recommendation 6: Develop Building Performance Standards to regulate actual energy use.***

6a ***Recommendation 6a: Convene a statewide meeting to develop a framework for Building Performance Standards. CPUC lead; CEC, CARB, local jurisdictions, and IOU Reach Code Staff support.***

Justification

California is not on a trajectory to meet its 2030 commercial ZNE goals, with penetration firmly in the innovator stage. ZNE buildings comprise only 0.1% of existing buildings. California has various policies that address energy, starting with the Warren-Alquist Act from 1974 and including more recent legislation (e.g., SB100, AB802), but none directly regulate energy performance.

Across the U.S., a few communities either have, or are considering an approach to regulate *actual energy consumption* of buildings. Typically called “Building Performance Standards” or “Building Emissions Standards”, these set minimum performance targets and often first apply to large buildings

(50,000 square feet and up), with smaller buildings regulated in the future. Three jurisdictions with Building Performance Standards are in the rulemaking process which will clarify implementation details:

- New York City Local Law (LL) 97, for existing buildings over 25,000 square feet, sets Building Emissions Performance Standards and calls for 40% GHG emissions by 2030 and 80% by 2050. Buildings must report and meet GHG benchmarks set in five-year increments. There are additional requirements for city-owned buildings (in LL31 and LL32).
- The District of Columbia's Law 22-257 establishes a Building Energy Performance Standard and relies on ENERGY STAR scores as reported in benchmarking requirements. Projects below the performance threshold will choose between a performance pathway to document a 20% reduction in energy usage over five years, or prescriptive measures.
- Washington State's House Bill 1257 establishes a Building Energy Performance Standard using a site energy use metric that varies by building type and climate zone.

Implementation Strategy

The regulatory agencies that have called for ZNE and carbon reductions in buildings should require regulation of energy use in existing buildings. AB 802 sets the groundwork for data collection to support a Building Performance Standard policy. As a starting point, the CPUC - supported by local governments representatives, the CEC, and CARB, should convene a statewide meeting to identify approaches, enforcement mechanisms and key elements of outcome-based standards. Key elements include evaluation metrics (e.g., carbon, energy, ENERGY STAR scores), minimum levels of energy performance, potential exemptions, timelines for requirements, and consequences if the minimum requirements are not met. Standards could meet cost-effectiveness requirements, but if so, non-energy benefits (as described in Recommendation 2) should be included.

6b ***Recommendation 6b:* *Local jurisdictions should initiate implementation of Building Performance Standards. Local jurisdictions lead, CEC and IOU Reach Code staff support.***

Justification

Initial implementation of Building Performance Standards may be more feasible at the local jurisdiction level than statewide.

Implementation Strategy

Local jurisdictions should take the lead in implementing outcome-based requirements as part of their Climate Action plans. The CEC IOU Reach Code programs can support them by coordinating efforts across jurisdictions to reduce jurisdictions' resource needs and to provide more consistency in the market.

11.2.4 Incentives, Financing, and Voluntary Programs

The TRC team directs the following recommendations primarily towards the IOUs for incentive and financing programs. The IOUs had previously provided incentives and technical assistance through the Savings by Design (SBD) program but are transitioning to a new program that will be administered by a third party. The SBD program includes several elements that should be retained in the new program, including a whole-building pathway, tiered (increasing) incentives to encourage deeper energy savings, incentives for a design charrette and other components of integrated design, and technical assistance. The new third-party program should also cross-promote existing financing programs, including Property Assessed Clean Energy (PACE) financing. Below are recommendations for additional elements of the new third-party program to encourage projects to achieve greater energy savings through participation in such a program.

7

***Recommendation 7*: In addition to the previous SBD offerings, the IOUs should consider several other strategies for the new third-party program. IOUs lead**

7a

***Recommendation 7a*: Provide financing as part of the program offering for ultra-efficient and ZNE projects.**

Justification

Market actors identified first costs as a barrier to ZNE and ultra-efficient buildings. Although most market actors estimated incremental cost at 5% or less – a relatively small value for a commercial project – they described that efficiency strategies are often removed through value engineering, and reported that tax credits, on-bill financing, and revolving green loans can help overcome first costs. Three interviewed market actors mentioned that the source of funds - such as utility incentives or financing for efficiency - plays a role in ensuring that efficient equipment is retained, and the literature review and market actor interviews found that some ZNE projects use financing specific to energy efficiency such as PACE or (for schools) Prop39 funds.

Implementation Strategy

The IOUs should recommend the On-Bill Financing (OBF) program as a resource (in addition to the SBD-replacement program) for retrofit projects. For new construction, the program should offer a financing option in addition to other program incentives. This financing should be a zero-to-low interest loan and could be part of a revolving loan fund. To qualify for the loan, project teams should provide modeling results showing that the project is estimated to achieve ZNE or ultra-efficient status, and the program should cap the loan at a certain percentage of the total project cost. This cap may vary depending on the building type and site specifics, since ZNE is more feasible for some building types and sites. Additionally, SBD currently has a higher Total Resource Cost ratio than many other commercial programs so there should be some scope for additional services. Furthermore, there are programmatic ways to increase training/design advice outside of the project level design incentives.

7b

***Recommendation 7b*: Provide optional post-occupancy support as part of the program.**

Justification

Market actors interviewed were split into approximately equal thirds in estimating that operations and maintenance costs for ZNE and ultra-efficient buildings were lower, about the same, or higher than standard practice buildings. Interviewees and the literature review identified that optimal operation of systems - including equipment controls, schedules, and setpoints, was key to the success of ZNE and ultra-efficient buildings.

Implementation Strategy

The program should provide post-occupancy support (optional to participants) to help ensure these buildings operate as planned, through incentives for commissioning, or provide free (or reduced cost) operational review by professionals familiar with the technologies for up to two years post-construction. The program should also require or encourage that the commissioning or operational review consultants provide findings to the owner and design team to close the feedback loop on strategies used. PG&E staff report that post-operational support was provided in a pilot several years ago; if a final report for the pilot is available, IOU staff should investigate the lessons learned from this pilot.

7c ***Recommendation 7c: Document predicted energy use and savings as part of the program.***

Justification

Based on the data received by the TRC team, energy data tracking varied by IOU SBD database. Some IOUs tracked predicted total energy use of the building (on an absolute scale), while others tracked energy and demand savings compared to a code-built baseline. Both metrics are valuable.

Implementation Strategy

IOUs should require that projects provide predicted energy use and predicted energy savings for custom incentive programs, including the nonresidential program for new construction and major retrofits that will replace SBD. The IOU databases should include fields to track these outputs. Once the EDR-metric is developed, IOUs should shift from tracking energy savings to tracking EDR-based values.

7d ***Recommendation 7d: Consider providing part of the incentive based on post-occupancy performance or (at a minimum) require projects to provide 12 to 24 months of post-occupancy data and strategies used (e.g., energy models).***

Justification

Shifting part of the incentive to post-occupancy will encourage actual (metered) energy savings instead of modeled savings. Most market actors interviewed here are measuring energy use for their ZNE or ultra-efficient projects, so providing performance data should not be a significant additional burden.

Implementation Strategy

The TRC team recommends a partial pay-for-performance approach, whereby IOUs provide most of the incentive during the design and construction phase but a portion after at least one year of occupancy based on performance. Projects could be allowed two years to meet targets, to allow for operating adjustments. Projects should continue to provide documentation of the approaches they used, such as energy models, so that future researchers can analyze energy savings by measure (or packages of measures). Alternatively, the IOUs could require projects to provide post-occupancy data for one to two years, which the IOUs could use to inform program design and CEC modeling assumptions (see Recommendation 11).

7e ***Recommendation 7e: Provide an incentive for administering an Indoor Environmental Quality (IEQ) survey of occupants.***

Justification

The most common driver to ZNE and ultra-efficient buildings identified by the market actors interviewed here is occupant health and indoor air quality (52% of respondents), and many also cited improved thermal comfort (43%), improved occupant productivity (32%), and access to daylight (20%; multiple responses allowed). A meta study of literature found that strategies for reducing thermal and lighting do not harm occupants' well-being and performance and may even improve them but found no direct link between energy use and human comfort (Kozusznik 2019). While IEQ outcomes of some measures (e.g., daylighting) are well documented, occupant surveys can identify how other measures lead to increased occupant satisfaction, which could support Recommendation 2. There are various IEQ surveys already available, which the IOUs could leverage to reduce costs for survey development and enable a comparison with other buildings, such as the Center for the Built Environment survey.

Implementation Strategy

The IOUs should consider providing an incentive for whole building projects to administer an IEQ survey and require documentation of measures installed (such as an energy model). The IOUs should provide analysis across all projects that use the survey to investigate whether there are NEBs associated with program participation with certain measures, or with program participation in general.

8

***Recommendation 8*: The IOUs should consider emphasizing NEBs and high return on investment for custom commercial programs and create a recognition program for ZNE buildings. IOUs lead**

While the TRC team directed the recommendations above specifically to the new third-party replacement program for SBD, the following recommendations are for both that program and other custom commercial programs. These following messages could be disseminated through program collateral, case studies, partnerships with national chains and public recognition, and other strategies.

8a

***Recommendation 8a*: Emphasize non-energy benefits to participants, utilizing the outcome of Recommendation 2.**

Justification

As described above, market actors cited various non-energy benefits (improved occupant health, thermal comfort, and daylighting) as drivers to ZNE. These benefits can outweigh energy savings financially due to increased occupant productivity, reduced sick days, and other benefits.

Implementation Strategy

Program collateral should identify these benefits – initially through project spotlights for different building types. As IEQ survey results are collected for program projects, these results can be aggregated to show the robustness of these benefits.

8b

***Recommendation 8b*: Highlight return on investment (ROI), particularly for privately owned buildings.**

Justification

Most market actors reported an incremental cost 5% or less for ZNE and ultra-efficient buildings. Other studies have found the buildings labeled as LEED have 10-31% sales premium and 15-17% rental rate premium, suggesting this increase will be compensated for at least some building types through reduced operating costs, and (for private buildings) higher sales prices, rent rates and reduced occupancy rates.

Implementation Strategy

While the IOUs should emphasize longer term benefits instead of immediate paybacks, program material should also discuss initial financial benefits including the findings of this study.

8c ***Recommendation 8c: Create a recognition program for companies with ZNE buildings.***

Justification

Particularly given drivers such as increased marketability for a building or improved public image from achieving an important sustainability goal, project owners may be attracted to recognition for reaching ZNE. While this analysis found that some building sectors had high participation in the whole building component of the existing SBD program (most notably the education sector), most building sectors had much higher participation in LEED[34].

Implementation Strategy

The IOUs should consider a recognition program to highlight companies and buildings that achieve ZNE. To identify projects to consider for recognition, the IOUs could leverage those identified by NBI or that participated in the Living Futures Institute or USGBC LEED-ZNE programs to reduce the IOUs' burden for verifying ZNE. This recognition initiative would not result in direct transactional energy savings, so would best be evaluated under criteria appropriate for non-resource programs and could be separate from the new custom commercial program so it does not affect its cost effectiveness.

11.2.5 Education and Training

Market actors reported that educational or training needs (n = 74) would help accelerate ZNE and reported that an experienced project team (n = 78) can help reduce incremental cost of designing and building a ZNE or ultra-efficient building. The following recommendations relate to the IOUs' workforce, education, and training (WE&T) programs.

9 ***Recommendation 9: IOUs should continue to provide integrated design training and conduct investigations into WE&T participation challenges and opportunities for improvement. IOUs lead***

[34] This finding applies to the SBD whole building pathway only, since the SBD systems path provides incentives for an individual system (e.g., lighting) so provides energy savings – but not deep energy savings.

9a ***Recommendation 9a*: *Continue to provide training on integrated packages and promote integrated design.***

Justification

The interviews and literature identified integrated design and close project coordination as a strategy for achieving ZNE and ultra-efficient buildings and for reducing the incremental cost. Since 2017[35], the IOUs have offered integrated design training through their WE&T program, and training on several of the aforementioned systems. The Itron (2019) study identified measure packages for ZNE scenarios.

Implementation Strategy

The IOU's training programs should continue to include integrated design, including its benefits and key aspects. The IOUs should compare their WE&T curriculum with the high priority technologies presented in the Itron (2019) study and adjust training as needed.

9b ***Recommendation 9b*: *Investigate opportunities to improve WE&T offerings and participation through the upcoming WE&T Market Assessment.***

Justification

In response to the question of resources that would help accelerate ZNE, 88% of interviewees selected some type of education or training and 82% selected financial assistance to offset incremental cost (multiple answers allowed), indicating that education is at least as important as financial assistance.

Interviewees reported that ZNE trainings, assistance with energy modeling, training with benchmarking, and tours of ZNE buildings (in that order) would be useful. The IOUs have offered several of these through their WE&T programs including workshops and webinars on energy modeling, benchmarking, and various emerging technologies and strategies used in ZNE and ultra-efficient buildings. The challenge may be more about increasing participation in existing offerings. WE&T staff have attempted to increase participation through lunch-and-learn webinars, evening or online trainings, and simulcast classes to reach market actors across their territories, and sometimes partner with trade associations, colleges, and trade schools to advertise or provide trainings. It was beyond our scope to investigate WE&T participation challenges. However, the IOUs are planning to conduct a WE&T Market Assessment to Inform Integrated Energy Education and Training (IEET).

In addition, the TRC team found evidence that, while there is a strong financial case for ZNE or ultra-efficient buildings, market penetration remains low.

Implementation Strategy

The WE&T Market Assessment to Inform IEET, or a process evaluation should investigate:

- WE&T participation successes, barriers and challenges, and better parse out what are actual training needs (i.e., training not yet offered), from lack of awareness of WE&T offerings, from challenges with participation (time or logistical issues).

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[35] PG&E started offering integrated design training through WE&T in 2017, although prior PG&E classes discussed the need for integration across systems.

- Value of and opportunities for expanding participation - such as "lunch and learns" at design and construction firms or opportunities to integrate ZNE education into accredited architecture and engineering programs – outside of the designated IOU training centers.
- More detail on some of the educational needs identified in this study, including whether requests for energy modeling training (which is already offered by the IOUs) is to meet a need for how to use modeling software or to address problems specific to Title 24 compliance software.
- Needs, audiences, and delivery methods for coursework that can build the business case for ZNE buildings including rebates, tax incentives, and real estate valuation.

10

Recommendation 10: CPUC should encourage broader reach of ZNE and GHG education through convening a forum on mandated licensing or continuing education requirements. CPUC lead, IOUs support

Justification

While the IOUs have been providing voluntary ZNE-related training, an approach to reach a broader audience would be to mandate training on ZNE and GHG-related topics. California is unique compared to most states in that it has very low continuing education requirements for architects.[36] Other studies – including the California Long-term Energy Efficiency Strategic Plan – have recommended continuing education as one means of achieving ZNE goals (CPUC 2008). However, California Governor Schwarzenegger vetoed a bill to expand continuing education requirements for architects. Governor Brown also vetoed a bill for continuing education requirements for court reporters, stating "the whole idea of legally mandated 'continuing education' is suspect in my mind. Professionals already are motivated to hone their skills."[37]

Implementation Strategy

The CPUC should convene a forum with fellow regulators and industry associations – including the American Institute of Architects (AIA) California – to identify opportunities for the professional licensing bodies to include ZNE or decarbonization related topics in the licensing exams or for requiring continuing education credits on these topics. This forum should discuss why such a requirement is needed, the best market actors for these requirements (e.g., architects and/or others), and the best structure for this requirement – i.e., to be included in the licensing exam, continuing education requirements, or both. If the forum decides that continuing education requirements should be pursued, the CPUC should develop the argument for why such requirements are needed to meet Statewide goals (including GHG targets), and why market forces are not enough to meet these needs.

11.2.6 Long Term Research Needs

In addition to the immediate research needs identified above, the TRC team recommends the following research that the CPUC, IOUs or CEC could pursue once sufficient data are collected.

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[36] The only continuing education requirement for California architects is five hours on disability access requirements. https://www.cab.ca.gov/licensees/ce/ As example states for contrast, both Oregon and Washington requires 24 hours of professional development every two years. https://www.aiaportland.org/education/ce-requirements and https://www.dol.wa.gov/business/architects/continuingeducation.html

[37] http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0651-0700/sb_671_vt_20110930.html

11 ***Recommendation 11*: Require building models, and update modeling assumptions by comparing aggregated modeling results with benchmarking data to improve modeling of advanced strategies. CEC lead, IOUs support**

Justification

The CEC recently required benchmarking data for all commercial and multifamily projects greater than 50,000 sf which will be publicly available[38]. In addition, many designers interviewed here identified modeling challenges as a barrier to ZNE.

Implementation Strategy

In addition to benchmarking data, CEC should require projects to provide modeling results to third party entities (with nondisclosure agreements with CEC, CPUC, or IOUs), to enable investigations of how modeling vs. measured data compares by building type, end use, and climate zone, to improve modeling assumptions. In addition, CEC should continue to work with its energy modeler contractors to improve modeling to include or better reflect ZNE and ultra-efficient building strategies. To focus resources for these updates, the IOUs could identify strategies most commonly installed in their custom nonresidential programs that compliance software does not currently accommodate, based on analysis of custom program participants (see Recommendation 7d).

12 ***Recommendation 12*: Track ZNE claims in central registry. CPUC lead, CEC support**

Justification

In a previous study, TRC (2018) found a need to conduct ongoing tracking of ZNE claims and verifications. The registry would allow for a transparent way to provide insights into ZNE growth, energy performance of ZNE buildings, challenges and opportunities for ZNE buildings, and progress towards goals.

Implementation Strategy

As suggested previously, the CPUC should work with CEC to develop a ZNE registry to track ZNE claims made and what type of evidence the project provided to support it (e.g., modeled energy, measured energy, other data). The CPUC could also consider creating an internship program to set up this registry and track data from ZNE projects. The Energy Trust of Oregon recently launched an internship program to assist companies that had committed to an American Institute of Architects 2030 commitment to track progress towards their goals[39].

13 ***Recommendation 13*: Identify strategies to reduce actual energy use behavior through industry competitions and feedback from ZNE projects. IOUs lead**

[38] For multifamily buildings, owners must follow this requirement for buildings 50,000 sf or larger and with at least 17 utility accounts. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-benchmarking-program

[39] https://www.energytrust.org/wp-content/uploads/2018/09/2019-Net-Zero-Emerging-Leaders-Internship-Application.pdf

13a ***Recommendation 13a: Consider providing an industry competition to identify opportunities to reduce energy use.***

Justification

For code-built and ZNE buildings, the actual energy use of a building can vary significantly from its modeled energy use, in part because of differences in building operations and occupants' behaviors. Building facility operators and others that work daily to manage systems and meet occupant needs are uniquely positioned to identify opportunities to reduce energy use.

Implementation Strategy

The IOUs should consider providing a monetary reward and recognition for companies – and the individuals at those companies – that identify strategies to reduce energy use in their facilities - both from facility managers' operational practices and occupants' behavior. For example, the IOUs could reach out to industry partners from a sector with a high EUI – such as the hotel or restaurant industry – and offer a cash prize for ideas for energy reductions. Ideally, IOU staff would request that executive staff members email their facility managers and others involved in daily operations requesting their ideas for the competition. The IOUs could then provide either additional incentives for industry representatives to flesh out the best ideas or provide a forum for representatives from across an industry to develop the ideas into implementable solutions. Although companies within the same industry compete for customers, programs such as the DOE Better Buildings Challenge have shown that they may cooperate to identify energy reductions strategies, since it generally benefits all parties.

13b ***Recommendation 13b: Identify strategies that ZNE and ultra-efficient buildings have used to encourage occupants to reduce energy use.***

Justification

Over half of market actors interviewed reported that they monitor energy use of their ZNE or ultra-efficient buildings. Owners or managers of ZNE and ultra-efficient buildings may be particularly motivated in encouraging occupants about the impact of their behavior on energy use to achieve the project's energy goals. One example of where this has already been done is at the Unisphere – a ZNE emerging building in Maryland, which has an interactive display where users can see how different decisions they could take within the building affects its energy use.

Implementation Strategy

The IOUs should consider following up with contacts at ZNE and ultra-efficient buildings – including those in their recognition program and those listed in the NBI Getting to Zero database – and request recommendations for encouraging occupants to use less energy. The IOUs could publicize results of both efforts through social media, short videos, or case studies.

11.2.7 Building Technology Recommendations

14 Recommendation 14: Consider opportunities to accelerate specific technologies. IOUs lead, CPUC and CEC support

Justification

Figure 47 summarizes – by building type – efficiency levels (relative to Title 24-2019 requirements) and solar PV needed to reach ZNE, and ZNE penetration (to indicate market interest). The column *Solar PV needed for ZNE* assumes a scenario in which the amount of rooftop PV is maximized, and any additional PV required would be accomplished through on-site PV. In all building types, community PV or other types of renewable energy could work in lieu of or in addition to rooftop and on-site PV, and (depending on the outcome of Recommendation 1) load management may be preferable compared to solar PV. For the column, *ZNE Market Adoption (% of New Construction),* "New Construction" includes all permitted projects (including retrofits), for both the numerator (from our database of ZNE and ultra-efficient buildings) and denominator (from CEC based on building permits).

Implementation Strategy

IOU programs, codes and standards, WE&T, and statewide policies should continue to explore opportunities to accelerate the adoption of the high priority technologies identified in Itron (2019) in both new construction and existing buildings, including advanced lighting controls, heat pumps, radiant heating and cooling, air sealing, grid integrated heat pump water heating, CO2 heat pump water heaters, and electrochromic fenestration.

Figure 47. Summary of Efficiencies and PV Needed to Reach ZNE

Building Type	Efficiency level needed for ZNE	Solar PV needed for ZNE	ZNE Adoption (% of New Construction)
Warehouse	Title 24-2019 efficiency	Rooftop PV or Community PV	0.003%
Retail	Between Title 24-2019 efficiency and Maximum feasible efficiency	Rooftop PV	0.003%
Small School	Between Title 24-2019 efficiency and Maximum feasible efficiency	Rooftop PV	0.40%
Large School	Maximum feasible efficiency	Rooftop PV + Small amount of On-site PV	
Small Office	Maximum feasible efficiency	Rooftop PV + Small amount of On-site PV	0.20%
Large Office	Maximum feasible efficiency	Rooftop PV + Moderate On-site PV	
HR Multifamily	Maximum feasible efficiency	Rooftop PV + Moderate	0%
Hotel	Maximum feasible efficiency	Rooftop PV + Large On-site PV	0.02%
Hospitals	Maximum feasible efficiency	Rooftop PV + Large On-site PV	0.004%
Restaurant	Maximum feasible efficiency	Rooftop PV + Large On-site PV	0%

15 ***Recommendation 15: For data centers, improve tracking of building stock and EUI to inform opportunities. CEC lead, IOUs support***

Justification

This study did not investigate data centers, because there are no ZNE or ultra-efficient data centers to date, the CEC does not have a prototype for this type of building for EUI analysis, and many previous studies do not have results specific to data centers. For example, the current CEC estimate of building stock shown in Figure 8 (in Section 6.1) includes data centers within the "Miscellaneous" category. The IOUs have recognized the importance of data centers with programs that target or serve these building types. Given the growth of data centers, more information is needed to track energy use and identify opportunities for net energy reductions in this sector. Although data centers are unique, there are some commonalities and likely some common strategies that can be used to reduce energy use – such as strategies for compressorless cooling.

Implementation Strategy

The CEC should provide results specific to data centers in their next building stock and/or building energy use survey. The CEC (supported by the IOUs) should explore data center EUI benchmarking data to support development of an EDR for this building type, and to identify strategies to reduce net energy use.

11.3 Concluding Statement

This study identified bright spots in the California ZNE market. The market actors interviewed were passionate about ZNE and ultra-efficient buildings and plan to construct more in the future. Most also estimated that ZNE and ultra-efficient buildings could be constructed at a fairly low incremental cost – 5% or less. In some building types, ZNE can be achieved with moderate efficiency gains (above Title 24-2019 requirements) and rooftop solar PV. However, ZNE has not taken off in the market. Approximately 0.4% of the total new construction market and 0.1% of existing buildings are ZNE, which includes both ZNE verified and ZNE emerging buildings (those with stated goal of ZNE, but that may not have completed construction or may not have attained ZNE). The market must make major shifts to reach California's Statewide goals of all new construction and half of existing buildings to be ZNE by 2030. This will require aggressive actions in many areas, including shifting to an EDR-type performance metric instead of "percent above Title 24"; revising cost-effectiveness assumptions to include non-energy benefits; accelerating the reduction of net energy reductions in codes and standards; expanding the SBD program; helping overcome first costs by providing financing, green revolving loans and tax credits; educating the market on issues such as the value of ZNE and how each type of project team member can help reach it; encouraging reach codes through opportunities such as joint analyses across jurisdictions; and conducting long-term research on topics such as best practices to reduce operational energy use and encourage occupants to save energy.

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13 Appendix B: Data Collection Results or Supporting Details

13.1 Methodology and Results of Literature Review

The literature review appendix outlines findings on a variety of topics outlined below, including drivers and barriers of ZNE, cost of ZNE, lessons learned, and the ZNE market.

13.1.1 Literature Review Methodology

Over the past ten years, New Buildings Institute has gathered and organized a rich set of ZNE related materials in a comprehensive knowledge management resource library. The library contains a variety of resource types including reports, articles, case studies, presentations, guides, definitions, articles, and white papers. It includes information on key technologies, including a growing set of information on renewable integration in the building sector. The library tags and organizes information with key words and by building type, resource type, and relevant geographic location for easy identification and sorting.

This knowledge management system served as the foundation for the assimilation of existing resources and literature review for this California commercial ZNE market characterization. To ensure the information on ZNE studies was current, the team also conducted research to find the latest ZNE materials. This included updating the literature review and sharing a relevant subset of this list with the California Investor Owned Utility (IOU) staff on the Project Coordination Group (PCG) for review and feedback. Members of the PCG provided additional insights and ideas on research informational materials that were added to the list.

The result of this comprehensive literature review was to compile the most up-to-date and extensive summary of resources on non-residential ZNE in California and elsewhere. The TRC team organized studies and sources that were a part of this search-and-gather task into four broad categories: (1) ZNE buildings in California, (2) research studies and books on ZNE, (3) case studies, and (4) policy examples. The team also organized this initial list of 265 resources in a spreadsheet that included information, where relevant, including title, author, document source, resource type, geographic location, building type (including whether it related to new construction or existing buildings) and keywords.

The next step in the research was to review the abstract for each of these 265 resources, with an eye toward key research objectives and questions that the team set out to answer with the literature review. Key research questions included: California market size, costs, benefits, barriers, non-energy benefits, lessons learned, energy targets, and definitions. Each of these research questions had a column in the spreadsheet. Researchers then ranked each of the resources for the value and insights it provided on the key research questions. A “0” in a particular column meant that that resource had no value to a particular research question while a “5” indicated a high value to help answer a particular research question. This exercise allowed the research team to focus on high-value informational materials and it reduced the total number of resources to seen as important to answer the research questions. in addition, it removed a few resources that were inadvertently on the list twice.

Figure 48 summarizes the number and value of resources for particular questions.

Figure 48. Number of Resources Ranked by Value to Particular Research Questions

Research Question	Number of Resources with no value ("0")	Number of Low Value Resources ("1" & "2")	Number of Moderate Value Resources ("3")	Number of High Value Resources ("4" & "5")
Drivers	52	29	14	28
Barriers	47	36	22	18
Non-Energy Benefits	55	29	26	13
Lessons Learned	43	32	21	27
Energy Targets	51	38	12	22
Definitions	51	32	16	24

Note: Some of the same resources were considered to be valuable to multiple research questions.

The research team was then able to prioritize the review based on the value of the resource to answer the research objectives and questions. This began by reviewing high value (#4 and #5) resources first, then moderate value (#3) to determine the extent to which the team could answer the question. If the team did not feel the research had fully answered the question, they added a review of low-value resources.

During this more in-depth review, the team studied more than 75 high-value resources and captured pertinent findings as they related to the research questions, organizing the data by topic and building type. The research team uncovered 361 data points, including key findings, definitions, quotes, cost data, etc. Specifically, the research team uncovered 69 mentions of drivers, 66 of non-energy benefits, 74 of barriers, 80 of lessons learned, and 72 of energy target data points that they used to analyze and compare to the results of the interviews. When drafting the interview guide, the entire project team considered all gaps uncovered in the literature review.

13.1.2 Drivers to ZNE

The literature review uncovered a number of drivers for owners and design teams in getting to ZNE. Many of these drivers were repeated in a variety of case studies and reports. The TRC team has combined similar drivers into general categories that they further describe below. The study supports each category with a specific example from the research. Some drivers may be more pertinent to a particular group of stakeholders.

Policy and Regulation

Policy that dictates future regulation along with targeted incentives is preparing the market for ZNE. In 2008, California published the first Energy Efficiency Strategic Plan which established ambitious goals for the development of ZNE buildings (CEC & CPUC 2008). These goals stated that:

- All new residential construction will be zero net energy (ZNE) by 2020.
- All new commercial construction will be ZNE by 2030.
- 50% of commercial buildings will be retrofit to ZNE by 2030.

Knowing that the residential ZNE goals became effective in 2019, one year ahead of schedule, provides clear evidence to commercial building owners and designers that ZNE will soon be required.

In advance of California's ZNE goals for the general public, the state also has policies that impact their own buildings, even before the aggressive deadlines set out in the 2008 Energy Efficiency Strategic Plan. Policies and efforts include:

- California Executive Order (E0) B-18-12 requires that state buildings and major renovations beginning design after 2025 are constructed as Zero Net Energy facilities with an interim target for 50% of new facilities beginning design after 2020 to be Zero Net Energy. According to the executive order, state agencies are to take measures toward achieving Zero Net Energy for 50% of the square footage of existing state-owned building area by 2025 (California EO B-18-12).

- California Department of General Services Director Dan Kim issued Management Memo 17-04, expediting California EO B-18-12, requiring ZNE for new construction state facility projects starting on October 23, 2017 (CDGS MM 17-04). The ZNE requirements is the ultimate driver for state agencies to procure ZNE in new and existing building renovations. According to the analysis of ZNE buildings in California, the Department of Motor Vehicles, California Lottery, Department of Corrections, Highway Patrol are a few agencies that has experience with ZNE.

- Beyond EO B-18-12, the *University of California's Carbon Neutrality Initiative* commits the university system to achieving carbon neutrality for campus operations by 2025 for direct emissions and purchased energy. The strategy for achieving this involves reducing energy use via efficiency in existing building stock, decarbonizing energy supplies, and planning campus growth to minimize net increases in greenhouse gas emissions by meeting increasingly stringent energy efficiency targets while supplying those buildings with carbon-free energy (University of California 2013).

- University of California at Merced has a Sustainability Strategic Plan (2010). The three principal objectives with regard to Zero Net Energy (ZNE) and Zero Net Carbon (ZNC) include:

    a. Maximize energy efficiency in building design and operations - with an initial goal to consume half the energy and demand of other university buildings in California and exceed Title 24 by 30% in all new buildings by 2010.

    b. Achieve campus zero net energy usage through renewable energy generation by 2020.

    c. Achieve zero net greenhouse gas emissions by 2020, prioritizing on-site and regional offsets.

- School districts, also known as Local Education Agency in California, are not bound by the state executive order for public buildings. However, some school districts have policies surrounding school construction, operation, and maintenance. For example, in 2007 the *Oakland Unified School District* developed a policy on the Collaborative for High Performance Schools criteria. The district hired sustainability consultant to assist in the development of their green schools program that prioritized low energy design and gradually improved toward a goal of ZNE. (Dean and Turnbull 2018)

Organization Vision / Corporate Environmental Commitment / Market Leadership

A corporate environmental commitment is a strong driver for some private owners. Consumers want to support mission-driven organizations and inquire about the implementation of corporate sustainability goals. ZNE buildings often garner attention from the press. Earned media coverage is regarded as more credible and is well received than a typical advertising campaign. Developers and design teams who have championed ZNE buildings are often able to get significant local and national attention in the press and trade media. Examples include:

- The Packard Foundation Headquarters is one of the early adopters of ZNE commercial buildings. The foundation has a strong environmental ethic and awards conservation and science grants with an emphasis on those that lead to carbon emission reductions. When they began design of their own building, they opted to develop a project that exceeded LEED platinum and achieved ZNE (Dean and Turnbull 2014, 4).

- The Watsonville Water Resources Center project did not originally include a mandate for a ZNE design. The client's stated mission of "environmental stewardship" combined with design team leadership and commitment to achieving ZNE performance within the client's financial and operational constraints. (Dean and Turnbull 2014, 58)
- Kaiser Permanente is a non-profit health care system that has a goal of carbon neutrality by 2020. The company sees itself as an "internationally recognized leader that is address the intersection of climate and health." The carbon neutrality goal is expected to be achieved by a combination of strategies, including a 180 MW power purchase agreement to fund development of utility scale renewables. The company also boasts a 29 percent reduction in net greenhouse gas emissions since 2008. (Kaiser Permanente 2018)
- Gunderson Health Systems, headquartered in Wisconsin, is nationally recognized for its Envision (Envision Gundersen Health System 2019) program which aims to:
- Improve community health
- Reduce the cost burden of delivering care
- Form community partnerships to encourage local, sustainable economic growth
- Improve the environment for future generations.

Energy efficiency, renewable energy, recycling, and waste management are the four key pillars of the Gundersen Health Systems program. The healthcare company reports a savings of 53% across their portfolio since 2008 (Envision Gundersen Health System 2019)

- A Navigant research study found that policy objectives and financing drive public building energy efficiency retrofits, while cost reduction, green branding, and productivity drive private building retrofits. (Nock & Wheelock 2010)

Leadership by Example in Schools and Public Buildings in California

Executive Order B-18-12 is an example of leadership by example in state government. In addition, cities and counties are stepping up to lead by example with carbon emission reduction policies and investigation into the energy and carbon use in their own municipal building stock. For example:

- As shown in the ZNE Market Size section, public buildings and schools comprise more than 50% of all of the ZNE performance and emerging buildings in California and more than 80% of the building square footage that is either pursuing or has achieved a ZNE goal.
- San Francisco Unified School District (SFUSD) developed sustainability goals "in order to provide students and staff with a healthy, safe and comfortable learning environment while saving money and resources and protecting the natural world." They have a stated goal of carbon neutrality by 2040 and an Energy Use Intensity (EUI) of 20 across their portfolio (SFUSD 2017).

Financial Investment / Reduced Utility, Operations and Maintenance Cost

ZNE buildings cost less to operate due to reduced energy bills. ZNE buildings reduce operating expenses which can boost the bottom line and increase return on investment for owners and developers. For example:

- 435 Indio Way is speculative ZNE office building retrofit that was developed strictly as a financial investment. In this typical suburban office, small and simple HVAC systems resulted in lower first cost, lifecycle cost, and costs upon tenant turnover. The building leased 15 months faster than the market average, which resulted in extra revenue for the owner. A financial analysis comparing the ZNE and conventional pro forma confirmed a higher profitability for the ZNE building than a retrofit. (Dean 2016, 56)

- DPR Construction is a national general contractor and construction manager. After working on their first ZNE new construction project, Packard Foundation Headquarter, DPR made a commitment to confirm that ZNE retrofits were possible and establish a financial case for ZNE (Dean 2016, page 4). Since then, DPR has opened four ZNE offices in San Francisco, San Jose, Phoenix and San Diego following a strict pro forma with acceptable financial returns (DPR 2019).
- Gunderson Health Services reports that the 53% savings in energy since 2008 has cumulated savings of more than $11.2 million. Energy savings came from investments in chillers, boilers with economizers, efficient data centers with heat recovery and central chilled water, and lighting improvements (Envision Gundersen Health System 2019)

Jobs and Workforce Development

ZNE buildings offer local job growth and tax benefits from more local construction. Investment means skill development and career opportunities for residents, economic development, and appeal to companies that provide products and services that support ZNE. For example:

- International Brotherhood of Electrical Workers - National Electrical Contractors Association Joint Apprenticeship Training Committee (IBEW-NECA JATC) Training Facility is a ZNE retrofit of a low-rise suburban office building. Since the organization provides education and training to union members and apprentices looking to become part of the union, the building itself serves as a living laboratory to teach about advanced technologies, including renewables, electronic communications, and control systems. (Dean 2016, 30)

Technical Feasibility / Proof of Concept

Some of the innovators in commercial ZNE projects were driven by the challenge of achieving ZNE. They were driven by demonstrating success in the technical proof-of-concept that ZNE is attainable in new construction or existing building retrofits. For example:

- The Packard Foundation Headquarters Building set an exemplary standard across all aspects of planning, design construction, and operation for ZNE buildings. They invested in research to expand design and technological innovations that reduce energy and carbon emissions with the goal of helping move the entire building industry forward (Dean 2014, 4).
- The *IDeAs Office Building* was one of the very first ZNE buildings. This small commercial office retrofit was driven by a desire to demonstrate technical feasibility in ZNE retrofits (Dean 2014, 42).

Incentive Programs

Energy efficiency incentive programs can sometimes be a driver of ZNE projects by providing additional funding to off-set some costs. For example:

- The *California IOU Proposition 39 ZNE School Retrofit Pilot* is an example where the utility program was certainly a driver, encouraging school districts and community colleges to go beyond the typical Prop 39 efficiency retrofit project and attain ZNE. A few of these districts (including San Francisco Unified School District, Los Angeles Unified School District, Hermosa Beach School District and San Bernardino Community College District) are moving forward with ZNE roadmaps and additional projects that incorporate deep energy efficiency, renewable energy systems, and electric bus integration. The Zero Energy School Accelerator program by the U.S. DOE has worked with many of these districts on the development of the ZNE roadmap for new construction in their districts (Getting to Zero 2019).

Educational Tools

The primary driver of all key decision-makers in K-12 and community colleges is to educate students. Operating safe and healthy schools is paramount, and energy is a low priority. As such, facilities design, construction, and operations are simply a means to the end result of educational outcomes for students. Two primary stakeholders in the school market are school business officials and capital project managers. These individuals care most about projects being on time and within budget (NBI 2017). For example:

- *The Exploratorium* in San Francisco is able to highlight the ZNE aspects of the building to visitors to the museum (Exploratorium 2019).
- *Discovery Elementary* uses the building itself as a learning tool that is connected with work in the classroom. They have a custom built "Sphere" online dashboard so that teachers are able to incorporate energy data into their lesson plans (AIA 2017).

13.1.3 ZNE Benefits

The literature review revealed a number of benefits from ZNE buildings. Some benefits are quantifiable while others are simply anecdotal. In addition, researchers noted overlap between benefits and drivers. Researchers have combined benefits into common groupings that the report describes below. The findings support each benefit by a specific example from the research. Some benefits may be more pertinent to a particular group of stakeholders.

Financial Benefits

ZNE buildings can offer unique financial returns to owners and investors. Operational cost savings can enhance the asset value of ZNE buildings in the resale and/or rental markets. For example:

- The 435 Indio Way project spent about 30% more than they would have for a code minimum building. Total construction costs were $5.1 million with photovoltaic compared to a code minimum without photovoltaic at $3.5 million. The project received a utility incentive of almost $300,000. It rented up quickly (by 15 months), so it began earning income sooner. Operating expenses, which included landscaping savings, were 34% less. The ZNE retrofit recovered a small additional premium in rent and had faster lease up rates. With a 5.8-year amortization time frame, this accounted for an additional $50 per square-foot of value (NBI, 2016e).
- DPR leased their San Francisco office by negotiating a below-market rate lease with the agreement that DPR would conduct substantial building improvements, including on-site renewable energy to offset the reduced rent. As a result of the building improvements, the property value increased for the building owner (Dean and Turnbull 2016, 3).
- Rocky Mountain Institute's ZNE Leasing Guide states that ZNE buildings can immediately meet the market demand for high quality buildings and forego future efficiency upgrades to remain competitive, reducing long-term building costs (Carmichael and Petersen 2018, 13).
- 1400 Page Mill Road in Palo Alto, a new construction project, was fully leased the day of building occupancy. The anchor tenant signed a 15-year lease more than two years before occupancy and second tenant signed a lease before construction completion (ibid, 21).

Firm Differentiation

A number of firms have developed a track record of success for ZNE buildings. This cachet surrounding this experience has value. For example:

- In the West Berkeley Public Library team illustrated how they could exceed the sustainability requirements in the request for proposal while meeting the budget. This resulted in them winning the bid which is also a financial benefit to the firm (Dean 2016, 76).

Protection from Future Regulation

ZNE can differentiate design firms from the competition by showing that they can support clients with future environmental regulation. For example:

- A number of sources noted that ZNE buildings offer the opportunity to avoid the future risk of rising electricity prices, necessary efficiency upgrades, and more stringent regulation. (Matisoff, Noonan & Flowers 2016, David Gardiner & Associates 2010, Cassidy 2011).
- In advance of statewide requirements under Executive Order 18-12, the California DMV adopted a ZNE project goal for the new project before the timeline required, thus future-proofing it from future regulation (Dean and Turnbull 2018, 63).

Enhanced Productivity

The health and productivity benefits of high-performance buildings have been well-documented (Singh et al. 2010 and GBIG 2014). ZNE buildings have many of the same benefits and performance advantages common in high-performance buildings. These benefits are derived from sustainable and efficient operations as well as comfortable visual, thermal, and acoustic environments. A review of technical approaches in the case studies reviewed by the TRC research team found the following **health and productivity benefits in ZNE buildings**. This may be due to increased daylighting and views, enhanced building envelopes for thermal comfort, improved indoor air quality through improved ventilation and air filtration. Below are some examples of how ZNE buildings are similar to other green and high-performance buildings:

- The major remodel of the San Diego DPR office included a specific goal to connect occupants to the outdoors. The design team provided operable top lighting, and improved vision glazing as an employee benefit**. Occupant complaints dropped with the increased access to views** and addition of operable windows compared to their previous office environment. (NBI, 2013c)
- Energy efficiency measures can provide unexpected comfort benefits. The highly efficient Albertson's grocery store in Carpinteria improved the energy efficiency of their reach-in display coolers by providing a tighter seal on the doors leading to a reduction in the necessary refrigeration load, further trimming energy consumption**.** The energy efficiency measures provided an added benefit of improved shopper thermal comfort due to less cold air leaking in the aisle. (Electrical Power Research Institute 2012, 5-15)
- The Western Cooling Efficiency Center at UC Davis has documented that poor classroom ventilation hinders student learning. (Fisk 2017) Traditional HVAC systems that help reduce CO_2 levels can be noisy and affect both teacher and student ability to focus and learn. Additionally, studies have shown that students in low-ventilated spaces have 50-70% more respiratory illnesses than those in naturally or well-ventilated spaces. In the Prop 39 ZNE school retrofit pilot project, one building auditor found a teacher who reported that before the retrofit she preferred to turn off a loud BARD system and suffer in a hot, cold, or stuffy room just so the students could hear. During the school retrofit, this system was replaced with a quieter, more efficient unit. (Karolides 2017)

Limit Environmental Impact

In a review of ZNE case studies, researchers found that ZNE project teams frequently stated the importance of reducing their climate impacts and aligning organizations' vision with the environmental benefits of ZNE buildings. Nationally, building operations contribute to 40% of carbon emissions and **ZNE buildings offer the financial benefit of reduced energy bills and a solution to limit community and organization's environmental impact** by limiting the amount of atmospheric carbon emissions. ZNE buildings use less energy and utilize clean, on-site renewable energy to generate energy, providing organizations' measurable goals to meet carbon reduction goals. As an added benefit, ZNE supports clear air through reduced greenhouse gas emissions, being a good community steward. For example:

- The University of California Carbon Neutrality Initiative commits UC to achieve carbon neutrality for campus operations by 2025 for direct emissions and purchased energy (University of California 2013). The University's strategy for achieving this involves improving the energy efficiency of the existing buildings, decarbonizing energy supplies, and planning campus growth to minimize net increases in greenhouse gas emissions by meeting stringent energy efficiency targets and supplying those buildings with carbon-free energy.
- On-site renewable energy provides organizations the opportunity to **mitigate the impacts of electric grid disruptions**, allowing them to continue working. Most ZNE case studies mentioned the importance of an enhanced thermal envelope which enables ZNE buildings to stay warm longer in the winter and cool longer in the summer. This may allow businesses to maintain a comfortable working environment and in housing, families can shelter in place, reducing the risk of outside temperatures. (Liljequist 2016 and Urban Green Council 2014) In many communities, schools are an important meeting place in emergencies, and, when provided on-site power, can become resilient community hubs and gathering places in times of disasters. (Pearson 2017)

13.1.4 Cost of ZNE

The building industry fundamentally approaches new construction or major renovation building projects based upon a whole building fixed budget and/or a dollar per square foot basis. For many developer-driven building projects, a proforma defines the business case for a particular building by analyzing expected initial and ongoing costs and returns a particular building in a particular location expected to achieve. The proforma outlines the program of the building (how it will be used) and sets the initial boundaries for the design team.

The perceived cost premium for ZNE buildings is a significant barrier to the growth of the market. Defining the bottom-line costs of ZNE buildings is challenging due to the wide variability of factors related to the design and construction of buildings and the difficulty to isolate incremental ZNE cost. ZNE, by its very nature, drives rarely quantified creativity, integrated approaches, and design and system tradeoffs in order to get to a performance-based outcome. This is new territory in the building industry and this research sheds light on the little that is known on the cost of ZNE.

Whole Building Approaches

Integrated design is the common threads among ZNE projects, often cited as key to achieving ZNE within a standard range of budget. Early in the design, these owners and developers set financial *and* energy targets with the design team. Throughout the design, the team examines options through the lens of both cost and energy (NREL 2013). In ZNE buildings, designers weave the building systems together, as opposed to assembling singular system pieces (Reeder 2016). Proper building-site orientation and passive systems result in reduced mechanical system size and smaller electric meters which can reduce first costs (NREL 2013). Aggressive air infiltration reduction goals are translated into construction practices to deliver a thermally tight envelope that reduces mechanical heating and cooling demands (Ibid). Building systems are integrated with controls to operate only when necessary (Dean and Turnbull 2016). All of these practices are woven together to reduce energy use and drive down first costs (NREL 2013). Integrating building systems is a very different approach than piece-meal energy efficiency "add-ons" with distinct incremental costs.

One additional first cost in ZNE buildings is for more robust energy modeling beyond that to demonstrate code compliance or to document savings for a voluntary building rating system like LEED. In ZNE buildings, the teams use energy modeling as an iterative process to inform continual design refinement and optimization of the building to meet the within the cost allowance (Ibid). This attention continues throughout construction, through "value" engineering and into construction and commissioning to evaluate how changes impact the anticipated energy performance.

Controls integration is another theme in ZNE buildings. In the PG&E Case Studies volume 2, Edward Dean mentions that a controls integrator was a new discipline added to many of the design teams. This individual is responsible for ensuring system compatibility since ZNE buildings commonly include multiple sensors and controls with unique sequence of operations. They also need time at the end of construction to verify that the controls are functioning properly – the absence of this follow up is a common problem in these advanced buildings.

Building Cost Examples

Construction costs vary widely for both code-level and ZNE buildings. Cost also varies widely based on building type and location. This wide range of costs poses a challenge for a meaningful comparison of the ZNE buildings to each other and code-level buildings (Lesniewski et al. 2013).

Building construction costs are typically reported as dollars per square foot ($/ft^2) for an entire project. The overall project costs of buildings of similar types and location are commonly used to compare projects. Knowing what is – and what is not – included in any reported information is important to ensure an apples-to-apples comparison. Given that the data sets are limited at these early stages of the ZNE market, comparisons inevitably blend multiple factors together.

Figure 49 summarizes the available cost data for buildings in California, starting with the earliest date of construction. The team has derived this information from various sources including the PG&E Case Studies and the Davis Energy Group Cost of ZNE Study (Dean and Turnbull 2014, 2016, 2018 and Davis Energy Group, 2012). The source data did not report whether the costs below include land costs, or only design and construction costs.

Figure 49. ***Summary of Available Cost Data for ZNE Buildings in California***

Building type	Project	City	Construction Date	Combined	$/SF	2019 $/SF[41]
Office	IDeAs Z2	San Jose	2007	$1,260,000	$175	$224
Office	Waterson Water Resources	Watsonville	2009		$556	$684
School	Redding School for the Arts	Redding	2011	$28,000,000		
Office	Packard	Los Altos	2012	$37,200,000	$756	$874
School	Sacred Heart	Atherton	2012	$2,400,000	$353	$408
Office	Indio	Sunnyvale	2013	$5,136,015	$162	$183
Office	SMUD	Sacramento	2013	$111,000,000	$231	$262
Museum	The Exploratorium	San Francisco	2013	$28,000,000	$909	$1,030
College/ Higher Education	IBEW	San Leandro	2013		$289	$327
Library	West Berkeley Library	Berkeley	2013	$5,745,000	$585	$663

[41] Costs were adjusted to 2019 values by the TRC team assuming 2.10% for inflation – based on calculated annual average of increase in Consumer Price Index (CPI) for the years 2007-2019 for the West region (CPI increases obtained from the Bureau of Labor Statistics)

Building type	Project	City	Construction Date	Combined	$/SF	2019 $/SF[41]
Office	CA State Lottery Office	Santa Fe Spring	2015	$5,744,000	$447	$486
Laboratory	The Craig Venter Institute Laboratory	La Jolla	2013	$39,000,000	$866	$981
College/ Higher Education	LACCD Harbor College Science Center	Wilmington, Los Angeles	2013	$55,638,595	$794	$899
School	La Escuelita Education Center	Oakland	Phase 1: 2012 Phase 2: 2014	$37,500,00	$303	$336
College/ Higher Education	Stanford University's Central Energy Facility Operations Center	Stanford	2015	$175,000,000	$327	$355

Another critical factor to consider is that these first costs do not provide a whole picture, because when considering lifecycle costs and return on investments, ZNEs may outperform conventional buildings due to greatly lowered operational costs and other factors.

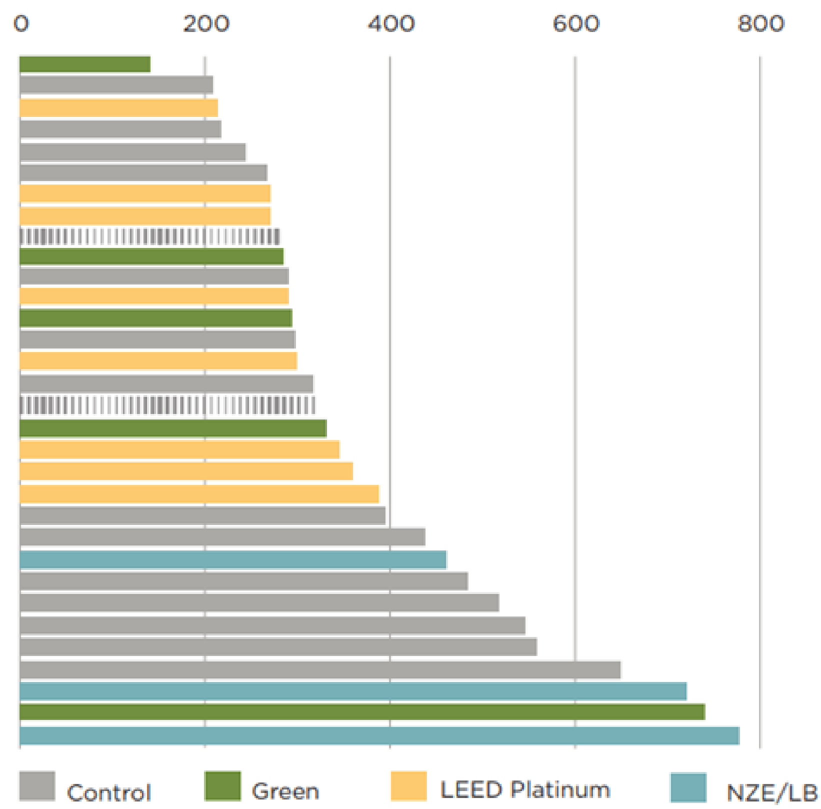
Organizations that retain their buildings for a number of years or offer community services, such as government aid programs and schools, benefit from ZNE buildings by utilizing the costs saved on energy bills and maintenance for books, after-school programs, and other resources. (Pearson 2017)

The Kentucky Department of Energy reported that the average new school budgeted $2 million per year in energy costs. The ZNE school, Richardsville Elementary team estimated energy costs to be $857,037 per year, with on-site solar generation estimated to provide a $1.5M revenue stream. (Bonnema et al. 2016) Additional income offers the ability to hire teachers or support staff, new teaching technology, or other operational necessities.

Cost Comparison

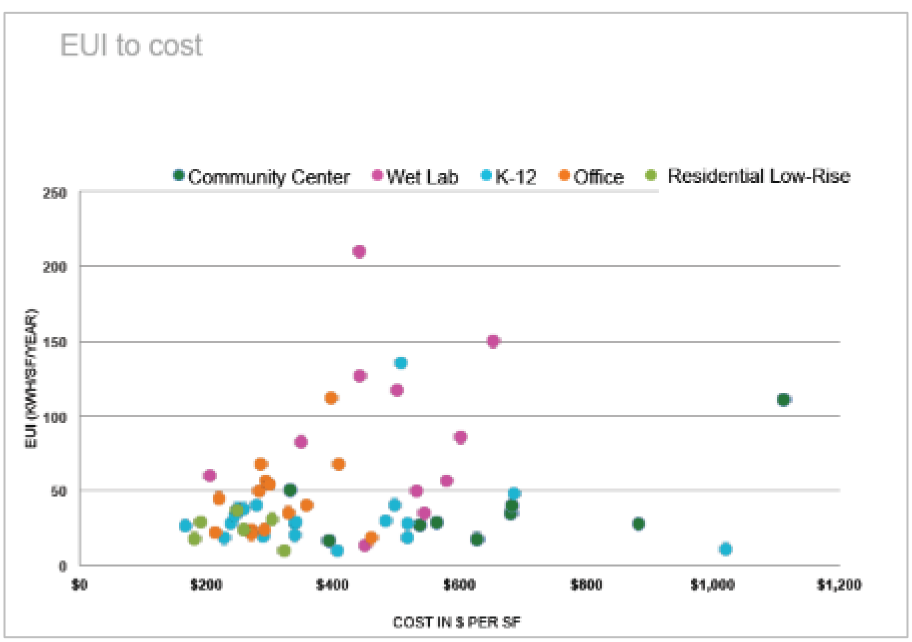
A 2013 study by BNIM, Integral Group, Davis Langdon and AIA continued work by Davis Langdon in 2004 by comparing buildings built to “green” standards to comparable code or “business-as-usual” buildings which served as a control group (Lesniewski et al. 2013). The study used a total of 88 buildings and normalized for location, year built, and similar building types and program. The dataset included buildings distinguished as “green” (those that received AIA COTE Top Ten recognition), LEED Platinum, and ZNE via the International Living Future Institute (ILFI) Living Building Standard. The quantity of buildings studied varied by building type; the ZNE sub-set counts were as follows: K-12 schools (eight), community centers (five), low-rise offices (five), and wet labs (three). Figure 50 shows the dataset for costs of low-rise offices in dollars per square foot and, as is the case in all four-building type analysis, buildings built to ZNE have been competitive with control-group buildings in the small sample set (Ibid).

Figure 50. Comparison of Cost for Standard, Green, LEED Platinum and ZNE Buildings (Source: Lesniewski et al. 2013)



The study also looked at building cost compared to energy consumption. Figure 51 shows cost data for green buildings. Again, the data set for this research is small. However, it indicates that buildings on the lower end of the Energy Use Intensity (EUI) scale are not necessarily the most expensive buildings.

Figure 51. Comparison of EUI to Total Cost per ft2 of "Green" Buildings (Source: Lesniewski et al. 2013)



Incremental Cost Estimates

Two additional studies across the U.S. focused on design cases of individual buildings against a defined baseline offer the estimated incremental cost for a limited number of building types and locations.

A 2013 cost study and report by ILFI, NBI, and Skanska focusing on Washington D.C. analyzed the incremental cost premiums for deep energy conservation strategies and solar PV systems to reach ZNE (ILFI et al 2013). This study used LEED Platinum as a baseline and analyzed new construction office and multifamily projects, as well as an office renovation. Washington D.C. is in ASHRAE climate zone 4A. The study investigated the cost of variable refrigerant flow and ground source heat pump systems as primary mechanical systems. Figure 52 presents the summary results of the overall building cost premiums for each building type in the study.

Figure 52. Cost Comparison of ZNE vs. LEED Platinum Buildings in Washington D.C. (Source: ILFI et al. 2013)

Total Cost in $/SF			
	LEED Platinum	ZNE	Average Cost Increase over LEED Platinum
Office New Construction	$283	$305	7.8%
Multifamily New Construction	$277	$304	9.7%
Office Renovation	$250	$291	16.4%

When looking beyond first costs, the Washington D.C. cost analysis study considered a net present value (NPV), simple pay back (SPB), and return on investment (ROI) in three cost scenarios a) the building with energy conservation measures (ECMs) equivalent to a ZNE building only but without PVs, b) a ZNE building with all ECMs, and c) a building solely pursuing ZNE through the placement of renewable energy. Figure 53 outlines the results of this analysis. The analysis hinged on a number of assumptions, specifically:

- Projects had a 10-year time horizon with a discount rate of 5.5%
- Blended energy costs were $0.13/kWh and rose at 2.5% over the ten years
- Maintenance cost or savings over time were not included
- Financial incentives from the district were not included
- Importantly, the analysis assumed that the owner does have sufficient tax burden to take advantage of all tax credits

Figure 53. Beyond First Cost Assessment of the Financial Value of ZNE Buildings (Source: ILFI et al. 2013)

	Estimated Incremental Project Cost	ECM only			Net Zero with ECM			Net Zero without ECM		
		NPV	SPB	ROI	NPV	SPB	ROI	NPV	SPB	ROI
Office New Construction	$3,790,218	($396,476)	11 yrs	9.1%	$2,672,413	3.0 yrs	33.8%	$2,508,026	3.3 yrs	30.3%
Multifamily New Construction	$4,608,518	($1,772,741)	17.7 yrs	5.7%	$3,192,398	3.0 yrs	33.1%	$2,943,543	3.4 yrs	29.3%
Office Renovation	$3,464,015	($137,039)	8.1 yrs	12.3%	$1,260,704	2.7 yrs	36.8%	$3,008,046	3.4 yrs	29.2%

Notes: NPV: Net Present Value, SMB: Simple Pay Back, ROI: Return on Investment

This study concluded that there is an incremental cost to get to ZNE in Washington, D.C. A new office costs 8% more to reach ZNE but estimated the return on investment for the new office to be greater than 30%. As shown, the ROI is highest in the scenario of a ZNE building that used both ECMs and PV (not PV only) at 33%-36%, which has a simple payback of approximately 3 years compared with the incremental first cost. The IFLI study also found that – while the incremental cost for ZNE office retrofits (16%) was higher than for office new construction (8%), the ROI for retrofits was also higher for retrofits, since retrofits provide the opportunity of higher energy savings. Overall, the study found that when ZNEs are assessed on a lifecycle cost, they can financially outperform most standard buildings.

Another study conducted by Maclay Architects for Efficiency Vermont (ASHRAE climate zone 6A) in 2015 analyzed several variations of residential and office buildings (Maclay Architects 2015). The report compares zero net energy and zero net energy ready designs to a code baseline design. In this case, the report also separated the energy efficiency measures needed to reach ZNE from the additional cost of renewable energy systems. Figure 54 outlines the results of the study for the commercial offices, showing a range of 6.5-16% for ZNE Ready (ECMs only) and 15.6 – 28% to achieve full ZNE reflecting the cost of both the ECMs and the PV.

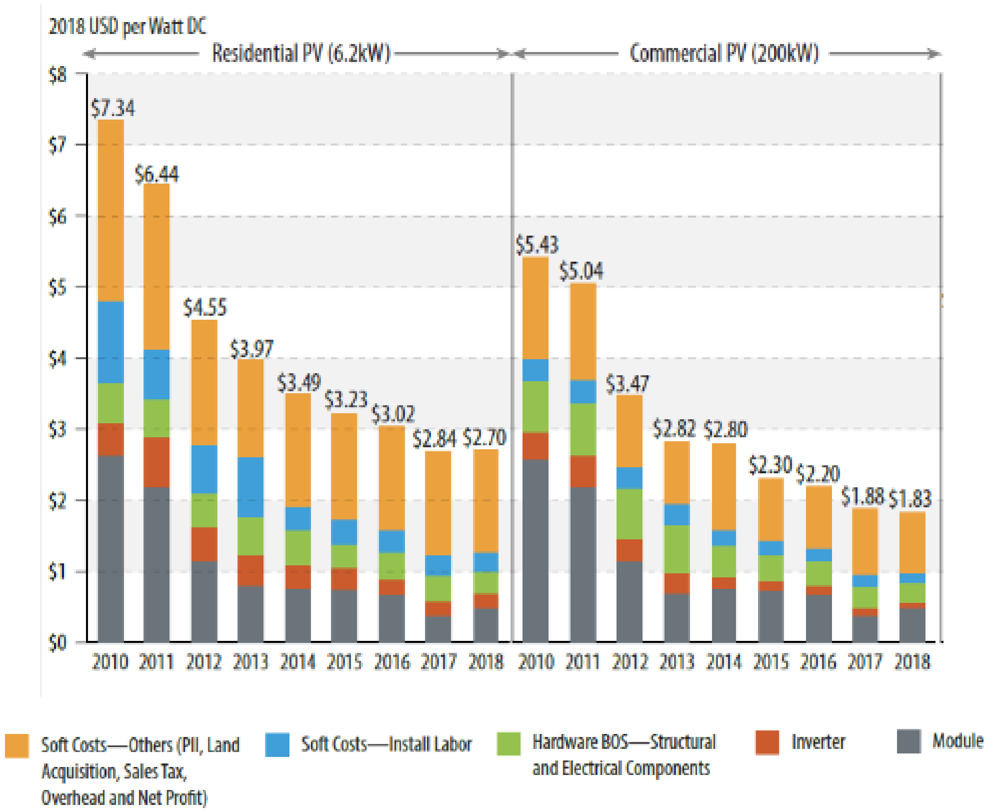
Figure 54. Incremental Costs for ZNE Commercial Buildings in Vermont (Source: Maclay Architects 2015)

	Total Cost in $/sf			**Incremental Cost Premium Over Code Level**			
	Code Level	Net Zero Ready	NZE	Net Zero Ready		NZE	
Open Office	$131	$140	$153	$9/ft^2	6.9%	$22/ft^2	16%
Closed Office	$154	$164	$178	$10/ft^2	6.5%	$24/ft^2	14%
Office and Light Manufacturing	$107	$124	$137	$17/ft^2	15.9%	$30/ft^2	24%

Solar PV Costs

Another extra cost in ZNE buildings is an on-site renewable energy generation source. For the buildings included in this research, this renewable energy source is almost always photovoltaic (PV). The rapid decline of PV system cost has changed the balance between investing in efficiency and renewables. As shown in Figure 55, the National Renewable Energy Laboratory (NREL 2018) found that the cost per Watt of direct current (Wdc) was $1.83 in Q1 2018 - a 2.6% decrease compared with Q1 2017 ($1.88/Wdc), and a drop off 67% compared with 2010 ($5.43/Wdc), for a 200 kW system. Recent federally-imposed trade tariffs may dampen this price decline.

Figure 55. National Solar PV Cost Benchmarks (Source: NREL 2018[42])



Since the overall cost of the photovoltaics is impacted by the energy consumption of the building, energy efficiency can reduce the first cost associated with renewables. Power purchase agreements (PPA) are a way to reduce initial costs for renewables while still producing energy onsite and reducing long-term energy rates. Through PPAs, local governments and schools can take advantage of tax benefits under the federal solar tax credit that they would not otherwise be able to leverage.

ZNE Cost Data

No statistically definitive answer can be provided regarding the cost to build a ZNE. A broader representation recognizes that the cost of ZNE is difficult to determine amid the broad range of factors affecting the cost of unique buildings. Much like asking how much it costs to build a house, it depends on hundreds of factors, design decisions, owner preferences, as well as the skills of the parties that drive the answer to the question. Just like other buildings, some ZNEs have been built within a comparable budget to code-compliant buildings, and some have been built to what would seem an extravagant cost per square foot. Design teams consistently state that through early goal setting and ongoing collaboration, ZNE can be achieved within budget (Sheridan 2018).

ZNEs represent the leading edge in design, technology, indoor environmental quality, and attract tenants, greater financial returns, and more market and media attention (Dean and Turnbull 2016, p. 50). There is also an undefinable opportunity cost of not building a new building to be best in class and future facing. From there, the conversation can continue around the factors and choices and the effort necessary to get to ZNEs within the range of standard construction.

[42] Reprinted with permission from the National Renewable Energy Laboratory (NREL), from https://www.nrel.gov/docs/fy19osti/72399.pdf

Cost

ZNE cost considerations include:

- The team has documented ZNE buildings as delivered with no incremental cost over conventional code-level buildings
- Whole building costs for ZNEs in California vary greatly, ranging from $162/ft up to more than $909/ft.
- The addition of PVs is a large budget adder as it is not a part of comparable buildings
- The incremental cost of the PV systems varies depending on the level of over- or under- sizing of the system relative to expected baseline energy usage
- Uncovering measure and/or system level costs is extremely difficult because design and system tradeoffs blur the line of incremental costs due to the integrated nature of building systems and financials
- When ZNEs are assessed on a lifecycle cost, they can financially outperform most standard buildings

Approach and Systems

ZNE system designers should consider:

- Setting an early goal of ZNE
- Prioritizing ZNE buildings' passive systems and strategies to minimize loads in the first place
- Reducing the building loads is the most critical factor to cost-control as it influences two large budget areas: the mechanical system and the renewable system size
- Utilizing design, cost control, and building procurement guidelines are available to minimize incremental costs.
- Performing iterative modeling (rather than code or program compliance modeling) to assess the various design and system factors as well as integrated, sustainable design, and construction.
- Exploring controls integration, which has an increased role in ZNEs, but should be simple for occupant and operation engagement and functionality
- Instituting regular maintenance and fine tuning, as ZNE buildings require ongoing attention to operation and occupancy factors and continuous measurement of energy performance upon project completion
- Evaluating design tradeoffs, which allow cost shifting but are project-specific, and they rely on the knowledge and commitment of the owner and design team.

Additional cost research is needed to expand the business case for ZNE buildings further. Research could include a continuation of efforts to expand the number of ZNE buildings with cost information. In addition, a better understanding of operational cost and possible savings associated with ZNEs as compared to more traditional buildings would be helpful to make the business case for ZNEs.

13.1.5 Barriers

The California commercial building market faces barriers that may prevent or delay success in the transition to ZNE. Many of these barriers are consistent with well-documented barriers to energy efficiency, including: imperfect information, split incentives, externalities, and imperfect competition (Vaidyanathan 2013). In addition to these common barriers, ZNE commercial buildings face ZNE-specific barriers which the below section describes in further detail. The team has organized the barriers into the following categories:

- Lack of awareness
- Technological barriers
- Regulatory barriers

Lack of Awareness

ZNE is still a relatively new concept with the first commercial buildings coming on-line largely within the last ten years. Given the enormous size of the California commercial building market, ZNE still suffers from a lack of awareness among market actors, including owners, designers, contractors, facility operators, and building occupants. The **lack of awareness impacts both the "supply" and "demand"** sides of the commercial building market.

On the "supply" side, building owners are skeptical that ZNE buildings are possible or that they can be done with a conventional budget (Cadmus 2012, 31). Moreover, traditional real estate developers find it difficult to justify the risk of trying something new when market data is lacking (ibid). Unless they are personally motivated by one of the drivers explained elsewhere in the report, owners are simply not asking for ZNE buildings.

On the "demand" side**, architects and engineers may not necessarily know how to sell and deliver ZNE**. The Davis Energy Group suggests that architects, engineers, contractors, realtors, and others' **lack of ZNE training and skills may delay the 2030 market demands for ZNE.** (Davis Energy Group 2012). The lack of awareness among commercial building decision makers leads to a perception that ZNE in new construction and retrofits of existing buildings has a cost premium, even though case studies have shown that ZNE buildings can be achieved at the same first costs with careful consideration and trade-offs that support efficiency and the budget (Davis Energy Group, 2012).

Similarly, **contractors may not have access to a trained workforce** to implement ZNE. They might be unfamiliar with approaches and unsure how to price them. For example, on the J. Craig Venter Institute project, the team trained potential bidders about chilled beam technology. The information avoided an intrinsic need to inflate the budget for an unknown technology. (Dean and Turnbull 2018, 32).

Technological Barriers

A technological barrier that also has elements of lack of awareness is the **appropriate balance between efficiency and renewables/storage** in ZNE buildings. As stated in the Davis cost controls study, "decreasing photovoltaic costs and power purchasing arrangements are altering the cost-effectiveness balance between efficiency and generation within the building" (Perry 2018, 7). This complexity is compounded when the boundary condition moves beyond the building scale to considerations of the grid, especially with more voices calling for 100% renewable energy (Sierra Club 2019). Research on the "duck curve[43]" in California has shown that unaligned electricity demand load and generation curves may place *extra* burdens on the electricity grid which may or may not be considered by building owners and designers at the building-level.

In addition, the list of **early ZNE projects has made apparent that not all building types and locations will have access to enough onsite renewable energy to achieve zero** due to the available site solar budget**.** This may be because the building is located in a climate less favorable to ZNE or it may be because the building has a high energy use intensity (for example, hospitals or restaurants), due to shading of photovoltaics by trees or adjacent

[43] In utility-scale electricity generation, the duck curve is a graph of power production over the course of a day that shows the timing imbalance between peak demand and renewable energy production. The term was coined in 2012 by the California Independent System Operator.

buildings, or because the building has many stories and not enough roof space to offset consumption with production. Examples include:

- In Palo Alto, the extensive tree canopy has the potential to limit new ZNE project's ability to produce all of the building's energy on-site, even with maximized efficiency. (Seto et al. 2016)
- Design teams, similar to the Sacramento Municipal Utility District's (SMUD) East Campus Project, are challenging the concept that ZNE buildings must have a low floor area ratio (number of stories relative to the building footprint) and are seeking to increase ZNE buildings' height (ibid). Naturally high energy use building types are expanding the limits of energy efficiency to achieve ZNE.
- The Albertsons grocery store in Carpinteria, California and United Therapeutics pharmaceutical lab (ZNE goal stated) achieve high energy reductions by evaluating their unique equipment needs (EPRI 2012, Getting to Zero Forum 2018).

Lack of Appropriate Regulation and Process

The research shows that jurisdictional codes and regulations do not always accommodate the unique needs of ZNE buildings. Some examples include historic buildings, height limitations, and tree ordinances:

- Historic building restrictions may prevent the addition of visible energy efficiency measures (specifically envelope improvements) and on-site renewable since alternations visible from the public right of way are prohibited.
- When a building has maximized its floor area ratio, height restrictions may prevent solar installation on the roof. West Berkeley Public Library conducted several solar and daylight access studies to ensure they complied with the local zoning ordinance that required solar access for neighboring buildings' windows. The requirement constrained the available height for the solar array and ultimately shaped the building design. (Dean 2016)
- Tree ordinances may trump other "green building" requirements when in conflict. For example, Palo Alto, CA has a Green Building Ordinance, a Solar Shade Act, and a Tree Ordinance. When conflict arises in this policy triage, the city has chosen to advance with the policy that is protective of the existing tree canopies. (Seto et al. 2016)
- School design regulations prevent any equipment that would increase the weight of equipment on the roof without a review by the California Division of the State Architect (DSA). A Prop 39 ZNE pilot project team was delayed because additional weight capacity on the roof from HVAC equipment replacement triggered review challenges, even before considering installation of photovoltaic equipment (NBI and Madison Engineering 2017, 56)
- Utility regulations change rapidly and can create barriers for ZNE buildings. Grid intertie agreements can be complicated and time consuming. The time dependent valuation metric for ZNE creates special complications in existing building retrofits. In addition, California's net metering lows only allow privately generated renewable energy to be sold back to the utility as long as the system is less than 1,000 kW. While few systems exceed the limit, the Exploratorium Museum's solar photovoltaic array in San Francisco was designed to exceed the allowable sell-back by generating 1,250kW.

13.1.6 Lessons Learned

ZNE has proven to be possible for many buildings. The literature review summarizes early research on ZNE projects that has revealed a number of key patterns and lessons learned associated with success in ZNE. Outlined in the *Getting to Zero: Zero Energy Project Guide* (NBI, 2017a), these steps are notably different from a conventional building development or retrofit process. They include:

- Stakeholder awareness
- Energy goals and targets
- Team selection and contracting
- Cost, financing, and incentives
- Early design/ predesign considerations
- Design and construct to the target
- Project hand off
- Operations and verification
- Design team leadership

The followed section describes the steps in further detail.

Stakeholder Awareness

The literature and case study review make it clear that a sincere and concerted effort, led by an internal champion, is a key ingredient to success in ZNE. This champion raises awareness and educates other stakeholders and decision-makers to gain widespread support for a ZNE project. This advocacy for ZNE begins early and continues throughout the design and construction process, into operations and verification. Sometimes the design team suggests the ZNE goal and other times the owner demands it.

Multiple case studies documented the importance of the champion in raising stakeholder awareness of the ZNE goal. Effective ZNE champions understand that different stakeholders have different drivers as outlined elsewhere in this report. Champions communicate the benefits of ZNE in terms that specific stakeholders understand and value. Examples include:

- Initial pre-design meetings with the design team, key subcontractors, and estimators are necessary to achieve the high-level of building energy efficiency. In the SMUD East Campus project, the technical manager credits the design team for making important decisions together, early in the process, to later reduced costs for meetings, document revisions, and change orders. (Davis Energy Group 2012, 50)

- In the West Berkeley Public Library, the integrated design and procurement processes were important procedures to meet ZNE goals. The request for proposals referenced city policies for green building standards. The ZNE goal and energy targets were stated early, understood, and implemented. With the full team supporting the goal, they were able to avoid accepting low bids that did not include essential high-performance and renewable energy components. (NBI 2016)

- When the Valley View Middle School project was imagined, the design team received the support of the community and school district staff to set an early goal and use the Living Building Challenge as a sustainability guideline. The district encouraged an integrated design team, with each discipline working closely to ensure that the agreed upon energy targets could be achieved, gaining buy-in on key decisions from the district and the client. (Bonnema et al. 2016, 89)

Energy goals and targets

Successful ZNE projects have clear energy and sustainability goals early in the project. Some owners include the ZNE goal in the request for proposals (RFP) for a design and construction team or in their owner's project requirements (OPR). Having these expectations for energy goals and targets well before design begins sets a clear understanding with the design and construction team about how the final building should perform.

Some examples of energy goals and targets from the literature review include:

- The ASHRAE Advanced Energy Design Guide (AEDG) Zero Energy Guide for Schools establishes energy targets and prescriptive approaches to achieving them in all U. S. climate zones (AEDG 2018, 34).
- San Francisco Unified School District's Owners Project Requirements has ZNE Guidelines that state, "new buildings should be designed to achieve a modeled Energy Use Intensity (EUI) below 20 kBtu/sf/yr," and a "solar analysis during Schematic Design (SD) should confirm that rooftop solar potential will be adequate to cover modeled energy usage." (SFUSD 2017)
- San Diego County had a design-build request proposal for the Borrego Springs Branch Library which stated, "The principal facility is anticipated to be a freestanding, one-story structure, of approximately 13,500 square feet and to attain a minimum LEED® Gold certification and County Net Zero Energy initiative" (San Diego County 2016)

While some building owners state their goal as simply "ZNE," design and construction teams translate this into a more quantifiable Energy Use Intensity (EUI) metric for that particular building type, solar availability, and climate zone. Early adopters in the ZNE tend to use a *Site ZNE Energy Use Intensity (EUI)* metric to set performance targets for their ZNE building projects. (Dean and Turnbull 2014).

This absolute EUI energy target is notably different than a "percent better than code" approach espoused by many green building and energy efficiency programs, for example LEED for Building Design and Construction and Savings by Design (USGBC 2019, 73 and Savings by Design 2018, 15). According to NREL, absolute EUI targets provide a clear and measurable target and emphasize the importance of capturing whole-building energy use (DOE 2012, 21).

Early design/pre-design

The review of case studies suggests that most, if not all ZNE building teams start an integrated design process early in design. According to *Facilities Net* "integrative design engages the ownership, architect, engineer, and construction teams to identify the best method for delivering the owner's project requirements within budget, on schedule, and to ensure efficient operation throughout the life-cycle." (Facilities Net 2018)

A number of case studies documented early design meetings, sometimes called an eco-charrette or an integrated design charrette, where the ZNE vision is discussed among a broad range of stakeholders (Dean 2018, NBI 2016). A charrette is an interactive, facilitated discussion where building design team members, including owners, architects, engineers, contractors meet with building occupants, and facility maintenance staff to review priorities and agree on shared project goals and outcomes. These charrettes were said to build consensus, streamline the design process, and set the team up for success.

Another important step early in ZNE design is the finalization of the basis of design (BOD). The BOD is the primary document that translates an owner's needs into a narrative by the design team that outlines specific building approaches such as building envelope, mechanical, electrical, plumbing, security systems, building automation system, etc. Essentially, this is the design team's documented response to how ZNE, as documented in the OPR, will be achieved.

Another notable difference between ZNE and conventional buildings is early energy modeling to make better decisions earlier because the earlier the decisions, the least costs are incurred by the project. (ASHRAE 2018). Early in a ZNE building design, energy modeling is often used to compare the building loads associated with different building orientations and system selection options. This is different than the energy modeling that many design teams use to document their decisions and prove some *percent better than code* estimate, often done later in design. Early energy modeling facilitates an overall reduction in absolute energy savings by making relative comparisons among design options. (Roberts 2013) This can prevent oversized mechanical systems which can reduce upfront costs. Often, this model is revised over the course of the project to further identify and refine energy savings measures and approaches.

Design and Construction

Design teams in ZNE buildings take an integrated, whole building approach to energy savings during design and construction. Most early adopters have maximized energy reduction to limit the cost of renewable energy resources (Arup 2012).

The review of case studies in early ZNE buildings reveal that these teams take advantage of building orientation and use passive strategies as appropriate to reduce absolute energy consumption and take advantage of daylighting, natural ventilation, and conditioning. Many ZNE barrier tests to prove that the envelope is sealed. In addition, minimizing plug loads is critical to ZNE buildings (Arup 2012, 6). As regulated energy loads (envelope, HVAC, and lighting) gets smaller, plug loads become a larger portion of the energy use that remains. (Arup 2012, 51).

One challenging area for the design is with regard to building controls. In the PG&E Case Studies, Volume 2, Dean states:

> “The inadequacy of standard building control systems for the typical level of sophistication of the operation of ZNE Buildings has been observed and lamented by many designers. Early ZNE projects were beset by problems of communication between building sub-systems that had different communication protocols built into them. The issue is derived from the lack of a universal communication software for all major building control system applications.” (Dean 2016)

All five of the case studies in Volume 2 show advancements in control integration (Ibid). The case studies highlight the role of a controls integrator on the team. The controls integrator is responsible for improving operational efficiencies and on-the-ground diagnostic capabilities through the proper inclusion of energy sub-meters. This professional can assist with the layout, access, and format of the lighting, HVAC, plug load meters, and control considerations.

In addition to commissioning the controls system, building systems commissioning is a critical process in ZNE buildings. (NBI 2016) Post-occupancy commissioning identifies and resolves any unexpected operational issues after move-in. Building commissioning can lead to cost savings and deliver significant non-energy benefits. A Lawrence Berkeley National Laboratory report found the typical simple investment payback in commissioning averages 1.8 years, with a range of 0.5 – 3.5 years (LBNL 2009)

At the end of the project, when project finances get tight, efficiency strategies can be “value engineered” out of the final design. This can be a problem when not everyone is familiar with the ZNE goal. Some energy conservation measures may have up-front costs, but they also have a long-term payback period and comparatively high first cost so they can be on the chopping block when it is time to save budget. However, this method often has unexpected consequences in building performance. Systems must be fully integrated to achieve the ZNE goal (Turnbull 2015)

Integrated designs do not always survive changes in the field during construction. In the West Berkeley Public Library project, the team noted that removing one building efficiency measure negatively impacted the performance of another building feature, negating the long-term savings for the sake of the initial budget. Specifically, the team removed integrated window blinds during the value engineering process only to add them back during construction due to their energy efficiency performance. (NBI 2016)

Project Hand Off

Facility managers must be well versed in the building energy savings approaches and equipment to be sure that the ZNE designed building performs at ZNE. Design teams and contractors should educate the facility managers about systems, especially those that may be unfamiliar once the building is occupied and during the first year of operation so that seasonal variations are understood.

In addition, occupants may need to be trained when they first move into the space (Dean and Turnbull 2018, 50) At 435 Indio Way, the owner prepared a building handbook that advised tenants on plug load reduction techniques, suggested Energy Star-approved appliances, and provided additional information about sustainability in the space. In an effort to control occupant behavior, the lease at 435 Indio Way explicitly restricts the use of appliances such as floor heaters. The lease also provides suggestions for building owners to use Energy Star approved task lighting and desk fans. Tenants benefit from a real-time dashboard in the lobby or on their smart devices that show their energy use and power generation. (NBI 2016e)

At the West Berkeley Branch Library, the staff were unfamiliar with the building operation and often modified settings or used override switching, resulting in higher than intended energy use. After a staff training, the energy use reduced. (#213 Dean Volume 2, page 101)

Team Selection and Contracting

Design team selection is critical on the path to success in ZNE because energy consumption in a building is a function of both design and operations. An owner must be sure that the design and construction team are able to deliver the building outlined in the Owners Project Requirements (OPR) and Request for Proposal (RFP). Energy targets in these documents set the stage for conversations about energy during the team interviews and throughout the project.

In the NREL Research Support Facility project, the governmental owner incorporated specific EUI target range into the contractual documents. (Hootman et al. 2012) This *performance-based procurement* approach sets a clear expectation with the building owner, design team and the building occupants on how the building should perform once it is occupied. Department of Energy documented the lessons learned associated with contracting approaches in a "how to" guide about project delivery methods for ZNE (DOE 2012)

Cost, Financing, and Incentives

ZNE teams manage costs by first drastically reducing energy consumption and then serving the remaining loads with renewable energy. In their cost control report, NREL recommends specific strategies by market phase (i.e. during acquisition and delivery, design, and construction) (NREL, 2014). NREL also suggest a number of overarching principles to control costs, including:

- Selecting a delivery method that elevates the importance of energy performance to be on par with other project objectives.
- Emphasizing integrated design and team communication.
- Leveraging energy modeling early and often.

The literature review identified a number of sources that suggest it is possible to construct ZNE commercial buildings at little or no incremental cost. (Davis Energy Group 2012, MacClay 2015, and AIA 2017). Successful ZNE project teams realize that system downsizing can result in budget savings that can be reinvested in other areas, such as architectural/envelope improvements, high efficiency lighting, and higher efficiency equipment. Maximizing synergies can reduce both first costs and ongoing energy consumption.

In addition, ZNE buildings may unlock financial incentives not available to other projects. Sources of additional funding include utility energy efficiency programs such as Savings by Design and the Proposition 39 ZNE School Retrofit pilot, Community Choice Aggregator (CCA) programs, tax credits, low-interest loans, or Commercial Property Assessed Clean Energy (C-PACE). C-PACE is a mechanism for energy efficiency and renewable energy financing. It allows local and state governments to fund the up-front cost of energy improvements on commercial properties and allow repayment by the property owners over time as part of the tax bill. This addresses an owner's need to finance large upfront costs and allows the cost of the investment to transfer with the property owner. (Kaatz and Anders 2014)

The federal government has provided a 30% tax credit for renewable energy, including photovoltaics, wind, geothermal (SEIA 2019). However, since they don't pay taxes, public buildings and schools need to partner with a taxpaying entity through a Power Purchase Agreement (PPA) in order to capture these benefits.

Operations and Verification

Another major difference between ZNE and code, beyond code, or LEED buildings, is that their energy consumption is often measured using a building management system, on energy dashboard, or in the EnergyStar® Portfolio Manager tool. This allows facility staff to compare actual energy consumption to predicted performance. It is also helpful to identify if systems are operating as expected.

An absolute energy target prediction is easier to compare to actual energy performance than a “percent better than code” metric. Metering electrical circuits and tracking the energy data with an online platform is common for ZNE buildings to receive detailed, real-time use data and evaluate their energy consumption against the production. Comparing hourly, weekly, and monthly energy use and production against the design stage energy model provides building engineers a guide for how tenants are using energy use and to measure their trajectory.

Occupants are often unpredictable with their energy use patterns, and their knowledge of efficiency varies. The San Francisco DPR office provided education of the building features and continued to engage the staff with an energy display, resulting in lower energy performance (Dean 2016). Post construction building alterations can also alter the initial design and threaten the ZNE result. The Sharp Development core and shell building developer for 435 Indio Way, designed the building for a specific layout offering passive ventilation and abundant daylighting. However, the leasing tenant’s space needs differed requiring the relocation of the conference rooms. Shifting the layout to meet the tenant’s desires, required that engineers add transfer ducts for cooled air to reach the conference room, potentially leading to additional energy use (Dean 2016).

Design Team Leadership

ZNE projects would not be possible without a champion and the commitment of the design and construction team. Some firms have positioned themselves as industry leaders. The West Berkeley Public Library’s RFP included green building requirements but did not include a ZNE goal. The design team, Harley Ellis Devereaux, won the bid by proposing a ZNE strategy that could be achieved within the fixed budget (Lesniewski et al. 2013, Dean 2016). The Exploratorium design team (including EHDD Architecture), proposed that the museum be designed to a ZNE standard at the initial visioning session, aligning with the museum’s mission to, “create inquiry-based experiences that transform learning worldwide” (Dean 2016).

Figure 56 and Figure 57 show the architectural and engineering firms with more than ZNE project in California.

Figure 56. Architects with Multiple ZNE Projects

Row Labels	ZNE - Emerging	ZNE – Performance Verified	Total
EHDD	5	3	8
HMC Architects	5	1	6
ZGF Architects	4		4
Siegel & Strain Architects	1	2	3
BNIM	3		3
HGA Architects	3		3
Group 4 Architecture	2		2
AEDIS Arch. & Planning	2		2
AP+I Design, Inc.	1	1	2

Figure 57. Engineers with Multiple ZNE Projects

Row Labels	ZNE - Emerging	ZNE - Verified	Grand Total
Integral Group	48	8	56
Brummitt	7		7
DNV-GL	5		5
Interface Engineering	1	1	2
Glumac	1	1	2
BNIM	2		2
Stantec	1	1	2

13.1.7 EUI Analysis Assumptions in Arup (2012)

The following figure provides parking lot solar PV assumptions that Arup (2012) assumed for prototype buildings to achieve ZNE in its technical feasibility study. Arup (2012) assumed high numbers of covered parking with solar PV (particularly compared to the total building area) for several building types. Early ZNE projects have illustrated that not all building types and locations will have access to enough onsite renewable energy to achieve ZNE. This may be because the building is located in a climate less favorable to ZNE or it may be because the building has a high energy use intensity (for example, hospitals or restaurants), due to shading of photovoltaics by trees or adjacent buildings, or because the building has many stories and insufficient roof space to offset consumption. However, the Arup (2012) results illustrate what buildings with relatively large parking lots – such as those in suburban or less dense urban areas - could achieve.

Figure 58. Parking Lot Production Capabilities from Arup Technical Feasibility Study

Table 9 – Estimated 2020 Parking Lot Solar Production Capabilities Using 35% of Standard Available Parking Area, Weighted by Associated Building Area

Solar PV on Parking Lots	Total Building Area (ft^2)	Average Parking Spaces	kWh/ bldg-ft^2	Site kBtu/ bldg-ft^2	TDV$/ bldg-$ft^2$
Grocery	45,000	180	19.5	66.4	76.42
Hospital	241,410	200	4.0	13.6	15.64
Large Hotel	122,132	80	3.2	11.0	12.65
Multi-Family High-rise	84,360	120	6.8	23.0	29.79
Multi-Family Low-rise	14,700	20	5.8	19.8	25.65
Large Office	498,600	750	7.1	24.3	27.99
Medium Office	53,600	180	15.6	53.1	61.16
Sit Down Restaurant	5,502	60	52.5	179.2	206.19
Secondary School	210,900	280	6.3	21.5	24.78
Strip Mall	22,500	120	25.9	88.4	101.74
Single Family	2,100	N/A	N/A	N/A	N/A
Warehouse	49,495	50	4.5	15.5	17.81

Note: kWh/parking space estimated at 3800 kWh/yr, with the high output coming from the use of trackers, high efficiency panels, optimizers, and other improvements that will arise through 2020.

The following figure is based on Arup (2012) and shows the baseline EUI in that analysis, examples of efficiency measures assumed for each building type, and the rooftop and onsite PV needed to reach ZNE.

Building Type	Baseline EUI (ASHRAE 90.1-2010)	Assumptions to get to Zero Net EUI			
		Examples of Efficiency Measures Assumed	Rooftop PV assumption	Onsite PV Assumption	Need Onsite to reach ZNE?
Multi-Family High-Rise	19.3-28	LED Lighting, Electric load reduction, Enhanced Insulation, Improved glazing, Overhangs, Thermal Mass, Drain water heat recovery, Boiler Efficiency, Energy Efficient Appliances	100% of available roof area used	**Medium:** 23.0 kBtu/Bldg-ft^2	**Yes**
Medium Office	15.9-21.5	Lighting power density reduction, Exterior lighting wattage reduction, Nighttime Load Reduction, Overhangs, Enhanced Insulation, Thermal Mass, Natural Ventilation, Optimized setpoints, Boiler Efficiency, Low pressure drop design	About 70% of available roof area used	**Medium:** 61.6 kBtu/Bldg-ft^2	**No**
Large Office	14.1-19.2	Reduce interior and exterior lighting power density, Reduce unoccupied plug load, Energy efficiency Elevators, Enhanced Insulation, Improved glazing, Overhangs, Natural ventilation, Thermal mass, Improved boiler and fan efficacy, Improve chiller coefficient of performance (COP)	100% of available roof area used	**Medium:** 24.3 kBtu/Bldg-ft^2	**Yes**
Strip Mall	24 – 28.5	Lighting power density reductions, Exterior lighting reduction, roof reflectance, vestibules, natural ventilation, Variable Air Volume (VAV) system, Boiler and Fan efficiency, Water heather thermal efficiency	About 30% of available roof area used	**High:** 88.4 kBtu/Bldg-ft^2	**No**
Secondary School	22-28.9	Envelope & Glazing improvements, Lighting power density reductions, Pop-up skylights, Water cooled chiller, PTAC units, Boiler and fan efficiency, Increased water heather thermal efficiency Reduce fan pressure drop, Optimize set points, Mixed Mode Natural Ventilation	About 70% of available roof area used	**Medium:** 21.5 kBtu/Bldg-ft^2	**No**
Large Hotel	73.4-94.8	LED Lighting, Exterior lighting reduction, Ozone laundry, Reduce unoccupied lighting and plug loads, Overhangs, Energy efficient elevator, Enhanced Insulation, Thermal mass, Reduce infiltration, Natural ventilation, boiler efficiency, Water heater thermal	100% of available roof area used	Low: 12.65 kBtu/Bldg-ft^2	Yes (but does not reach ZNE)

		efficiency, Allow setback temperatures, Water-cooled Chiller			
Grocery	66.4-90.5	Load Reduction, Efficient Refrigeration, Improved glazing, Enhanced Insulation, Heat Recovery, etc.	100% of available roof area used for most climate zones	**Medium:** 66.4 kBtu/Bldg-ft^2	**Yes** (for some climate zones)
Sit Down Restaurant	158-225	LED Lighting, Reduce exterior lighting, Reduce appliance loads, Hot gas defrost and smart defrost, Energy Efficient Refrigerator/Freezer, Enhanced Insulation, Low flow exhaust hoods, Low flow fixtures	100% of available roof area used	**High:** 179.2 kBtu/Bldg-ft^2	**Yes**
Hospital	67.6-70.1	Improved HVAC: chilled beams, DOAS with heat recovery, 55F supply air temperature; LED Lighting, Occupancy sensors, Energy efficient elevator, Shades and improved glazing, Reduce infiltration, Boiler and Fan Efficiency, Improve chiller COP, Optimized set-points, Right sized chilled water plant, Load Reduction	100% of available roof area used	**Low:** 15.6 kBtu/Bldg-ft^2	**Yes** (but does not reach ZNE)
Warehouse	6.4-13.1	Exterior lighting reduction, LED Lighting, lighting power density reduction, Office plug load reduction, Roof reflectance, Improve COP, Economizer in office, Natural ventilation, Fan efficiency	About 12% of available roof area used	**Low:** 17.8 kBtu/Bldg-ft^2	

Figure 59. Assumptions in Arup (2012) Study to Reach ZNE

Based on these assumptions, and accounting for the construction volume by building type, Arup (2012) developed the following technically feasible EUIs based on efficiency only (without solar PV) and with efficiency and solar PV.

Figure 60. Statewide technically feasible EUIs without Solar (TDV$) distributed by projected 2020 Construction Volume (Source: Arup 2012)

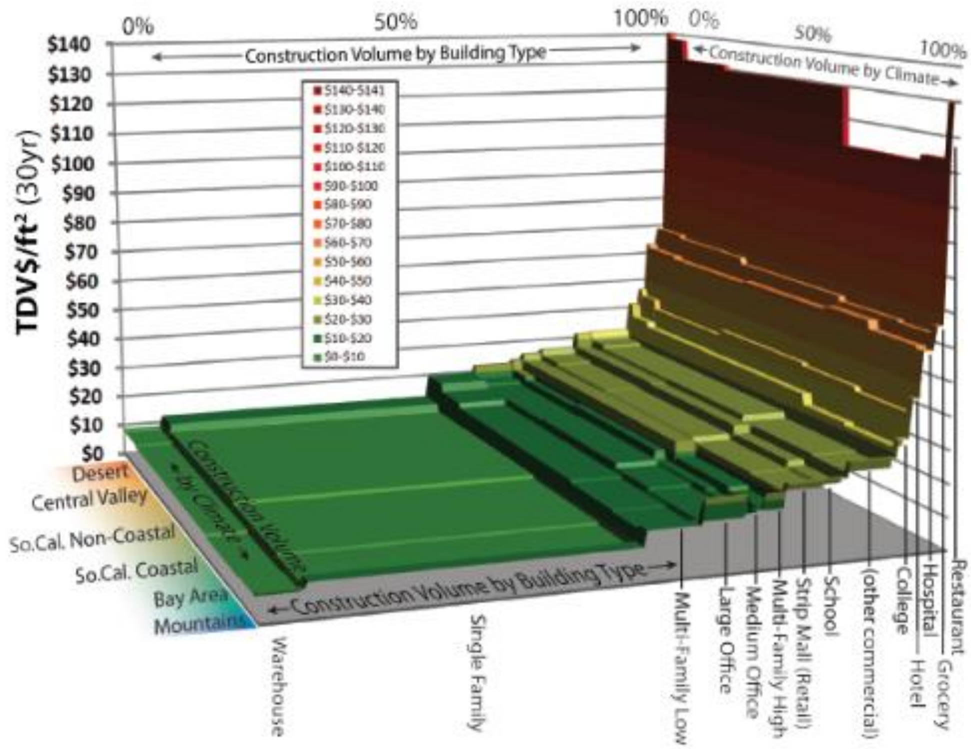
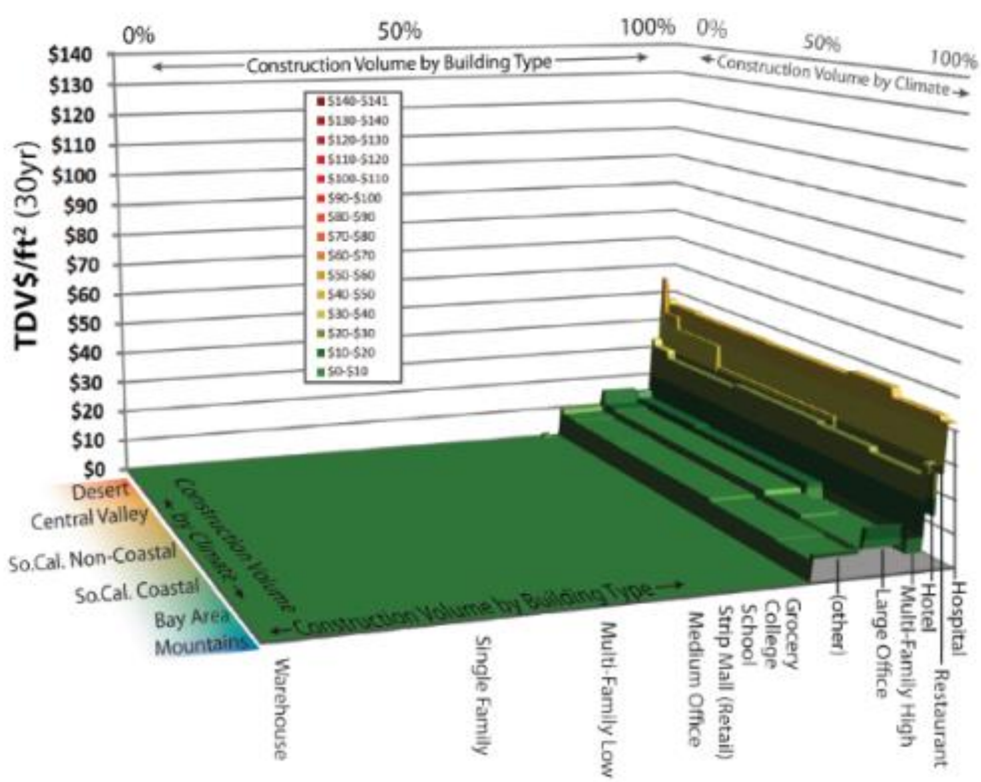


Figure 61. Statewide Technically Feasible Net-EUIs with Solar (TDV$) by Projected 2020 Construction Volume (Source: Arup 2012)



Demand Impacts

As described in the introduction, statewide goals have shifted to include an increased focus on reducing peak demand. While it was beyond the scope of this analysis to investigate these topics, this section provides findings from one report that looked at the intersection of demand response and energy efficiency.

An LBNL demand response potential study (2017) described the intersection of energy efficiency and demand response (DR) as follows: "There is an ongoing discussion around interactive effects of energy efficiency and DR, and the bifurcation of DR into load-modifying and supply resources facilitates a new way of viewing these effects. One could broadly consider energy efficiency as a load modifying DR measure, whereby the net load is decreased by an efficiency investment (and the timing of service remains unchanged). Thus, energy efficiency investments in general have 'load-modifying' DR effects, reducing the need to procure peak capacity because the peak load is reduced. Depending on the load types that are upgraded or improved, it is possible as well that less Controllable DR resources, including behind the meter battery storage, can provide flexible services to existing wholesale markets that can potentially defer the need for additional conventional generation resources, with sufficient penetration. Controllable DR resources can support the integration of renewable energy sources, and support policy targets for renewable standards and a low carbon future." While the study did not discuss ZNE specifically, ZNE buildings include high levels of energy efficiency, which should therefore reduce demand.

13.2 Market Actor Interview Results

This appendix provides the results of interviews with 80 market actors working with new construction and major renovation in commercial buildings. The sections cover market actors':

- Overview of respondents
- Market actors ZNE definitions
- Market size and characteristics
- Awareness and interest in ZNE
- Drivers and ZNE
- Barriers and resources needed
- Approaches to ZNE and distributed generation
- Cost of ZNE

The section begins with an overview of key characteristics of respondents.

13.2.1 Overview of Respondents

Respondents were technical professionals that represented a range of organization types involved in the building industry. Most respondents had been in the commercial buildings industry for more than 30 years and more than half were in their current role for at least five years. They largely worked in the urban areas of coastal Northern and Southern California and a large majority had experience with at least one ZNE building or other ultra-efficient building.

Figure 62. Respondent Characteristics (n=80)

	Count	Percent
Profession Type		
Technical Professionals	**60**	**75%**
Engineering	*35*	*44%*
General Engineering (incl. combined architecture and engineering)	23	29%
Energy Consulting	6	8%
Sustainable Building Consulting	5	6%
Commissioning	1	1%
Architecture	*14*	*18%*
Construction Management or Other Profession	*11*	*14%*
Construction Management	5	6%
Energy Efficient Product Company	3	4%
Energy Project Financing	1	1%
HVAC Contractor	1	1%
Utility (codes and standards program)	1	1%
Owners and Developers	**20**	**25%**
Building Owner (design & operation)	17	21%
Developer	3	4%
Time in Commercial Building Industry		
5 or fewer years	6	8%
6 to 10 years	11	14%
More than 10 years	63	79%
Time in Current Role		
5 or fewer years	36	45%
6 to 10 years	19	24%
More than 10 years	25	31%
Location		
Coastal -- Northern California	50	63%
Coastal – Southern California	37	46%
Inland – Northern California	11	14%
Inland – Southern California	8	10%
Even distribution across California	12	15%
Building Type Experience		
Experience with ZNE and ultra-efficient buildings	64	80%
Experience with beyond-code buildings	14	18%
Experience with to-code experience	2	3%

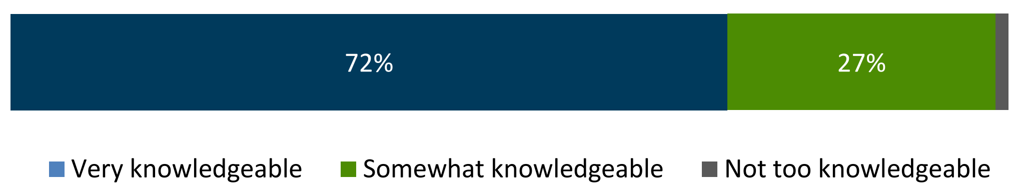
Figure 63 shows market actors' self-reported estimates of the number of ZNE and ultra-efficient buildings they (first column) or their firm (second column) had worked on in the past five years.

Figure 63. Respondents with ZNE and Ultra-efficient Building Experience in Last Five Years

Metric	Respondents (n=63)	Respondent Firms (n=57)
Sum of all ZNE and ultra-efficient commercial buildings	375	1,350
Maximum number of all ZNE and ultra-efficient commercial buildings	38	425
Average number of all ZNE and ultra-efficient commercial buildings	5	24

Nearly all interviewed market actors reported they were knowledgeable about ZNE and ultra-efficient buildings. Of the 78 respondents that reported how knowledgeable they were about ZNE, 72% reported they were very knowledgeable and 27% stated they were somewhat knowledgeable.

Figure 64. Respondent's Reported Knowledge of ZNE Design and Construction Practices (n=78)



13.2.2 Market Actors ZNE Definitions

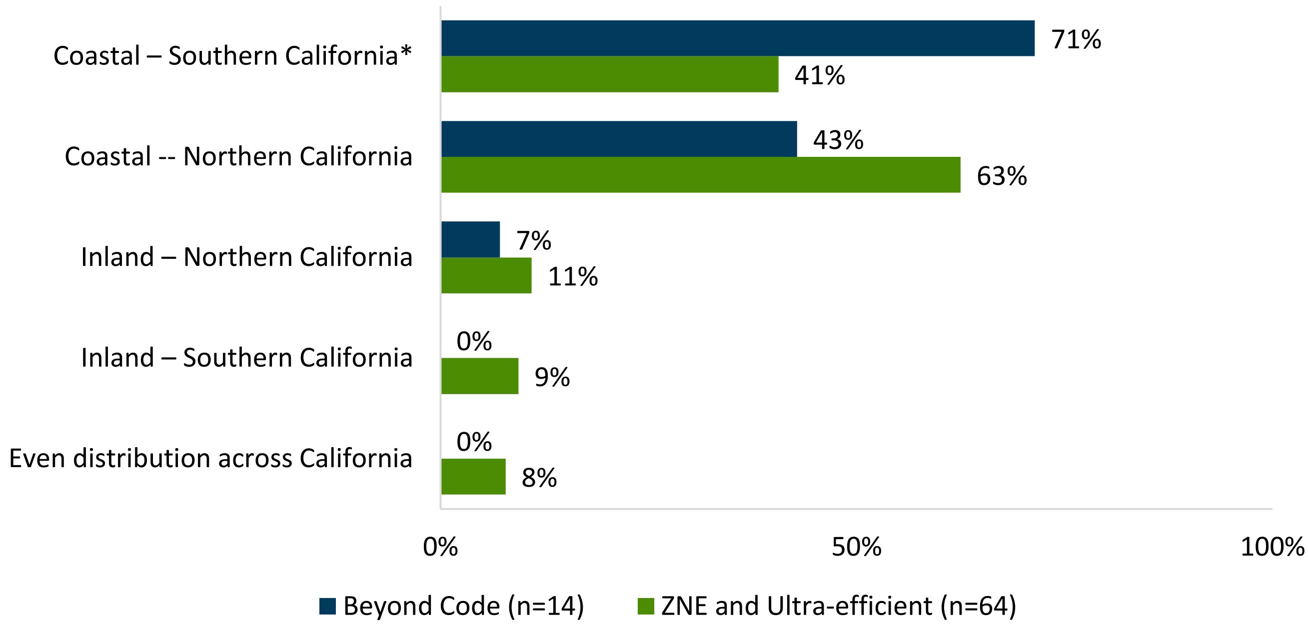
All respondents provided very similar definitions of ZNE buildings, however there was some disagreement related to the use of natural gas in ZNE and ultra-efficient buildings. All indicated that ZNE buildings annually generate as much energy on-site as they use. A few respondents added considerations when defining ZNE. Responses included the following:

- Ten respondents (six technical and four owners) mentioned conflicting opinions about the use of natural gas systems in ZNE and ultra-efficient buildings.
- Six respondents (four technical and two owners), stated that a ZNE building needs to exclude natural gas. One respondent reported removing any gas equipment from any modern building and another stated "you can't really have gas in ZNE" because, according to this respondent, ZNE is about being carbon neutral and therefore all efforts should be taken to remove any fossil fuels.
- Four respondents (two technical and two owners) countered that including natural gas in a ZNE building is acceptable. According to one respondent, "most people understand it [ZNE] to be just electricity but I think of other things. I think the point of ZNE is to reduce our footprint and be environmentally friendly. It is ZNE and "E" stands for energy, not just electricity."
- One respondent recalled a project in Sacramento that "could not possibly generate enough energy on-site" so they made an agreement with the Energy Commission and others to generate power off-site through a Power Purchase Agreement (PPA).

13.2.3 Market Size and Characteristics

ZNE and ultra-efficient building has largely occurred in coastal Northern and Southern California and there is some suggestive evidence that more ZNE buildings were in Northern California and more ultra-efficient buildings were in Southern California. Seventy-one percent of beyond-code respondents reported completing beyond-code projects in Coastal Southern California compared to 41% of ZNE and other ultra-efficient building respondents. The opposite pattern appeared for Coastal Northern California – that is more ZNE respondents reported building in Coastal Northern California and less near-ZNE respondents reported building there. Very few respondents reported work elsewhere in the state (Figure 65).

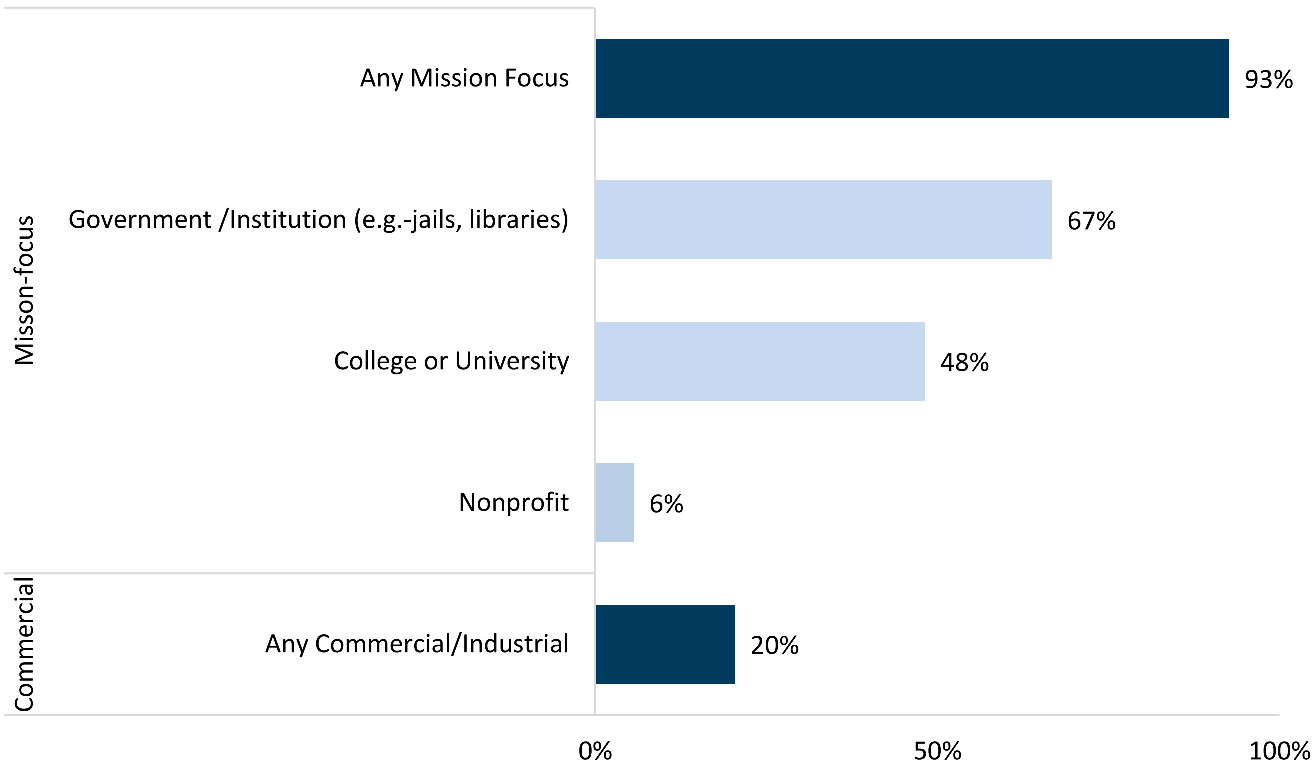
Figure 65. Where ZNE and Beyond-Code Construction Occurs



* Statistically significant difference (p<.05).

ZNE buildings are generally associated with mission-focused organizations such as educational institutions and governments, not commercial or industrial organizations (Figure 66). Interviewed market actors stated that most of their ZNE construction projects occurred with mission-focused buildings owners – that is they are long-term building owners and they often have a mission to save money long-term. For example, one architect reported that a federal agency was a key client. That federal agency signed a contract with his firm to do all new construction projects for the agency for a set amount of time and all those projects were to be ZNE. Presumably, that federal agency is interested in long-term building ownership and is therefore interested in the long-term savings associated with ZNE construction. To illustrate Figure 66, 67% of interviewed market actors who had worked on ZNE and ultra-efficient buildings, reported working on them for government or institutional property owners.

Figure 66. Market Actors' ZNE-and Ultra-Efficient Buildings They've Worked on in the Last Five years by Owner Type (n=54)



13.2.4 Awareness and Interest in ZNE

A large percentage of market actors pursued ZNE with existing buildings. This is consistent with the fact that respondents often worked in urban areas with limited building space for new construction and they concentrated heavily on mission-based organizations with a large stock of existing buildings. About two-thirds (64%) of all participants noted doing ZNE as part of a major retrofit exclusively (14%) or in combination with new construction work (50%). The remaining one-third (36%) had experience with new construction projects exclusively. This finding is consistent with two other findings:

- As noted in Figure 65, respondents work in the urban areas of Northern and Southern California – two-thirds work in the coastal northern part of the state and about half work in the coastal southern part of the state. Urban areas have less space available for new construction, so they are required to renovate existing building stock.
- As noted in Figure 66, respondents concentrated their ZNE work with mission-focused organizations. Ninety-three percent work with these types of organizations on ZNE projects. Educational institutions and governments typically have large stocks of existing buildings – they already have libraries, police stations, and similar buildings – that need renovation.

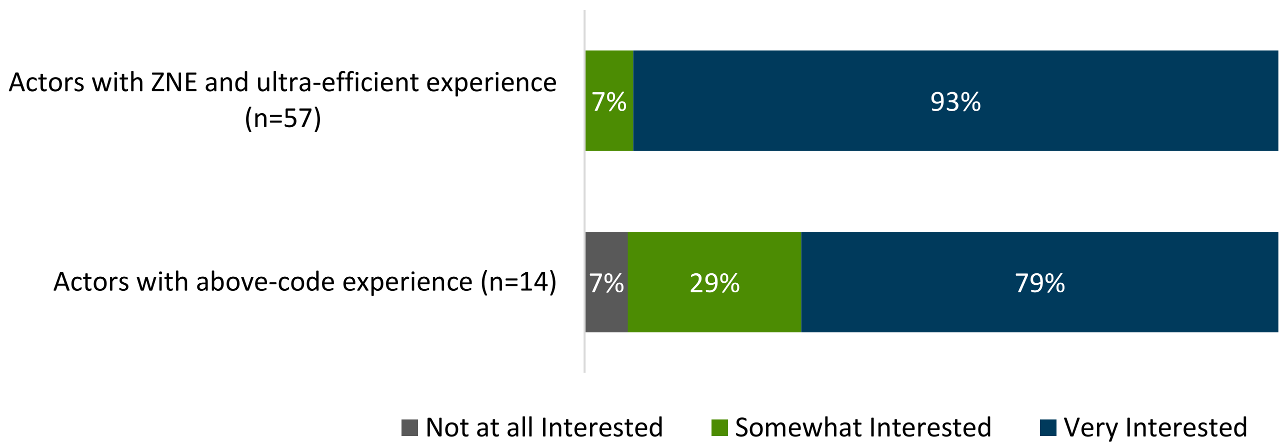
Interviewed market actors and their companies are highly interested in working on more ZNE and ultra-efficient commercial projects and expect this type of work to increase in the next five years (Figure 67 and Figure 68). The most common reason they gave for being highly interested was that their firm specializes in this type of work and, because they have staff with expertise in high-performing buildings, they would welcome more of this type of work. They also reportedly find this type of work interesting and would like to pursue it more.

Several market actors mentioned that state and local policies are pushing in this direction, so they expect this type of work to increase and want to be able to serve the market. A handful mentioned interest in high-performing buildings for environmental reasons and because the occupant and owner benefit from high-performing buildings. The two interviewed market actors with to-code experience were both very interested in doing ZNE and ultra-efficient work because of the high-quality building it produces for the owner.

The market actors who were "somewhat interested" in doing ZNE and ultra-efficient work said that, in their experience, building owners are not willing to pay the price premiums for this type of work nor the required necessary system commissioning, and that they have not seen the market demand this type of work.

One market actor that works primarily for hotels and who stated that energy costs are their largest expense, reported his company was not at all interested in ZNE and contrasted that answer to his own interest. While *he* was highly interested in doing more ultra-efficient projects, he said his company tended to pursue low-hanging fruit and measures with quick paybacks, such as tankless water heaters.

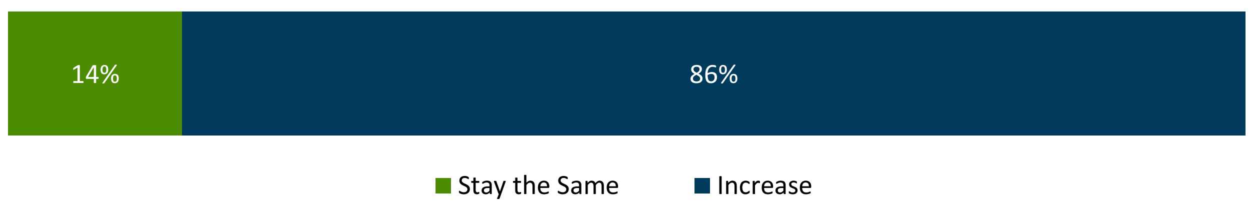
Figure 67. Company's Interest in Working on ZNE and Ultra-Efficient Commercial Building Projects Over the Next Five Years



The reasons why market actors expected their company's project work to increase over the next five years included the fact that there is growing interest in ZNE and ultra-efficient buildings, the technology to make it happen is available, the cost of solar photovoltaic (PV) has declined making ZNE more feasible, and that mandates will start requiring it. A few market actors reported that the number of proposals for ZNE and ultra-efficient projects their company has seen has been increasing in recent years.

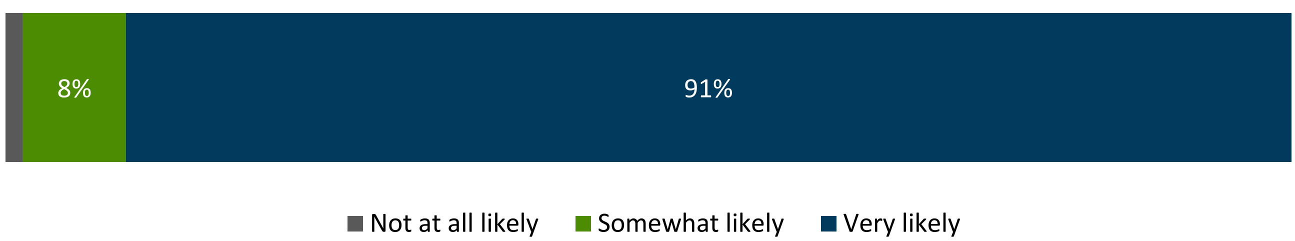
All market actors who said they expect their ZNE and ultra-efficient commercial building work amount to stay the same in the next five years had experience with at least one ZNE or ultra-efficient building. The reasons they gave were that the company does more renovations than new construction projects or that the proportion of clients requesting high-performance buildings was expected to stay the same. No interviewed market actors expected their company's work on ZNE and ultra-efficient buildings to decrease in the near future.

Figure 68. Expectation of Company's ZNE and Ultra-Efficient Project Work in the Next Five Years (n=64)



Interviewed market actors are highly likely to recommend ZNE and ultra-efficient buildings to their clients or colleagues moving forward (Figure 69). All of those who reported not at all likely or somewhat likely had experience with at least one ZNE or ultra-efficient building. We discuss everyone's reasons why following the figure.

*Figure 69. Market Actors' Likelihood of Recommending ZNE and Ultra-Efficient Buildings to Clients or Colleagues (n=75) **



* Two market actors said they did not know and are not included in the figure.

The reasons market actors gave for recommending ZNE and ultra-efficient buildings included (multiple responses allowed):

- Incorporating ZNE is "the right thing to do," that they "believe" in the concept of ZNE, and that "everyone should" aim for a ZNE building (28 of 68).
- Constructing ZNE buildings are a way to help the environment, save natural resources, and fight climate change (20 of 68).
- Aiming for ZNE produces a high-quality building that benefits the owner and its occupants (25 of 68).
- Designing or constructing ultra-efficient buildings is the type of work they do, and they want more of it (15 of 68).
- Helping push the industry towards ZNE (14 of 68).

Seven market actors reported that they would only recommend a ZNE or ultra-efficient building if it fit their client's budget and needs. Of these seven, four said they were somewhat likely to recommend a ZNE or ultra-efficient building and three said they were very likely to recommend them.

The one market actor who said they were not at all likely to recommend ZNE and ultra-efficient buildings was a construction manager. When asked why, he said: "If you're working with someone who's never done a ZNE building, everything that can possibly go wrong will be blamed on you."

Market actors had future-looking, big-picture questions about the grid. At the close of the interview, we asked market actors if they had any questions; very few did. The questions they posed reflect deep experience and understanding of energy delivery and energy markets in California. They asked:

- How will the supply/demand duck curve change building energy analysis?

- How does California, with its duck-curve, go to 100% renewable energy without grid-level storage and without importing dirty energy from other states?
- What happens to the gas company as communities go all electric?

13.2.5 Drivers and ZNE

Nearly all interviewed market actors agreed (69 of 76; 91%) that the property owner is the person who most influences the decision about whether a commercial building will be ZNE or exceed the energy code. One-fifth of these respondents also voluntarily added that the design team is integral to the execution of the decision and the achievement of the performance goal. The architect was named as the second most influential actor in making the decision to go ZNE. For public entities, the property owner making the decision is often the City Council or City Manager at local governments and the Board of Trustees, President, or Chancellor for Universities, for example.

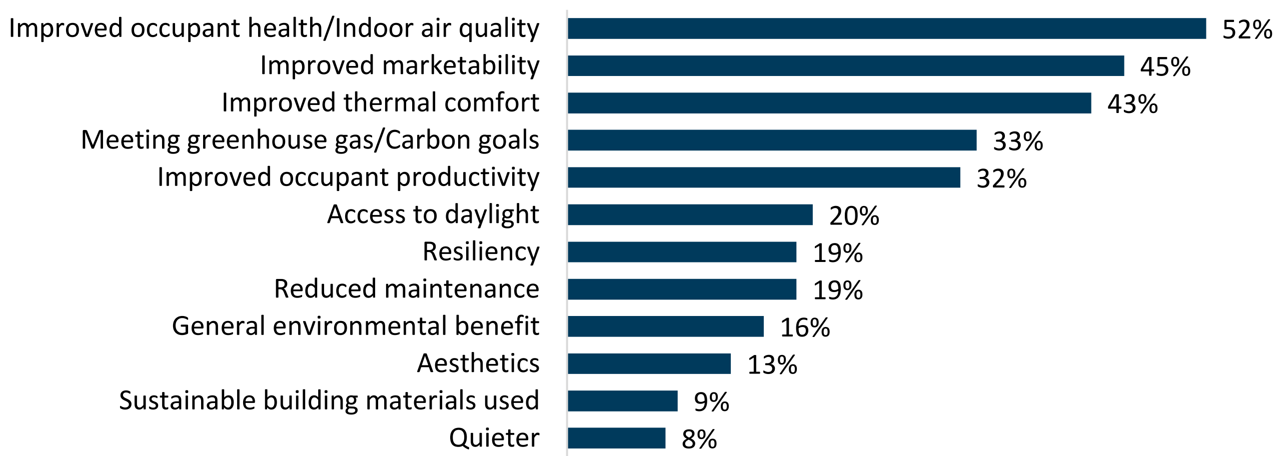
The motivations that influence the decision to pursue a high-efficiency building varied. Some market actors said that non-energy benefits motivate non-profits and commercial entities who want to use the image of sustainability in their marketing, while energy bill savings are a driver for owner-occupied buildings and long-term ownership situations, including K-12 schools (Figure 70). Nearly one-third of market actors said that the motivations did not differ between building types or sectors (13 of 41; 32%).

Figure 70. Sector Differences in the Decision Drivers to Exceed Energy Code n=41

Driven by Non-Energy Benefits	Driven by Energy Benefits
No difference between building types (n=13)	
Non-profits or public entities guided by organizational sustainability goals or mission (n=13)	Owner-occupied, long-term owner driven to reduce long-term operating costs (n=6)
Commercial entities driven by public relations image or marketing (n=8)	Energy intensive buildings (such as data centers) driven to reduce energy costs. (n=4)
K-12 schools driven to improve indoor environment to benefit students (n=1)	K-12 schools driven to reduce operating costs so funds can go to textbooks and other student needs (n=2)

Interviewees reported that ZNE and ultra-efficient buildings have a variety of non-energy benefits, including an improved indoor environment (better thermal and acoustic comfort, improved air quality, and access to daylight) which, in turn, improves occupant productivity (Figure 71). Companies that occupy ZNE or ultra-efficient buildings can also market their commitment to the environment, attract green-minded tenants, and meet their carbon or GHG reduction goals. We briefly elaborate on each non-energy benefit following Figure 71.

*Figure 71. Non-Energy Benefits of ZNE and Ultra-Efficient Buildings Reported by Market Actors (n=75) **



* Multiple response allowed

Non-energy benefits include:

Improved occupant health/Indoor air quality: The highly-efficient HVAC systems and well-sealed building envelopes reduce the amount of pollen and other contaminants that would diminish air quality.

Improved marketability: Owners of ZNE and ultra-efficient buildings can market the building's features which can reportedly help owners lease their units faster, charge a rent premium, and have improved tenant retention. Owners of these buildings can also generate prestige, "bragging rights," and an image of being environmental stewards from marketing their ZNE and ultra-efficient building.

Improved thermal comfort: The occupants' thermal comfort is improved in ZNE and ultra-efficient buildings because the well-sealed building and optimized HVAC systems reduce the likelihood of drafts and leakage of conditioned air.

Meeting greenhouse gas/Carbon goals: Occupying a ZNE or ultra-efficient building that uses most of its energy from renewable sources of energy is one way for an organization to help meet its GHG or carbon reduction goals.

Improved occupant productivity: Occupants with access to natural light, good quality air, and comfortable thermal conditions (and reduced access to VOCs and harsh fluorescent lighting), can be more productive at work. The psychological benefits of being in an environmentally beneficial building can also positively affect work productivity, according to market actors.

Access to daylight: The daylighting incorporated into ZNE and ultra-efficient buildings minimizes the need to have electrically-powered lights on. The natural light has been known to avoid the headaches caused from fluorescent lights and can make building occupants feel "more connected to the outdoors," as one market actor put it.

Resiliency: The resiliency, or ability to bounce back after a catastrophic event, is enhanced in ZNE and ultra-efficient buildings because the materials used are more durable, reliable, and long-lasting, and the building has its own power source, which it can use in case of power outages. One market actor also mentioned that the energy grid itself will be more resilient with distributed generation.

Reduced maintenance: The long-lasting LED lights and durable equipment used in ZNE and ultra-efficient buildings reduce the need for ongoing maintenance.

General environmental benefit: This category contains general references to environmental benefits reported by market actors, which included comments such as: lower carbon emissions, environmental sustainability, resource conservation, reduction in pollution, and low impact on the environment.

Aesthetics: The ZNE and ultra-efficient buildings are visually-pleasing and inviting. One market actor added that the "architecture is well-integrated."

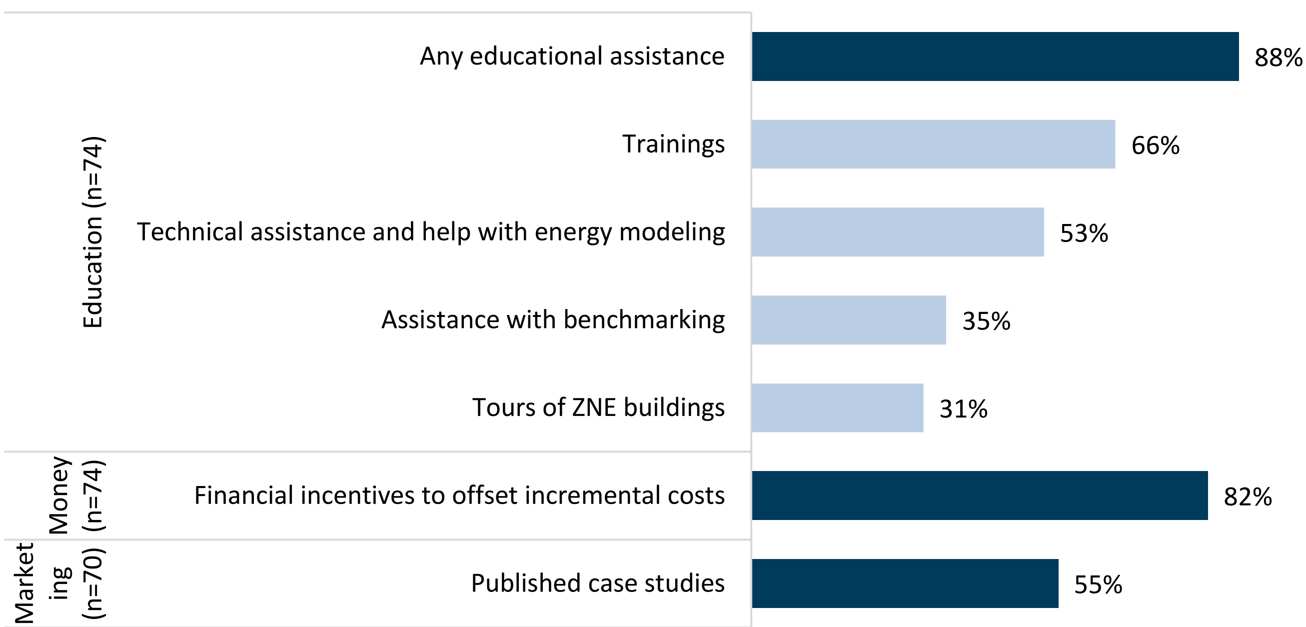
Sustainable building materials used: The building materials used are more sustainable and healthier for those constructing and occupying the building. LEED certification partially drives the use of these improved materials, which do not allow for vinyl, formaldehyde, or materials with high levels of volatile organic compounds (VOCs).

Quieter: The indoor environment in ZNE and ultra-efficient buildings is quieter because the thicker walls reduce noise penetration from the outside and the efficient HVAC systems are quieter indoors. This translates into a more enjoyable environment for the occupant.

13.2.6 Barriers and Resources Needed

Educational assistance related to ZNE was as important to respondents as financial incentives. Eighty-eight percent of respondents indicated receiving some type of educational assistance related to ZNE would be useful to their firm. Of those, most were interested in trainings or technical assistance and help with energy modeling. Fewer were interested in benchmarking assistance or tours of ZNE buildings. Most respondents (82%) indicated financial incentives would be helpful and about half (55%) indicated marketing support via published case studies would help staff at their firm. No significant differences were seen between owner and technical respondents or by ZNE experience.

Figure 72. Requested Assistance from Market Actors



A variety of financial, technical, and human resource challenges confront market actors as they pursue ZNE and ultra-efficient buildings (Figure 73). Chief among them are: 1) an insufficient budget for the building's highly-efficient energy-using systems and renewable energy-producing systems, and 2) a lack of expertise and resulting reluctance to try new things among the design team's architects and engineers. We discuss each of the challenges in more detail following Figure 73.

*Figure 73. Barriers and Challenges to ZNE Buildings (n=78) **

* Multiple responses allowed.

ZNE challenges include:

Insufficient budget: The project budget may not always be large enough to account for the various components needed to achieve a ZNE building. These components include the more expensive, efficient mechanical and lighting systems, the envelope measures, the energy modeling, and sufficient renewables to offset the building's energy load. Eight of the 30 market actors who mentioned budget as a barrier specifically said the budget for onsite renewables can be a challenge.

Inexperienced design and construction team: Engineers and contractors inexperienced with high performing buildings are often reluctant to work with new systems with which they are unfamiliar. Interviewed market actors described "entrenched attitudes" where the design teams specify familiar equipment and will push back or attach a price premium to their services if they must work with different equipment. One interviewed construction manager reported:

> *The big reason why we don't see more ZNE buildings is that construction is an exceedingly complex and hassle-prone endeavor. ZNE strikes fear in the heart of everybody, especially contractors. If that fear is not dispelled, owners will see very big price tags from the construction industry. They need to cover themselves for unforeseens. That is the biggest reason that prevents the project from going ZNE. The owner sees the price tag and wants to eliminate some feature.*

Architects reportedly do not always realize they need to check with the energy modeler in the beginning to see how the design affects energy consumption. Another market actor said, "there is a lot of ignorance and stubbornness" and a third reported "the human factor is the biggest challenge at this point in time." Interviewed market actors agreed that this was a mindset issue that can be solved by education.

Placing enough renewables onsite: Industrial buildings and high-rise buildings with little roof space relative to the conditioned space make it challenging to place enough renewables onsite to offset the building's energy load. Sometimes PVs can be placed in parking lots or renewable wind energy can be used to supplement the building' energy generation. See 9.2.1 for more discussion on when renewables need to be placed offsite.

Lack of team coordination: Weak coordination of the design and construction teams throughout the duration of the project can make it challenging to reach the energy goal. Market actors reported that it is essential to repeatedly communicate the owner's energy performance or labeling goal to the design, construction, and maintenance teams, so those goals are followed through. Ensuring everyone is on the same page and "rowing in the same direction," as one interviewee put it, makes them less likely to suggest eliminating components through value engineering and makes the ZNE design more likely to be realized in construction.

Accounting for occupants' behavior and plug load: Planning for the types of appliances and equipment that will be plugged in and contribute to the building's energy load can be challenging to estimate and model. The energy modeler should consider whether they need to adjust the default inputs for occupancy periods and plug load to reflect what is expected during occupancy. Some market actors mentioned the need for occupant engagement so that the occupants' behavior does not appreciably contribute to the energy load.

Energy modeling to achieve ZNE: Inaccurate inputs into the energy model and reluctance to run many iterations of the energy model can be a challenge to executing the ZNE concept. If there is not enough data available from comparable buildings to do a feasibility analysis, that can make energy modeling difficult. Additionally, aesthetic and design features also affect the building's energy performance and anytime those are changed, they need to be reflected in the energy model and other building systems may need to be adjusted. An interviewed engineer said that they have to sometimes push back against changes the owner or architect make because it will negatively affect the buildings' performance or potentially prohibit it from being ZNE.

Undervaluing commissioning: Some property owners undervalue system commissioning, yet it is necessary to ensure that the building performs according to the design parameters. Market actors said it is important to allocate budget for commissioning and ensure the building operators have technical knowledge on controls. Complex systems with more controls have more potential points of failure, and trained commissioners are integral to maintaining optimal performance. Also, once people occupy the building post-construction, retrocommissioning may be warranted to adjust the system's performance and reduce energy usage.

Value engineering discussions: When the owner is focused on the ZNE goal and the budget is dwindling, the team will engage in value engineering to identify what project components can be cut to save money while maintaining the building's high performance. However, when this occurs, changes need to be made to the design and energy models; market actors reported that they will sometimes get pushback from the design team or energy modelers because they do not want to have to re-run their models. A project champion must ensure the most important energy efficiency items are not subject to value engineering. We discuss strategies to avoid value engineering more in Section 13.2.7.

Owner perceives risk: Owners and developers may be reluctant to aim for a ZNE building because they find new technology risky or are unsure if they can sell or rent the finished building. Market actors also reported that property owners may see the projects' upfront cost as a risk and not account for the positive payback over the long term. Market actors said that this barrier can also be reduced with education.

Existing building challenges: Technical challenges are more common in existing buildings than new construction projects. Market actors said there are "more constraints" and fewer things you can control with existing buildings, which increase risk and cost. If the building remains occupied during the renovation, it is a challenge to address each of the systems one by one without disrupting the building occupants too much.

Challenging policy: Market actors mentioned a few types of policies that place constraints on the activities needed to achieve ZNE and ultra-efficient buildings. These included policies related to:

- Historic buildings
- Roof ordinances
- New construction permitting processes
- Utilities' Time-of-Use rate structure

- Utilities schedules to upgrade infrastructure

Building operator's lack of knowledge: The mechanical systems in ZNE and ultra-efficient buildings can be more complicated than their respective systems in built-to-code buildings, and someone at the new building should feel comfortable with controlling those systems. Training usually needs to occur to teach the occupant or their team how to operate the new systems. A representative of an organization with several ZNE and ultra-efficient buildings said that if an organization has not invested in the "human capital to operate these buildings in an efficient manner once they're online" it can prevent realization of energy savings.

Split incentive issue: Three market actors said that tenants do not prioritize ZNE buildings when looking for places to rent. Owners are less likely to pursue ZNE and ultra-efficient buildings when they are unsure whether they can charge a price premium to cover their higher design and construction costs. One market actor mentioned that the owner finances the project, but the tenants pay the utility bills and receive much of the financial benefit from a ZNE building, making ZNE less attractive to owners.

Unfavorable utility rate structures: The Time-of-Use rates that charge more for electricity during peak times affect the cost-effectiveness and return on investment for ZNE buildings. If a building must use energy during peak periods, they will be paying more for that energy than a building that uses most of its energy during off-peak periods. A couple market actors mentioned that the smart systems in ZNE and ultra-efficient buildings are capable of responding to automated demand response events and pricing that is more dynamic than Time-of-Use rates, potentially saving money on energy bills, and making the return on investment more attractive to property owners. It is a challenge to explain utility tariffs, peak periods, and dynamic pricing to owners and have them understand the implications.

Not pursuing energy efficiency before renewable energy: A few market actors mentioned an educational challenge of convincing owners to pursue energy efficiency to the greatest extent they can before adding renewable energy. This is particularly important because of the challenge of placing enough renewable energy onsite to offset the building's energy load.

Vague goal: When an owner says they want a green or sustainable building but does not settle on a specific goal, it makes it more difficult to achieve the high-performance building because the design team is unsure of the goal. Market actors recommended deciding on a specific goal and making sure the design team is committed to it, so that options that could have made a big difference on the way to ZNE do not get eliminated (see the next section and 9.1.3 for more on goal setting).

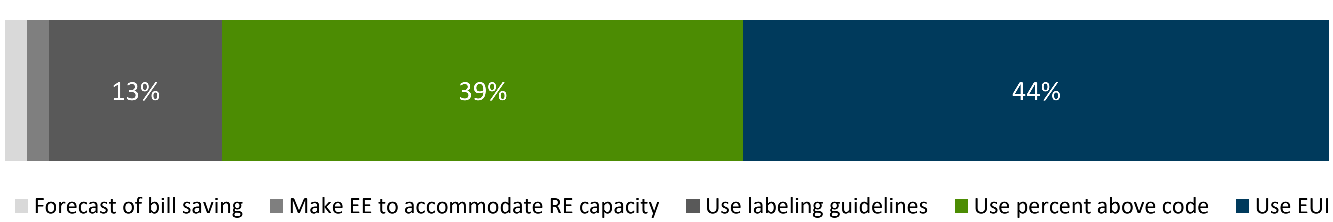
13.2.7 Approaches to ZNE and Distributed Generation

Approaches to ZNE and High-Efficiency Buildings

Setting Energy Goals

Most respondents have efficiency and renewable energy goals for their ZNE projects, and these targets are typically established during the conceptual design phase. Of the respondents that could specify how they measured their energy efficiency goals (n=61), a bit less than half (44%) used an energy use intensity value and two-fifths (39%) used a percent above code value. Far less (13%) reported using labeling (e.g. LEED) requirements or other techniques.

Figure 74. Targets for ZNE Projects (n=61)



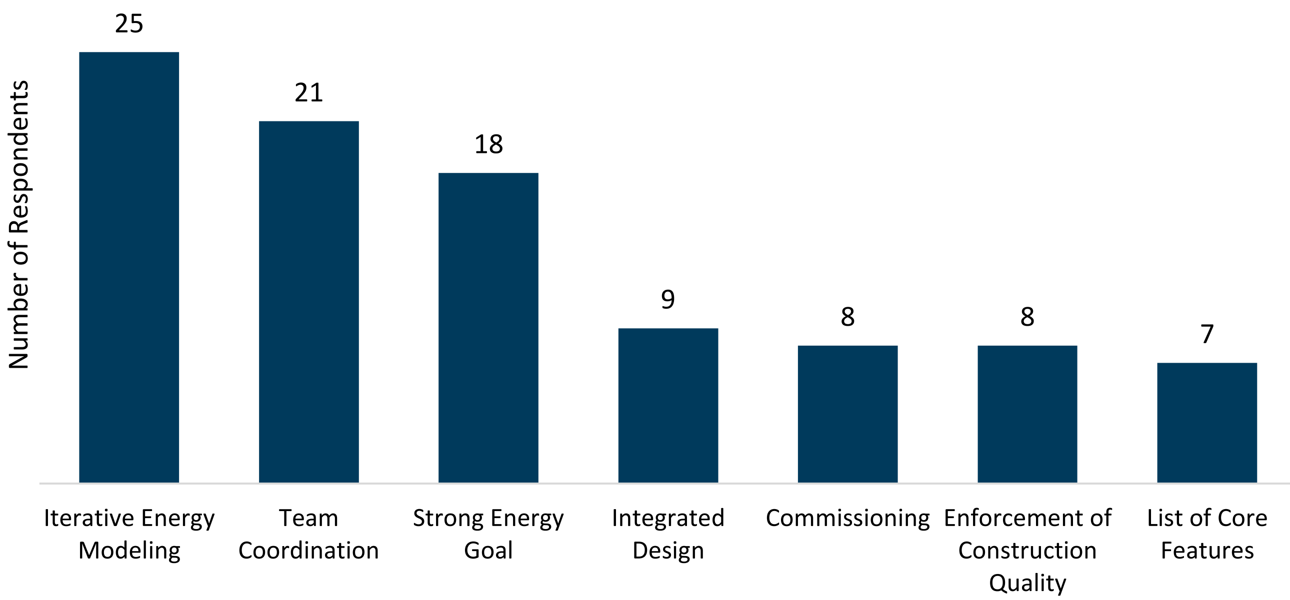
One respondent noted using a forecast of bill savings as the target and one reported making the building only as efficient as it needed to be to offset whatever renewable energy could not. Most respondents (84%) established their efficiency target around the conceptual design phase, 12% during schematic design, and the remaining four percent establish the goal during design development or when preparing construction documents.

Similar numbers of respondents established renewable energy targets. Of those able to report about establishing renewable energy targets, two-thirds (67%) reported establishing the targets around the conceptual design phase. The remaining establish the renewable targets during the schematic phase (27%) or during the design development phase (7%).

Approaches to Ensuring Energy Targets are Met

Market actors experienced with ZNE and ultra-efficient buildings learned a variety of approaches to ensure that energy goals are met in later stages of a project, particularly when value engineering comes into play. In particular, they emphasized the importance of iterative energy modeling to test options and strong coordination among team members to align their efforts with the energy goal, among others. We elaborate on these strategies and more, following Figure 75.

Figure 75. Strategies to Ensure Energy Goals Are Met (n=68) *



* Multiple responses allowed.

Strategies that help insure goals are met include:

Iterative Energy Modeling and Integrated Design: Having a skilled energy modeler who can run models to see how a decision affects the building's energy performance was one of the most important strategies interviewees mentioned to ensure that a building's energy targets are met. The energy modeler can inform the building owner and decision-makers about the financial and energy implications of changing different building components and how they affect each other.

Also, an "integrated design" at the start of the project minimizes chances that any one system or design feature will be nominated for elimination (9 of 68). To illustrate, the building's orientation and amount of glass influences the daylighting which influences the amount of lighting needed, which affects energy load, which affects PV sizing. Changing any one component will necessarily affect other components. When team members understand that all the components have been modeled to be interactive, they will be less likely to suggest changes to any one of them.

Along these lines, seven interviewees said that having a list of core elements needed to meet ZNE is another tool they use to meet energy targets. A few of these described this list as the "basis of design." Interviewees said that having such a list to refer to is helpful when value engineering conversations arise, and frequently referencing the list helps remind the project team of the energy goals and keeps them on track. Eight interviewed market actors mentioned that when the project cost exceeds the project budget, they look for ways to save money while maintaining the features integral to the ZNE performance target.

Team Coordination: The second most important strategy to meet energy targets reported by market actors was having a champion to coordinate team members. The champion ensures team members understand the ZNE goal and that their activities stay aligned with that goal. In these situations, the team members offer design or equipment suggestions to cut costs while still maintaining energy efficiency and meeting the owner's goals. Having a core list or basis of design to refer to guides these conversations. One market actor summarized the team coordination necessary when cutting costs in the following way:

> *You need to make sure that your energy modeler stays involved and shows the impact of any value engineering decisions and makes sure the team understands the key design features that really impact energy use and comfort. So, when there are value engineering conversations, the key items that make the building perform well stay in, while the extras like aesthetics might get cut.*

Strong Goals: A quarter of market actors (n=18) said that having a strong and immutable energy target or ZNE goal helps ensure that goal is met once the building is constructed. They said it is important to clearly define the goal as early as possible and continually refer to that goal. Ensuring the team's efforts are aligned to the goal is beneficial. Market actors mentioned that some companies' energy performance goals are so strong, the project team must meet them, including buildings on the University of California campuses, State of California buildings, local government buildings, and K-12 schools.

Construct as Designed: Interviewed market actors (n=8) also mentioned the importance of ensuring that the building is constructed in the way the design intended if energy targets are to be met. Three of these respondents described the need for a quality assurance (QA) representative to be onsite during construction. One builder said they encourage property owners to allocate funds for onsite construction QA in order to catch installation errors that could cost the owner substantial money over the building's performance lifetime. Five market actors suggested the need for strong enforcement of performance requirements in contracts with vendors, ESCOs, or contractors to ensure their work achieves what they promised.

Commission to Perform Appropriately: In a similar vein, interviewees (n=8) mentioned that energy-using systems need to be commissioned to perform in accordance with the energy models. These market actors emphasized that having a knowledgeable and experienced commissioning agent or controls contractor helps ensure energy targets are met. Ongoing monitoring of energy performance after the building has been occupied is critical to assessing the performance of the building and identifying opportunities for retro-commissioning.

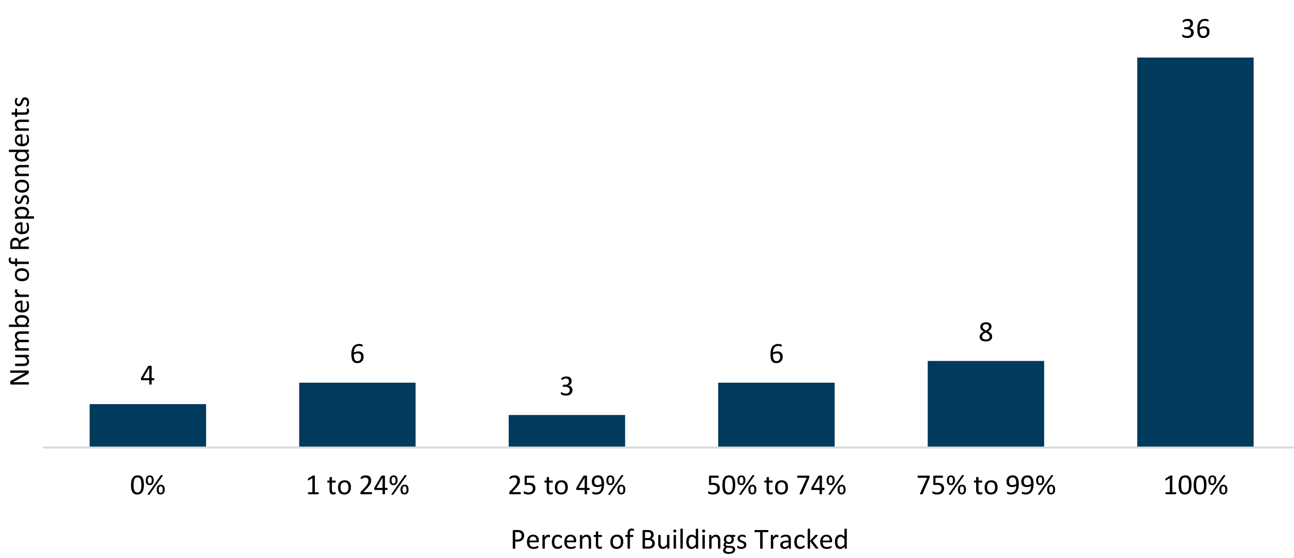
One market actor said that, in their experience "The commissioning process has been continuously under-valued and under-cut." A few market actors mentioned that budgeting for submetering infrastructure and connecting it to a building energy management system facilitates identification of system performance issues and optimal system commissioning. One engineer mentioned a case where a project budgeted for submetering infrastructure but did not budget an additional $10,000 for commissioning and networking of the submeters, which prevented them from executing measurement and verification.

Financing Sources Ensure Efficiency: Establishing an accurate budget early on in the design process was a strategy that minimizes value engineering later, according to two interviewees. One engineer said they recommend their clients include a "buffer" in the budget, so that they can afford the important energy efficiency and renewable energy measures if other construction costs exceed their estimates. A property owner reported using a similar strategy; at their firm, they keep the budget for the energy efficiency measures separate from the rest of the project so that those funds are safely allocated and protected from any value engineering discussions.

Three interviewed market actors mentioned that the source of funds plays a role in ensuring that energy efficiency equipment is kept in a project. One interviewee mentioned that, in many cases, the owner relies on Utility incentives to make the project financially feasible and eliminating the efficient system jeopardizes losing the incentives. For example, the IOUs' Savings by Design program and CHIPS program require energy targets for their incentives. One engineer mentioned that some non-profits fundraise to cover their construction costs. Those funds come with stipulations on the types of equipment they can be spent on, which ensures the equipment is not eliminated.

Tracking of Energy Performance: **It is common for someone to track a building's energy performance, and market actors agreed that tracking this post-construction was important or necessary to demonstrate the building is ZNE or high-performing.** Figure 76 shows that 70% of market actors (44 of 63) reported that at least three-quarters of their buildings have someone tracking the energy performance. The market actors viewed energy performance tracking as part and parcel with ZNE and ultra-efficient buildings. As an interviewed architect explained, "ZNE isn't ZNE unless you can track the data. Anyone who says they did a ZNE building and isn't tracking isn't doing a ZNE building. That's a big difference from LEED, which is all prescriptive and very little about performance."

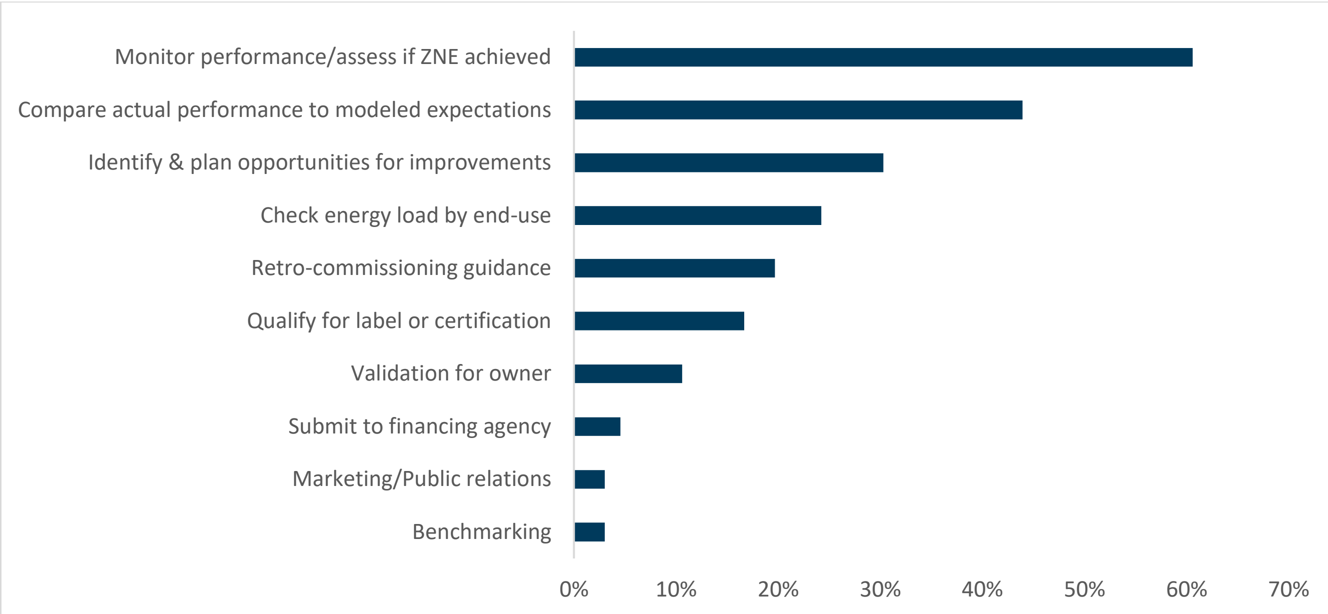
Figure 76. Percent of Buildings Energy Performance is Tracked (n=63)



Such tracking requires the necessary metering infrastructure or energy management systems to be installed. Four interviewed market actors mentioned that a lack of necessary submetering infrastructure or a lack of professionals trained on the energy management system prevent proper tracking of building energy performance.

Many interviewed market actors reported tracking building performance by end-use, including HVAC systems and plug loads, which is necessary to troubleshoot in case the building is not performing to expectations and when performing retro-commissioning (Figure 77). We discuss the various ways that market actors use the energy performance data following the figure.

*Figure 77. Uses of Energy Tracking Data (n=66) **



* Multiple responses allowed.

Ways in which market actors can use energy performance data include:

Monitor performance/assess if ZNE achieved: Most commonly, market actors monitor the building's energy performance to see if the building is tracking toward the ZNE goal, or if they achieved the ZNE goal.

Compare actual performance to modeled expectations: As is evident elsewhere in this report, the energy modeler may predict the building can achieve ZNE, but the actual performance can deviate from the models. The energy performance data will be compared to the modeled expectations to check the model's accuracy and that feedback is used to update future energy models. If the building performs as expected, then the data can also be used a measure of the energy model's success. Regarding the last point, one market actor stated, "It's important because that is the key for repeatability. If you can prove that this particular concept works, then you can use it in more buildings and anticipate it will become ZNE."

Identify and plan opportunities for improvements: In case the building is not performing as expected, the tracking of energy use can help identify when or how the excess energy is being used so that corrections can be made. One market actor explained how the tracking helped them identify when the meter's sensor was not working properly and that a power outage scrambled the HVAC controls and needed to be reconfigured.

Check energy load by end-use: About one-quarter of market actors voluntarily added that they monitor energy performance by end-use, instead of just tracking the building's overall energy use. Disaggregating the load by end-use facilitates identification of opportunities for improvements and retro-commissioning, and comparison to the energy model to see where modeled versus actual use is discrepant. As one market actor explained, "If we see the EUI [Energy Use Intensity] is off-target, we break it down. Where is it off target? Plug loads, cooling, heating, ventilation? Once we track it down to the end-use, we begin our investigation into what is causing it to under-perform."

Retro-commissioning guidance: The energy performance data can inform where and how retro-commissioning needs to be performed. A few market actors mentioned they will service their buildings on an annual basis to keep them attuned properly. In one example, the energy tracking data exposed that the HVAC controls had been overridden and they needed to re-commission them. Guidance for retro-commissioning is particularly helpful when plug loads have changed over time, affecting the building's load.

Qualify for label or certification: Market actors reported that all labeling programs require one year of energy performance data to demonstrate the high performance of the building. These include the New Building's Institute, LEED, GreenPoint Rated, Passive House, and Living Building Challenge.

Validation for owner: Some market actors used the energy performance data to demonstrate to the owner that their extra expense was justified, and the building is an ultra-efficient building.

Submit to financing agency: The market actors who mentioned that they submit the energy performance data to a financing agency were referencing Proposition 39 that provides funds for energy efficiency upgrades and solar on K-12 schools.

Marketing/Public Relations: Two market actors mentioned they use the data for marketing purposes, highlighting how efficient the building is. One of these actors said the data went to a kiosk in the lobby that showed how energy efficient the building was, which served to engage and educate occupants and visitors.

Benchmarking: Another two market actors said they use the energy performance data for benchmarking to help gauge typical EUIs for similar buildings.

Approaches to Distributed Generation

Renewable Energy

Respondents had mixed perspectives about on-site and off-site renewable energy generation, though many preferred to put them onsite to the greatest extent possible. Nearly half of the interviewees (31 of 64) voluntarily mentioned that they preferred on-site generation for their ZNE and ultra-efficient buildings or had no experience with off-site renewables for their projects.[44] A small number did not think that off-site renewables fit the spirit of ZNE. For example, one architect stated, "Depending upon how much of a purist you are, some people would argue that offsite renewables is not really ZNE."

About a quarter of interviewees mentioned viable strategies for off-site renewable energy generation and a few mentioned that the industry is trending toward more acceptance of off-site renewables. While utility tariffs can make off-site renewable generation more complicated, some market actors found net metering aggregation programs, community solar, and power purchase agreements (PPAs) to be advantageous ways of sourcing renewable energy from off-site.

Interviewed market actors noted that off-site renewable energy generation was needed most in cases of tall, skinny buildings in dense urban environments or for buildings with intensive energy loads, such as laboratories. Figure 78 displays the main reasons why market actors would site renewables off-site, of those who could comment on off-site placement. We elaborate on each of them following the figure. After that, we discuss challenges market actors have encountered when trying to place solar PV onsite.

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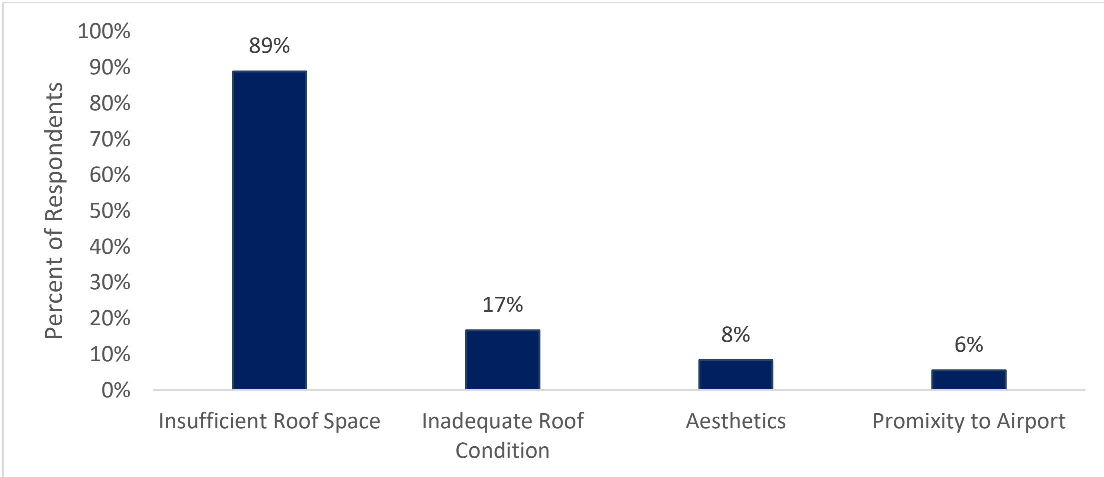
[44] The interview question asked, "Under what conditions do you install renewable energy generation on-site versus off-site?" Those that mentioned a preference for on-site versus off-site voluntarily offered the information without the interviewer probing for an answer. As a result, we do not know every market actors' preference for on-site versus off-site.

*Figure 78. Reasons Why Renewables Placed Off-Site (n=64) **



* Multiple responses allowed.

Factors that would influence owners and design teams to consider siting renewables off-site included:

Roof space to place PV arrays sufficient to offset the building's energy load. Having sufficient roof space depended on the energy load of the building and whether other necessary equipment was on the roof (such as HVAC equipment). Nearby land or a parking lot provided attractive options for mounted PV arrays (31 of 64).

Roof condition including its age, structural integrity, and orientation. The age of the roof factors into whether renewables are sited onsite or offsite; older roofs and roofs lacking in structural integrity favor placement off-site. The roof's orientation and presence of trees shading the roof can also limit the viability of PV on the roof (6 of 64).

Aesthetics can play a role in sourcing renewables from off-site. In some cases, the owner finds the PV panels unappealing and, in other cases, historic buildings are required to maintain an architectural style that can prohibit PV placement (3 of 64).

Proximity to an airport necessitates Federal Aviation Administration (FAAs) compliance, which can limit onsite renewables. Respondents mentioned how PV can cause "glint and glare" that affects aircraft and FAA-imposed wind-sourced power system restrictions (2 of 64).

Reasons why respondents said it was important to maintain renewable energy generation onsite included the fact that "it feels more like ZNE" to the design team and owner, and that the visibility of PV on the building can carry "marketing cachet" which strengthens the building's sustainability image.

A variety of challenges to incorporating PV panels onsite confronted market actors, including sufficient roof space, first cost, and complicated utility tariffs including Net Energy Metering (NEM; Figure 79). We elaborate on each challenge following the table.

*Figure 79. Market Actors' Challenges to Incorporating PV (n=57) **

Challenge	Number of Respondents
Insufficient unshaded roof space	39
High first cost	18
Complicated utility tariffs, NEM, and PPAs	9
Existing buildings not solar ready	7
Unfavorable local codes or permitting processes	6
Shoddy panel providers	4
Complex interconnection process to utility grid	2
Improper submetering	2

* Multiple responses allowed.

Challenges to incorporate solar PV include:

Insufficient unshaded roof space: As described above, there must be enough roof space to place sufficient PVs to offset the building's energy use. This becomes a challenge with tall, skinny buildings that have higher energy loads relative to the available roof space. Shading from trees and the presence of mechanical equipment can also limit viable roof space. Finally, other usage of the roof space can prohibit PVs; in one case, the building owner reportedly desired to have a rooftop patio, which prevented the inclusion of PV on the roof.

High first cost: The upfront cost of the solar panels and their installation can be a challenge to incorporate into the budget for some building owners. If the panels will be in a parking lot, the trenching required to connect it escalates the cost. Two market actors added that government buildings cannot take advantage of the tax credits that private properties can, which can cover up to one-third of the cost.

Complicated utility tariffs, NEM, and PPAs: Changing solar rate tariffs, time-of-use rates, and net energy metering billing arrangements complicates the economics of solar PV and can be difficult to explain to building owners. PPAs with third-parties are complex legal arrangements and can be administratively difficult to execute. PPAs can present challenges for property owners with a lot of bureaucracy, such as government entities and universities. One actor mentioned that third parties are not as inclined to serve small sites through a PPA because it is not cost-effective for them.

Existing buildings not solar ready: Two primary conditions in existing buildings can make it difficult to incorporate PV: the roof's structural integrity to support the weight of the panels, particularly if the roof is older (~20 years old); and the existing electrical panels may need to be upgraded with a converter.

Unfavorable local codes or permitting processes: Three market actors mentioned challenges related to local fire codes that restrict PV placements so that firefighters can access the roof. Other codes related to glint and glare near airports or aesthetics of panels on buildings.

Unreliable or unqualified panel providers: A few market actors said it was important to carefully choose the panel provider. Two market actors reported experiences where the panel provider went bankrupt after they had supplied some panels, but not all. Integrating two manufacturer's panels added cost and complexity to the project. Another reported that the low-bid solar provider was able to deliver the right kW but not enough kWh. Finally, a fourth market actor reported that government contracts require union labor and few solar PV installers have labor in unions.

Complex interconnection into grid: The interconnection process to connect the system to the utility grid is complex and caused project delays for two market actors. The challenge includes filling out the utility's application forms and agreements.

Improper submetering: Submetering infrastructure is important to understand how much power the panels are producing and manufacturers design meters and their integration into building management systems in different ways. In one case the solar energy information was only going to “the cloud” and not the building’s energy management network, which caused the building owner’s IT department to carve a hole in the firewall to allow the building network to accept information from the PV network. Another market actor mentioned that some meters owned by the solar companies do not have consistent up-time, leading to gaps in data.

Electric Vehicle Charging Infrastructure

About half of market actors (11 of 24) said there were no challenges to incorporating EV infrastructure at their projects, while the other half (13 of 24) cited challenges. The main challenges relate to the electric load generated by the charging stations, their first cost, and how to implement their use (Figure 80). We describe each of them in more detail following the table.

Figure 80. Challenges to Incorporating EV Charging Infrastructure

Challenge	Number of Respondents (n=24) *
No challenges related to EV infrastructure	11
How to account for electric load	6
High first cost	5
Questions around implementation of service	4
Space constraints	2

* Multiple responses allowed.

Challenges to incorporating electric vehicle infrastructure include:

No challenges related to installing EV charging infrastructure: These market actors said that installing EV charging stations is becoming standard practice and a growing number of clients are requesting them. Two said that local codes or policies in their area require installation of EV chargers.

Accounting for increased electric load: The added electrical load from charging stations needs to be taken into account when considering the electric load of the building and the amount of renewables needed to offset that load. For small buildings, the charging infrastructure load can be a significant amount, and for buildings with many EV-charging parking spaces, there can be a demand spike when all the EVs arrive and start charging. One market actor said that they exclude EV infrastructure from their ZNE projects because the EV charging load is difficult to predict and there are not reliable load assumptions to build into the modeling calculations.

High first cost: The cost of the chargers alone can reach up to $2,000 each and then the owner incurs other installation costs, such as adding a separate electrical branch. Adding this electrical branch can require trenching which is expensive and disruptive if the parking lot is already in use. Further, existing buildings may not have sufficient power available for the charger, requiring an expensive infrastructure upgrade.

Questions around implementing the charging service: Building owners had unanswered questions about how to implement the charging service. For example, should they just charge for the parking space, charge for the energy to charge the car, or both? One building owner who had installed charging stations told an interviewee they will not add additional infrastructure because occupants were not being courteous by moving their vehicles after they finished charging. Others had questions about their frequency of use, fearing there was not enough demand to justify their installation.

Space constraints: A few market actors mentioned that sometimes programs or policies require a minimum number of parking spaces to provide EV charging. This can be a challenge for sites that do not have a lot of parking spaces.

Battery Storage

The two main challenges to incorporating batteries were their high first cost and a lack of space for them (Figure 81).

Figure 81. Challenges to Incorporating Battery Charging

Challenge	Number of Respondents (n=14) *
High first cost	10
Lack of space for battery	4
Unattractive rate structures	3

Challenges to incorporating batteries include:

High first cost: Market actors said there has been some interest in including batteries on ZNE and ultra-efficient building projects, but they have not been able to overcome the first cost barrier. Two market actors added that the high first cost and lack of utility incentives for commercial storage makes it difficult to convince a building owner to include it.

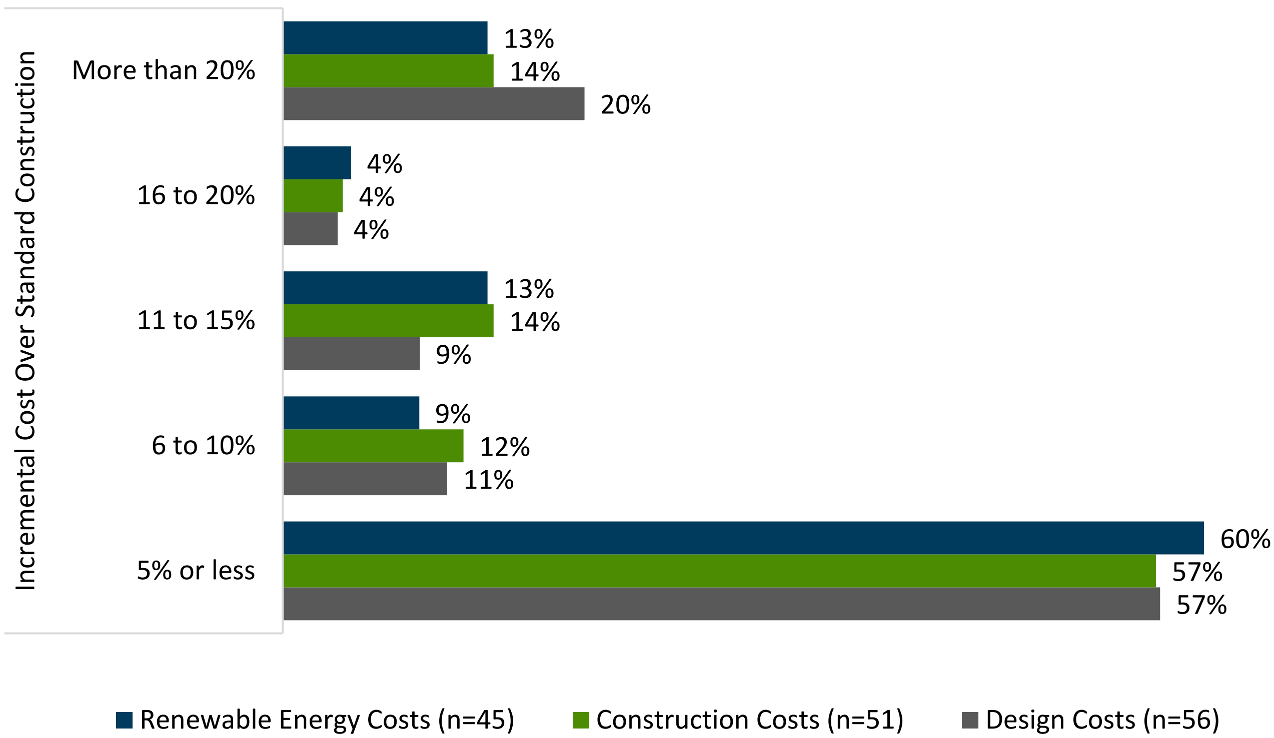
Lack of space: Market actors mentioned challenges related to locating the battery on-site, particularly for retrofits. One market actor mentioned that the electrical room needs to be three times as large to account for the battery infrastructure. Market actors said that batteries are often placed outside and that if they were to be placed inside, it must be in conditioned space since they generate heat.

Unattractive rate structures: Market actors mentioned that the rate structures in California make batteries more attractive for selling energy to the grid than for increasing the amount of renewable energy used at the building. They said that the building's energy peak and the grid's peak are at different times and therefore, the battery is discharged when the grid peaks and when the building is empty. Market actors said the Utilities are not yet offering attractive rate structures or the right incentives for commercial battery storage.

13.2.8 Cost of ZNE

Most respondents estimated that achieving ZNE or ultra-efficient added five percent or less to the overall project cost compared to standard construction and their estimates were very similar across the various elements of building ZNE and ultra-efficient projects. Of those able to provide an estimate of the incremental costs of building ZNE and ultra-efficient, about three-fifths of respondents reported that the incremental cost of achieving ZNE or ultra-efficient was five percent or less for design, construction, and renewable energy. Similar numbers of respondents provided estimates of the incremental cost for each category – that is respondents did not report that any one element added a larger incremental cost than the others, on average (Figure 82). Responses did not vary significantly by whether the respondent had ZNE, ultra-efficient, or above code building experience. Almost one-third to almost one-half of respondents could not provide answers to these cost questions, and they are not included in Figure 82.

Figure 82. Incremental Cost of ZNE



Incremental Design Costs

Respondents reported the incremental design cost could be as little as zero to as much as 75%. On the low-end of the estimates, respondents suggested that ZNE has been around long enough that designers should be able to design a ZNE building for a similar amount to designing a standard building. As one respondent stated, ZNE "shouldn't cost more if done right." On the other end of the estimates, a respondent who estimated design can cost 20% more for ZNE implied that the back and forth communication between building stakeholders on ZNE construction adds to the design cost. Another stated that ZNE requires the designers to investigate many more options for the building which takes time and money. And, finally, respondents reported that additional design costs come from the increased time it takes to do energy modeling beyond what Title 24 requires.

Incremental Construction Costs

Respondents report that incremental construction costs could be zero to as much as double what standard construction would cost. One of the respondents that estimated that ZNE construction can cost as much as 40% more than standard noted how important it was to find a general contractor that is knowledgeable and willing to achieve ZNE – "and you'll pay for that experience." Going with the low-bid contractor on a ZNE project will result in a poor-quality building according this respondent. A respondent that estimated ZNE construction cost no more than standard, suggested that experience matters – that is after a contractor has done a couple ZNE projects, they learned their lessons and can now do ZNE for a similar price to standard construction.

Incremental Renewable Energy Costs

Respondents reported that incremental renewable energy costs could add as little as zero percent – if they do a third-party photovoltaic array – to as much as 70% over standard construction. A respondent who estimated renewables add about 4% to a ZNE project over a standard project, noted that solar panels have markedly come down in cost "because everyone is doing" them. A respondent that stated solar arrays can add 50% to the cost of a building stated that are many things to consider when adding solar such as the need to add a new transformer to support the array. Considerations like this can add significant cost to construction.

Overall, respondents disagreed about how much more or less ZNE construction added or subtracted to the operations and maintenance of the building compared to standard construction. Results included:

- Forty-four respondents could estimate how much more or less it costs to operate and maintain a ZNE or ultra-efficient building compared to a comparable current standard practice building.
- Seventeen respondents estimated that **operating and maintaining a ZNE or ultra-efficient building would cost 14% more, on average,** than a standard building. This additional cost results from the need to find qualified staff to run an ultra-efficient building. For example, one respondent indicated that additional training of existing staff is necessary, and it can be difficult to find new staff that can operate a ZNE or ultra-efficient building. Another respondent indicated that operations staff need to pay more attention to operating, tuning, commissioning, retro-commissioning, and "staying on top of it" than a standard building requires.
- Fourteen respondents estimated that a ZNE or **ultra-efficient building would reduce operations and maintenance costs by 31%, on average**. These respondents suggested that the energy savings would be more than enough to offset any costs related to operator and occupant training necessary for a ZNE or ultra-efficient building.
- Thirteen respondents reported **no difference in operations and maintenance costs**. These respondents suggested that the energy savings offset any additional staff costs. One respondent also noted that ZNE and ultra-efficient buildings require very little maintenance with some systems – for example lighting – but require more maintenance than a standard building with other systems – for example sophisticated HVAC systems.

Tax credits, on-bill financing, and revolving green loans make it easier to afford ZNE and ultra-efficient commercial buildings, yet there are still barriers in traditional financing for existing buildings.[45] Four market actors mentioned using Prop39 funds to support their public schools' projects. One market actor, whose company constructs high-rise multifamily buildings for low-income families, takes advantage of federal and state tax credits, administered by the California Tax Credit Allocation Committee. Applicants for the credits earn points for pursuing green building standards and exceeding Title 24 by at least 7% (TCAC 2016).

Low- to no-interest on-bill financing is another attractive way to finance energy efficiency upgrades for ZNE and ultra-efficient commercial building projects. The IOUs offer 0% interest, on-bill financing to commercial and institutional customers, including small businesses. One market actor reported financing their retrofit project with 0% interest on-bill financing through SDG&E.

Another market actor said that it would be advantageous if "green bonds" -- a form of on-bill financing -- were available to commercial entities in the United States, as they are in some European countries. The green bonds pay for the cost of an energy efficiency or clean energy measure, and then the property owner pays for the cost of it via their bill. As the entity who provided the loan gets repaid, they put the money back into the fund, so it is available for another project. Some green bond programs exist in California, but are used for local government buildings, as they have been established between local governments and their respective IOU. They are called "revolving energy loan funds" and are part of California's Long-Term Energy Efficiency Strategic Plan for local governments (CPUC 2008; ICF International 2013; Research Into Action 2016).

Two market actors mentioned challenges they experienced obtaining financing for ZNE and ultra-efficient buildings. One described the challenges for an office renovation project with a "small square foot" that was seeking financing:

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[45] The interview guide did not explicitly ask about financing options for ZNE and ultra-efficient buildings, yet eight market actors made unsolicited comments about financing, which forms the basis of this write-up.

"One of the bank's challenges was they had a hard time finding comparable projects to gauge the cost per square foot and a valuation of what it would cost to do the project, because there aren't many of that type. From a financing perspective, I think it is still challenging for owners to get financing for ZNE projects because their cost basis is different than what a traditional Class A office building is. As there's more comparables, it'll be easier for banks to get their head around it."

The other market actor reported, "Financing an existing building is difficult too. Why should a bank finance to something over code?" As with other barriers to ZNE and ultra-efficient buildings, educating lenders may be a way to reduce the barrier.

13.3 Reach Code Interview Results

13.3.1 Methodology and Reach Code Overview

The TRC team conducted interviews of planning and code officials to assess progress and strategies jurisdictions are undertaking to exceed commercial energy code requirements, and identify challenges and successes in developing, implementing, and enforcing these reach codes. The interviews also discussed reach code scope development and the objectives that informed the scopes.

To identify the jurisdictions and contacts, the TRC team reviewed the approved and pending reach codes on the CEC's website and the supporting documents[46]. Figure 83 provides an overview of current commercial reach codes in California. Seven jurisdictions have residential-only reach codes (not shown in the figure), three have nonresidential-only reach codes, and eleven have reach codes for both residential and commercial projects. From reach code development documents from the CEC's website, the TRC team identified staff associated with the reach codes and supporting analyses and contacted them for the interviews. Out of the seventeen approved reach codes and one pending, the TRC team interviewed staff from six cities and counties. In addition, the TRC team interviewed one consultant who has supported reach code development and analysis for over twenty (20) jurisdictions and multiple code cycles. Figure 83 also shows which jurisdictions have staff members that TRC interviewed as part of this study.

While commercial activity was the focus of the interviews, some of the jurisdictions have mostly residential construction activity and shared comments from that perspective. The TRC team found some commonalities between the commercial and residential projects in these regions and confirmed that the results reported here also applied to commercial buildings.

[46] https://www.energy.ca.gov/title24/2016standards/ordinances/

Figure 83. Adoption Status of T24-2016 Reach Codes

Jurisdiction	Status: Pending or Approved	Scope: Nonres (NR) or Both NR and Res	Type: EE, PV, or both	Summary	Interview Y/N
Brisbane	Approved	MF and NR offices	Both or EE only	Cool roof on New Construction (NC) Multifamily (MF) and NR with solar reflectance ≥ 0.70 and Thermal Emittance (TE) ≥ 0.85	No
Chula Vista	Approved	NR	EE	Outdoor Ltg - lower LPA reqs for NR NC and retrofits with 50% replacement	No
Del Mar	Approved	NR (NC, remodels >$150k)	EE	NR w/ indoor Ltg or mechanical (not both) ≤95% of T24-2016 energy budget	No
				NR w/ indoor ltg and mechanical ≤90% of T24-2016	
Fremont	Approved	NR	Both	Outdoor ltg - lower lighting power allowance (LPA) for NR NC and retrofits with 50% replacement	Yes
Marin County	Approved	Both NC	EE	NR and MF high-rise - 10% more efficient than T24-2016 or all electric	Yes
				Single-family (SF) <4,000 sf - 15% more efficient than T24-2016 or 20% w/ PV	
				SF ≥ 4,000 sf - 35% more efficient or 20% w/ PV (2.5 kw) or Passive House	
				MF low-rise - 10% more eff or 15% w/ PV than T24-2016 or all electric	
Palo Alto	Approved	Both NC	Both	SF: 10% more eff than T24-2016 w/ PV, 20% w/0 PV	Yes
				MF: 10% more eff w/ PV, 12% w/o PV	
				NR: 10% more eff w/o PV OR 0% with ≥5kW PV	
San Francisco	Approved	Both	PV	NR - exemption for bldgs with <150 sf of solar access	Yes
San Mateo	Approved	MF and NR offices	Both	Cool roof on NC MF and NR with SR ≥ 0.70 and TE ≥ 0.85	No
				MF NC 3-16 units must have ≥2 kW PV; >16 units have ≥3 kW	
				NR NC <10,000 sf must have ≥ 3kW PV; ≥10,000 sf must have ≥5 kW	
Santa Monica	Approved	Both NC	Both	Res - 15% improvement above T24-2016 and achieve Energy Design Rating of Zero	Yes
				NR - 10% improvement over T24-2016	
Los Angeles	Pending	Both	EE	NR (high-rise res, hotel/motel) - TE >=0.75, and other requirements dependent on slope Res: Cool Roof: TE ≥ 0.85, other requirements depends on roof slope	No

In addition to reach codes, some green building ordinances include requirements that affect energy. In particular, LEED mandates – which affects energy use – are typically included in a green building ordinance rather than an energy efficiency reach code. The TRC team used a web search to identify cities that require commercial projects to meet LEED standards. Since the search for green building ordinances is outside of the original scope to investigate reach codes, this effort was not exhaustive, and there may be additional jurisdictions with LEED-related ordinances not shown here. As shown in Figure 84, in general, cities require projects to achieve Certified or Silver ratings, and some cities make registration voluntary. In all cases the checklists must be submitted during plan review.

Figure 84. Jurisdictions with LEED Certification Requirements

City	Muni-ony?	NC or RET	Level	Requirement	Stipulation
Los Angeles	No	Both	Certified	Projects > 50,000 sf	Actual certification is voluntary
San Francisco	No	Both	Certified, Silver, Gold	All muni projects must be Silver NC and projects >25,0000 sf must be Gold Projects 5,000-25,000 sf must be Certified	Projects pursuing Gold receive priority permit review
San Jose	No	NC	Certified, Silver	Projects >25,000 must be Silver Others must be Certified	Projects must pay a deposit to ensure they will meet LEED standard
San Diego	Yes	Both	Silver	Projects > 5,000 sf	
Brisbane	No	Both	Silver	Non-muni projects > 10,000 sf must be Silver Muni projects >5,000 sf must be Silver	Actual certification is voluntary
Oakland	Yes	Both	Silver	For projects valued >=$ 3 million	
Calabasas	No	NC	Certified, Silver	Projects >5,000 sf must be Silver Others must be Certified	
West Hollywood	Yes	NC	Certified	All new public buildings must be Certified	Those participating in LEED are exempt from city's own point system

This study did not investigate jurisdictions that required only solar PV because renewables offset rather than reduce energy consumption. But jurisdictions that have adopted a requirement for solar PV for any new construction commercial building include: San Francisco, Santa Monica, Culver City, and Sebastopol.

The interviews covered the following topics:

- Challenges with reach code adoption
- Scope development and measures included and considered for the reach code
- Publicizing reach code requirements
- Future reach codes

13.3.2 Challenges with Reach Code Adoption

The building and planning officials interviewed here were involved in reach code development and adoption but not enforcement, so could not comment on enforcement of reach codes.

Many interviewees commented that they work in progressive, environmentally-concerned communities, so typically there is not much resistance from the community to reach codes. Sometimes builders or local professionals will voice concerns. The smaller jurisdictions cited fewer issues due to lower building activity. The reach code consultant also observed that if the jurisdiction’s council supports the reach code, that endorsement enables the necessary analyses for the reach code. Furthermore, analysis can start sooner, which allows for reach code adoption and enforcement within the respective energy code cycle.

In addition, all of the staff interviewed were from jurisdictions that had existing reach codes, meaning the reach codes active now (with requirements above Title 24-2016) are revisions or updates to reach codes adopted during a previous code cycle (e.g., with requirements above Title 24-2013) with much of the same structure. Interviewees reported that most of the effort to gain approval occurred in the first iteration of the reach code, and this was when the reach code development team faced more questions and opposition. Consequently, jurisdictions that are not affluent or progressive, or that are adopting new reach codes may face stiffer opposition from local stakeholders than what interviewees reported here.

A few jurisdictions identified resource availability as a challenge to reach code development, and that sharing analyses across nearby jurisdictions can help overcome this issue. On the reach code development side, sharing or co-leveraging analyses with other jurisdictions, especially for cost-effectiveness analysis, significantly reduces staff burden and accelerates reach code development. Moreover, jurisdictions can conduct a more robust analysis with deeper resources. For the past code cycle, some of the jurisdictions had shared analyses. Those whose shared were pleased with the outcome, and the others decided they would prefer to contribute to the shared analyses. Usually, the larger entity (county or developing city) leads the analysis. One interviewee from a small jurisdiction reported her jurisdiction would not have a reach code without the analysis from a larger nearby jurisdiction.

Several interviewees identified challenges with project teams meeting reach code requirements, and that compliance tools – such as the CalGreen checklist can be helpful. Interviewees from three Bay Area jurisdictions reported that a publicly available checklist – such as the CalGreen checklist - facilitated adoption and should help facilitate compliance. Interviewees reported that their reach codes refer to CalGreen checklists because they are understood by professionals in their jurisdictions and elsewhere, which simplifies implementation and compliance. Providing the compliance tools before the reach code takes effect is ideal. One interviewee mentioned the burden of creating separate models or reports simply for compliance, especially if projects are participating in a rebate or incentive program. The reach code consultant also described that not all tools or software address all measures. For example, modelers cannot include drainwater heat recovery directly in compliance software, so the jurisdiction needed to identify a workaround for including it in the reach code. One jurisdiction reported that projects need additional resources to meet reach codes and leverage utility rebate and incentive programs to do so, but that the stop-and-start nature of programs negatively affect the projects.

13.3.3 Reach Code Scope

All interviewees reported that cost effectiveness influenced their reach code scope. As part of updating requirements from the last code cycle, the jurisdictions evaluated cost effectiveness and updated the energy efficiency reduction goals and revisited requirements to ensure they are still aggressive yet attainable. Some jurisdictions require that buildings exceed Title 24 requirements by a certain percentage; some interviewees from these jurisdictions reported that the greater stringency in Title 24-2016 meant that the reach code did not change much. In fact, for reach codes that required a minimum percent better than Title 24 requirements, the specific energy reduction requirements were lowered in a few cases. No one said that their jurisdiction increased the minimum percent reduction (relative to Title 24) compared to the previous reach code.

To meet cost effectiveness requirements, the measures required in reach codes vary by jurisdiction because measures yield different energy savings depending on climate zone and building types. One jurisdiction with multiple climate zones reported difficulty defining aspects of the reach code. The terrain of that territory also precluded adopting a PV ordinance. Another Bay Area jurisdiction contended that cost effectiveness is an important tenet, but it constrains design. Consequently, that jurisdiction evaluates only prescriptive measures instead of building performance. A small jurisdiction found commercial building requirements were not cost effective, so only single family and low-rise multifamily buildings have a reach code. Another interviewee reported his jurisdiction categorized all multifamily buildings as commercial to bring them into the scope of the reach code.

As shown in Figure 83, many jurisdictions limit the scopes of their reach codes to new construction buildings, and none of the jurisdictions interviewed have an active reach code for retrofits. **Interviewees reported that that reach code scopes excluded retrofits because retrofit requirements were not cost effective.** The consultant that supports jurisdictions with development of reach codes agreed. One Bay Area jurisdiction commented that benchmarking makes more sense for retrofits because many are performing limited scopes of work (rather than a gut rehabilitation), and believes that benchmarking, a site audit, and commissioning could lead to better operation.

A few jurisdictions added PV or EV-readiness requirements to their reach codes because the jurisdictions found these measures to be cost effective. Note that – due to cost reasons – the EV requirement is currently limited to EV-readiness for a determined number of parking spaces. As described above, all interviewees represented jurisdictions that were revising existing reach codes. Many of the jurisdictions targeting solar PV systems or EV chargers develop those reach code requirements independent of the existing reach code updated to prevent delayed approval of the revision, because the newer requirements for PV or EV attract greater scrutiny and discussion. One jurisdiction added outdoor lighting requirements, and this stemmed from the city wanting to upgrade all its municipal lighting.

13.3.4 Publicizing Reach Codes

The interviewees reported various processes for publicizing the reach code requirements. Common approaches included announcements in websites, emails, press releases, and newsletters; providing resources in the permit office; and providing online videos. Some jurisdictions also provide tool such as calculators. The jurisdictions provide an effective date that follows the adoption date (e.g. 60 days later) to provide time to publicize the reach code and provide these materials, engage with stakeholders, and partner with the building departments. One interviewee from Bay Area jurisdiction said that enthusiasm is not enough for success, and the team behind the reach code needs to make adoption easier.

13.3.5 Future Reach Codes

TRC asked interviewees about the next reach code cycles and what scope changes they are considering. Interviewees reported they would revise the existing reach codes based on cost-effectiveness but keep the structure the same as much as possible. One interviewee reported his jurisdiction will consider bringing retrofits into the scope and conduct cost-effectiveness analysis for retrofits but will not be limited to the results. This could mean that this particular jurisdiction will not have a formal reach code to enforce but will set recommendations or a voluntary code.

Half of interviewees stated they will seriously consider decarbonization when asked (in an open-ended question) what measures they may consider in the future. The reach code consultant echoed this movement, reporting decarbonization is a popular measure that jurisdictions are proposing for future reach codes. As described above, interviewees reported they will likely develop a carbon reduction requirement separately to avoid delaying adoption of the revised reach codes. Because jurisdictions have not begun development scope development, respondents could not describe specific decarbonization requirements, but reported they will consider electrification and fuel mix requirements. If proven cost-effective, interviewees reported their jurisdictions may set a requirement for a mixed fuel site with PV, or for EV and battery storage. The consultant reported that some cities are considering banning natural gas infrastructure in buildings to support decarbonization. A few interviewees reported that electrification is out-of-reach because it is too expensive or infeasible (e.g. multifamily retrofit). One Bay Area jurisdiction has already completed a cost analysis for electrification and will instead make it voluntary. This jurisdiction emphasized the need for public awareness, utility incentive programs, and education to illustrate alternatives to natural gas, especially for residential construction.

As noted above, several jurisdictions reported that they conserved resources when they shared reach code analyses (including cost-effectiveness analyses) across jurisdictions. **Most of the interviewees reported they are participating in the statewide cost-effectiveness study and are waiting for the results** before revising the reach codes for the next energy code cycle.

13.4 ZNE Market Size

13.4.1 Methodology for ZNE Building Market Size Analysis

Since 2010, New Buildings Institute has been tracking ZNE and ultra-efficient new construction and retrofit buildings in the NBI ZNE Building Tracker tool. This list of commercial buildings (including multifamily) has been gathered from multiple sources including from designers, owners, utility programs, private and public organizations, articles, e-news, research, and commercial real estate professionals. Owners and designers can also submit projects for inclusion in the list through a portal on the NBI website at https://newbuildings.org/project-registry/. In addition, each year NBI augments this list by issuing a formal call for projects through media releases, events, and direct communications with design teams and owners. The last public call for projects included in this research happened during the Fall of 2018.

During the annual update to the list, NBI collects information including building name, location, size, and type (e.g. school, office, multifamily, etc.). When the data is available, NBI will note when the project is new construction or a major retrofit, as well as predicted and measured energy consumption, on-site renewable energy production and net energy use.

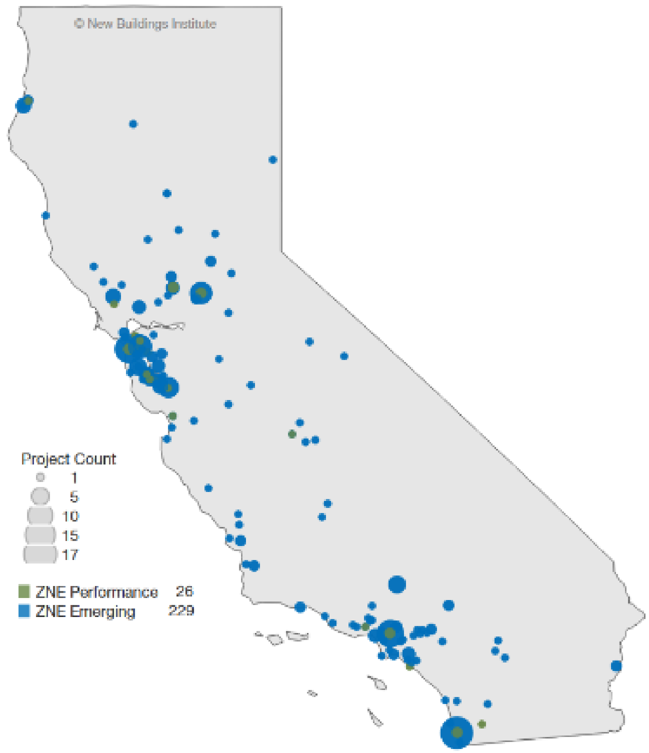
This ZNE Building Tracker tool has served as a robust set of data that demonstrates what is technically possible in ZNE and ultra-efficient buildings. This data set was the starting point for research on ZNE and ultra-efficient buildings that are included in this analysis.

Tracking of market progress over time is based on an analysis of California Zero Energy Watch Lists that NBI produced on behalf of the California Public Utilities Commission. Between May 2015 and the Fall of 2017, NBI published five updates to the California Watch List (available at https://newbuildings.org/resource/california-zne-watchlist-fall-2017/). The purpose of the watch lists is to support the awareness, acceptance, and adoption of ZNE goals and outcomes throughout California and the nation. This research provided an opportunity to update this list for publication in this report.

13.4.2 Size of the ZNE Market

California leads the country in the number of building projects that are ZNE performance and ZNE emerging. As of March 2019, California has 255 known commercial buildings that are either performance verified (26) as ZNE or emerging (229) toward that ZNE target. ZNE buildings are spread across California as seen in Figure 85.

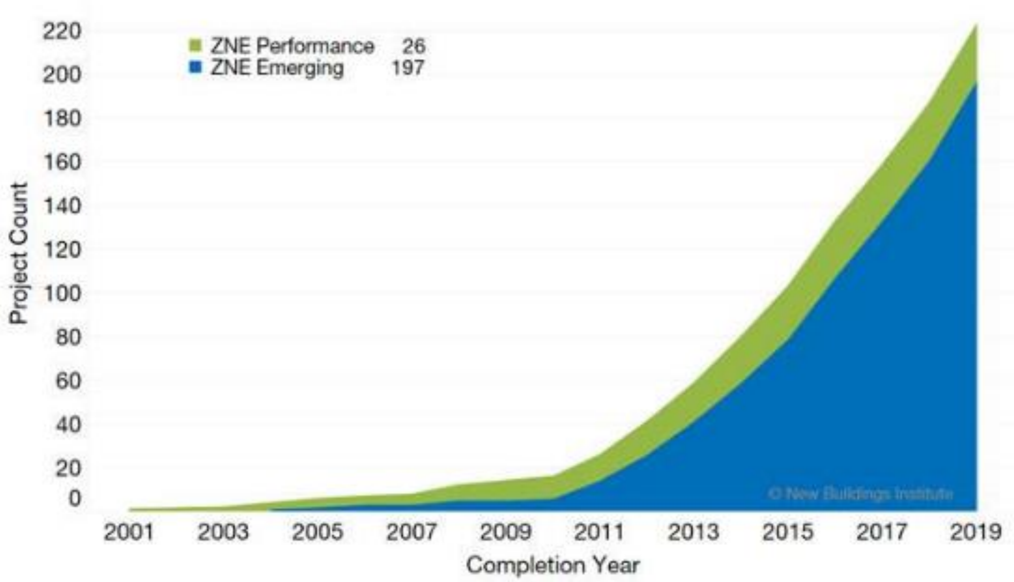
Figure 85. Map of ZNE Buildings in California



California has seen growth in ZNE projects, particularly since 2012 when year over year growth exceeded 50%. As small, early pilot demonstration projects proved the feasibility of ZNE, more diverse building types and larger projects joined the market. The pipeline of upcoming ZNE projects increases every month of new projects are targeting ZNE and existing buildings are retrofit with ZNE goals in mind.

Figure 86 shows total stock of ZNE (separated into ZNE Performance and ZNE Emerging) by year, as of March 2019. This figure excludes some ZNE projects as the completion year may be either unknown or under construction. These values are cumulative, so represents total stock – not new projects added each year.

Figure 86. Total Stock of ZNE buildings in California over Time



The TRC team also analyzed growth over time and found consistent trends across the major building types in California – offices, schools, multifamily (which includes both low-rise and high-rise), and other building types.

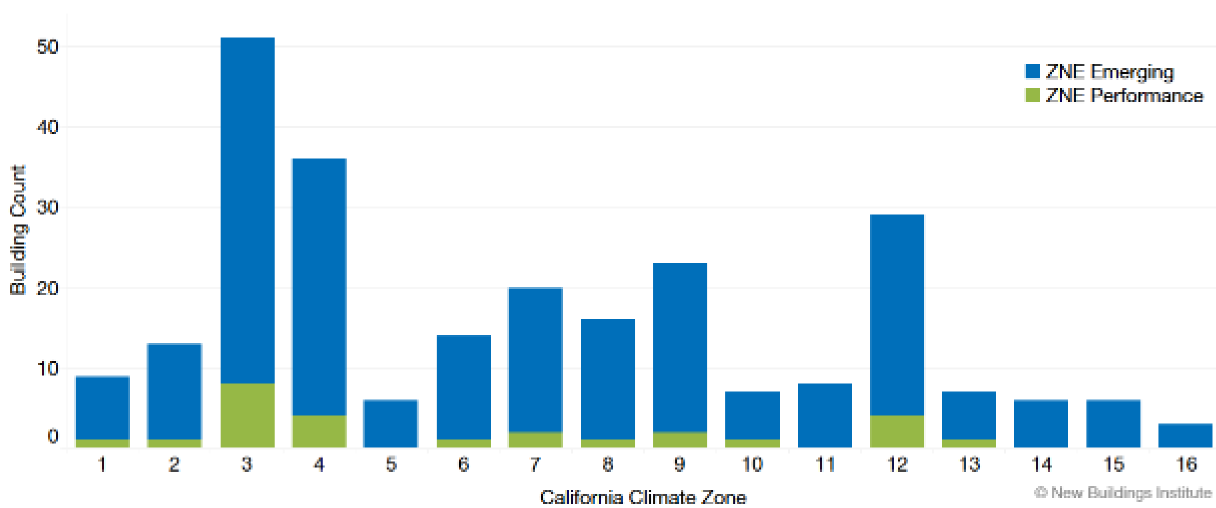
Figure 87. Climate zones in California

The Bay Area (CZ 3) and Los Angeles (CZ 8/9) have clusters of activity with 51 and 39 buildings, respectively. ZNE-performance verified buildings are located primarily in climate zones 3, 4 and 12, as seen in Figure 88. However, every California CZ has at least one ZNE performance or ZNE emerging project.

Figure 88. Count of ZNE Verified and Emerging Projects across California Climate Zones

Climate Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
ZNE Performance	1	1	8	4	0	1	2	1	2	1	0	4	1	0	0	0
ZNE Emerging	8	12	43	32	6	13	18	15	21	6	8	25	6	6	6	3

Figure 89. Graph of ZNE Performance Verified and Emerging Projects across California Climate Zones



Public buildings continue to display leadership, advancing the growing ZNE market. According to the list of ZNE performance verified and emerging buildings, the growth trends for both public and private sectors by number of ZNE performance verified and emerging buildings are very similar. The continued growth of the ZNE among both public and private owners is a positive indicator of diverse growth. Outside of California, the public and private sectors are also growing in unison.

Figure 90. Public and Private Sector ZNE Building Market Growth in California

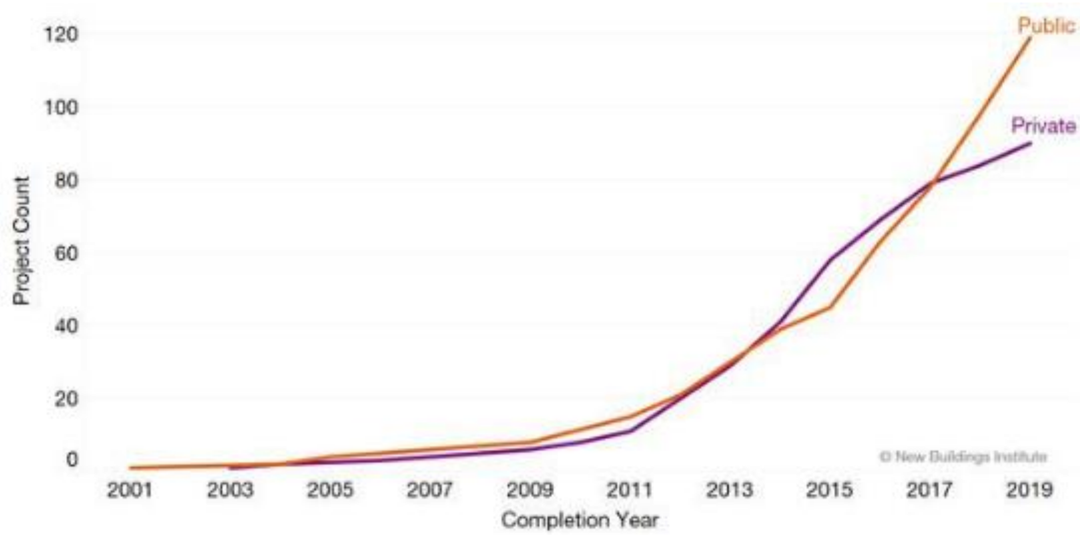


Figure 91 and Figure 92 show a categorization of ZNE building floor area by category type – privately vs. publicly owned, and by subcategory of private and public buildings. The public sector has more ZNE buildings than the private sector. When considering not just the number of buildings, but the square footage of the building stock, the public sector in California dominates. This is largely due to the heavy investment seen at the state level in ZNE. Many state departments are following through with California's climate action goals, including the California Lottery, correctional facilities, military installations, the Department of Motor Vehicles, and various other government offices.

Figure 91. Private versus Public Ownership of ZNE Buildings by Floor Area

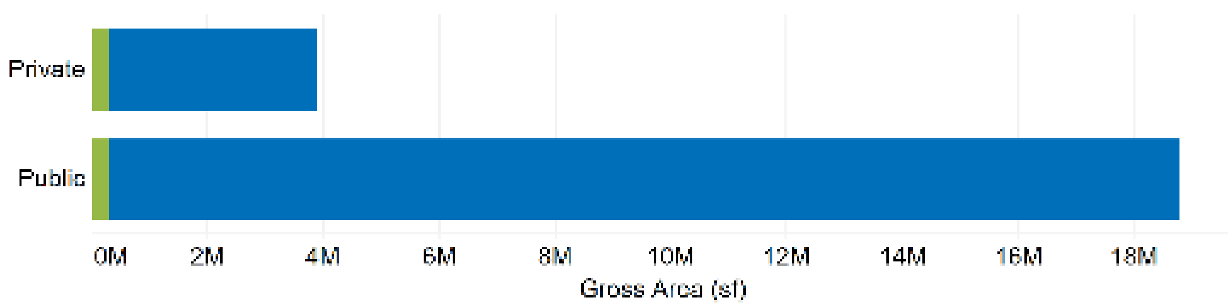
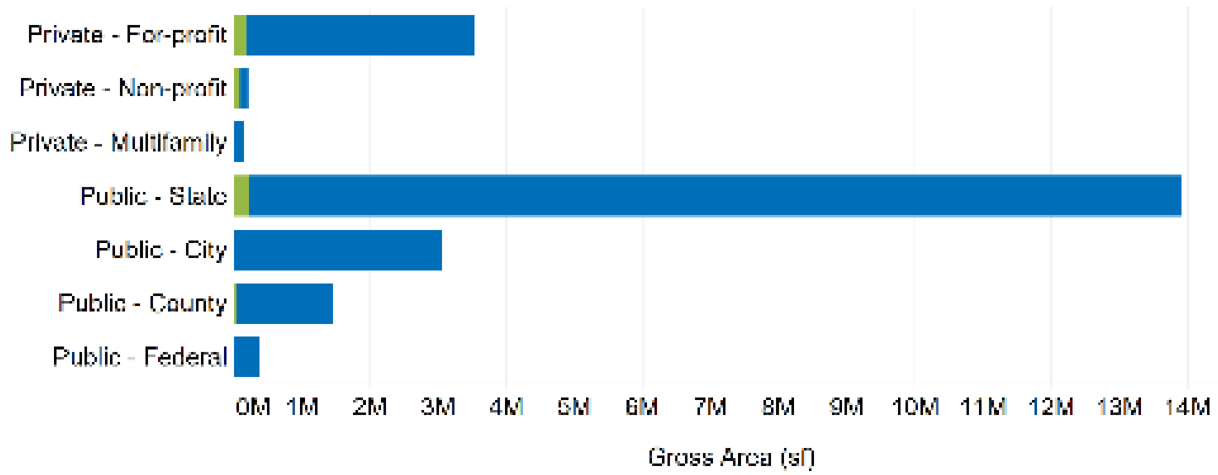
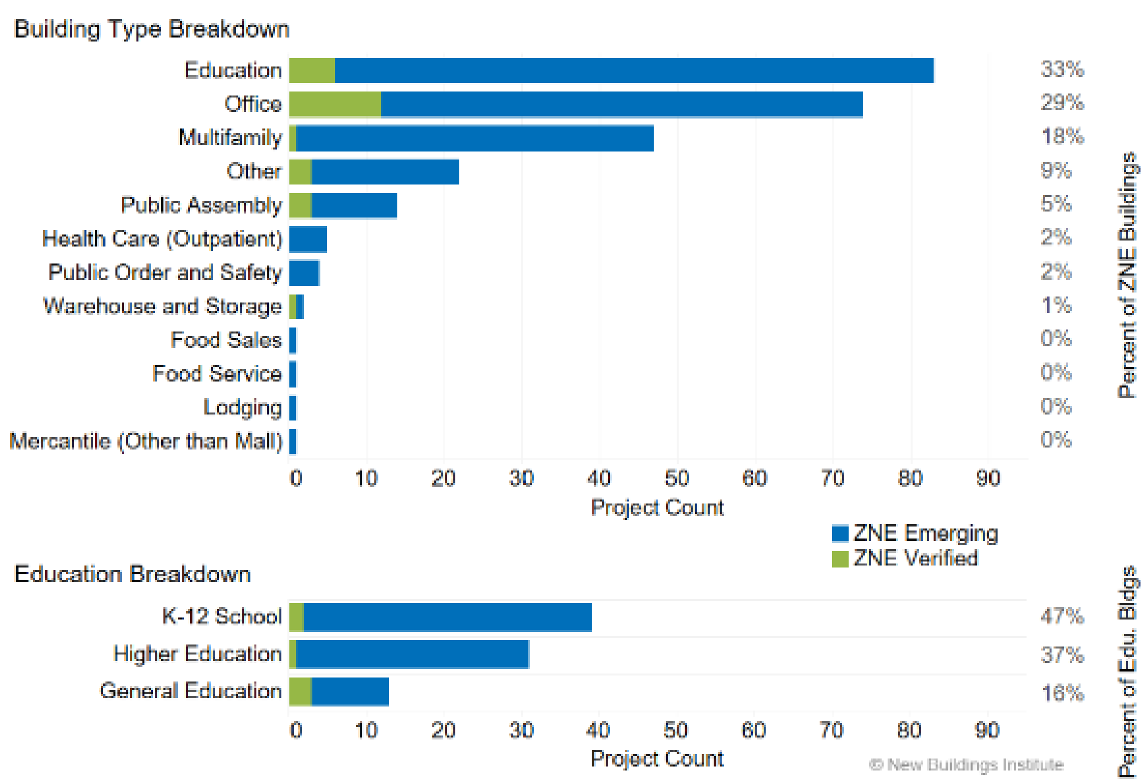


Figure 92. Ownership of Public and Private ZNE Buildings by Floor Area



The following figure includes a detailed breakdown of the various ZNE building types in California. Education, offices, and multifamily together account for 80% or four out of five ZNE buildings. One out of every three ZNE buildings is an educational facility. The education category is nearly half K-12 schools, which may be a result of strategic efforts to advance ZNE school retrofits through California's Proposition 39 ZNE Retrofit Pilot Project. Education is not only the largest category, but also the earliest adopter of ZNE in California.

Figure 93. ZNE Building Types in California (top), with Break-out for Education by Subcategory (bottom).



The CPUC's K-12 and Community College Retrofit Readiness Study explained how to accelerate market transformation to zero in the education sector (NBI and Madison Engineering 2017). Since that research has been published, more districts across the state are getting to zero with policies to establish district wide zero energy policies for schools (for example in Carlsbad, CA where the School Board reviewed and discussed a proposed District-wide Solar Energy, Battery Storage, and Sustainability projects (Carlsbad Unified School District, 2019). Policies like these will likely fuel continued increased market growth in ZNE in the education sector across California.

Project teams are pursuing ZNE in buildings of all sizes. The first ZNE buildings were primarily small: in the zero to 25,000 square foot (sf) range. As seen in Figure 94, beginning around 2012, larger buildings were joining the market and contributing to the rapid growth of the overall ZNE building stock in California. Now, ZNE buildings are distributed among various building sizes. However, note that most of the large buildings (over 50,000 sf) are ZNE Emerging, and most of the ZNE Performance projects are small (25,000 sf or less).

Figure 94. ZNE Market Growth by Building Size

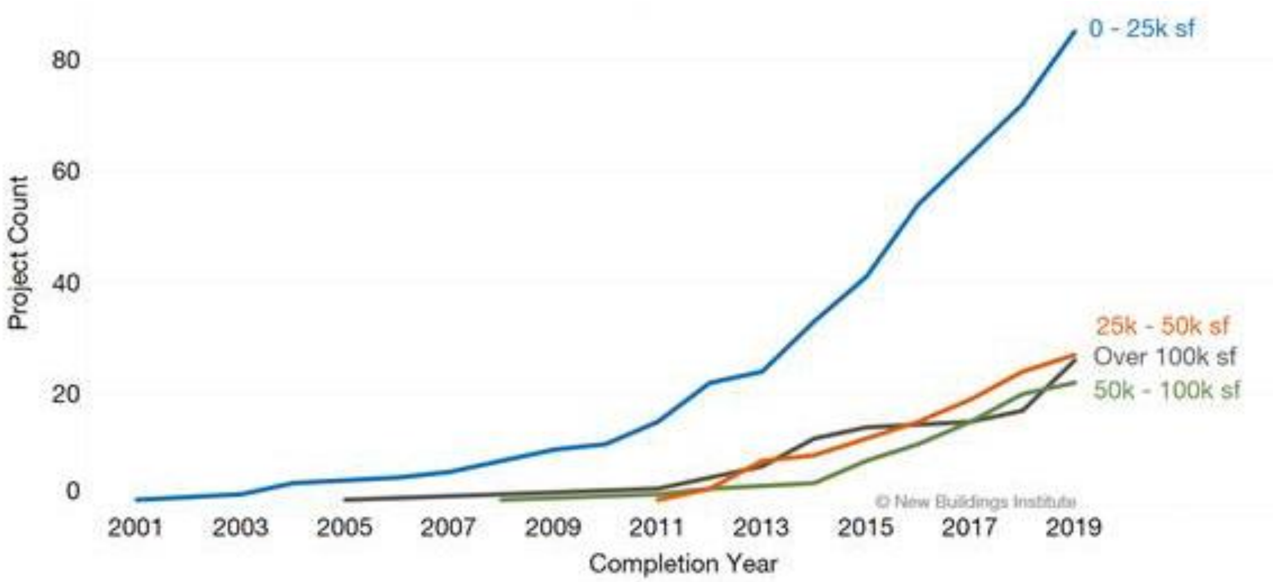
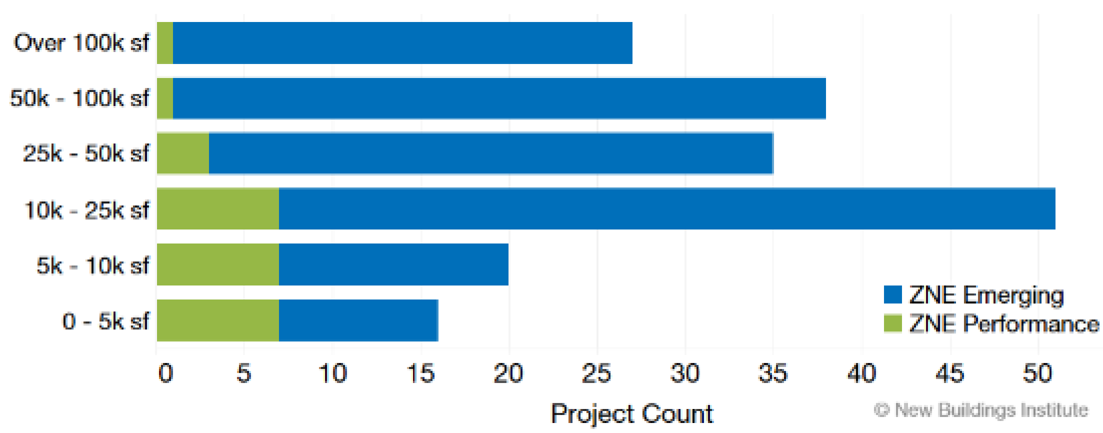
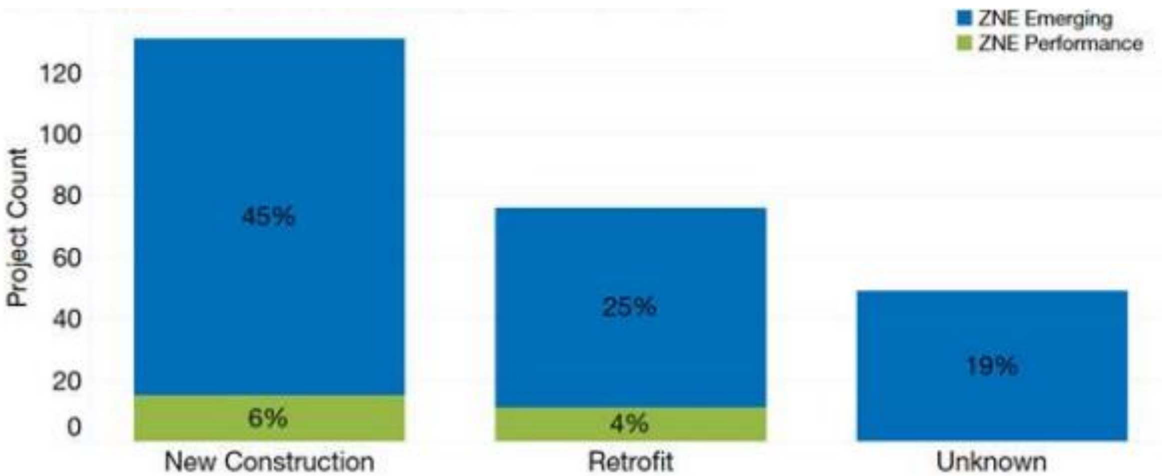


Figure 95. Distribution of ZNE Buildings by Size



Existing buildings are also achieving ZNE. **Over a quarter of California's emerging ZNE projects are existing buildings retrofitting to ZNE.** Retrofits typically include efficiency upgrades coupled with new solar installations. In most cases, moderately efficient buildings are able to upgrade their HVAC equipment and retro-commission other systems in order to reach the low-energy use needed to reach ZNE performance.

Figure 96. Existing Building Retrofit vs. New Construction Breakdown of ZNE Buildings in California



13.5 Relative size of ZNE, Ultra-efficient, and Beyond Code Buildings

13.5.1 Market Share of ZNE, Ultra-efficient, and Beyond Code Buildings for New Construction

The TRC team studied the relative market share of ZNE, ultra-efficient and beyond code buildings for new construction to understand where the market stands today in terms of ZNE buildings and what proportion of the market has the potential to become ZNE. Because the State does not track ZNE buildings, the team focused on ZNE buildings identified by NBI or through TRC's previous research, buildings with LEED certifications and buildings that participated in the Savings by Design (SBD) program to study beyond code buildings.

Data Sources

- ZNE and ultra-efficient building were obtained by the 2019 California Watchlist provided by NBI
- Buildings in the SBD program were provided by CA IOUs
- LEED certified buildings were downloaded from the USGBC projects website: https://www.usgbc.org/projects
- New construction square footage was found using CEC building stock forecasts (CEC 2015), which are based on the number of planned building permits

Methodology & Assumptions

To study the market share of projects, the TRC team compared the relative stock (square footage) of each project to the forecasted building stock provided by the CEC. The team did not look at building number as building number forecasts were not included as part of the building stock data. For the ZNE, ultra-efficient and beyond code buildings, the TRC team included any buildings that were new construction or major renovation.

Savings by Design Data

Some of the buildings in the SBD dataset did not have square footage (buildings in the PG&E and SDG&E regions). Therefore, in order to look at square footage, the team imputed the dataset with average square footage of each building type reported in the 2012 California Building Energy Consumption Survey (CBECS). Compared to the average square footage of buildings with square footage data in the SBD dataset, the values obtained from the CBECS were generally lower, making this a conservative estimate. In addition the SBD data varied by IOU in terms of whether projected energy savings was tracked (as a percent above Title 24), and whether total projected energy use was tracked.

The data from CBECS was based on buildings over the United States grouped geographically into 9 regions. To calculate average values, the team used buildings reported to be in the Pacific region comprised of Washington, Oregon, California, Hawaii, and Alaska. It was not possible to obtain more granular geographic region from the CBECS dataset. The study provided all the buildings with sampling weights, which could be used to compute the average square footage. Figure 97 shows the calculated average square footage values that were used to impute the SBD dataset.

Figure 97. Average Square Footage by Building Type of CBECS Data

Building Type	Average Square Footage (ft^2)
Education	11,359
Food Sales	12,574
Health Care	25,979
Lodging	36,593
Non-refrigerated Warehouse	16,511
Office	14,476
Restaurant	4,799
Retail	23,247
Refrigerated Warehouse	264,678
Warehouse (General)	17,049

LEED Dataset

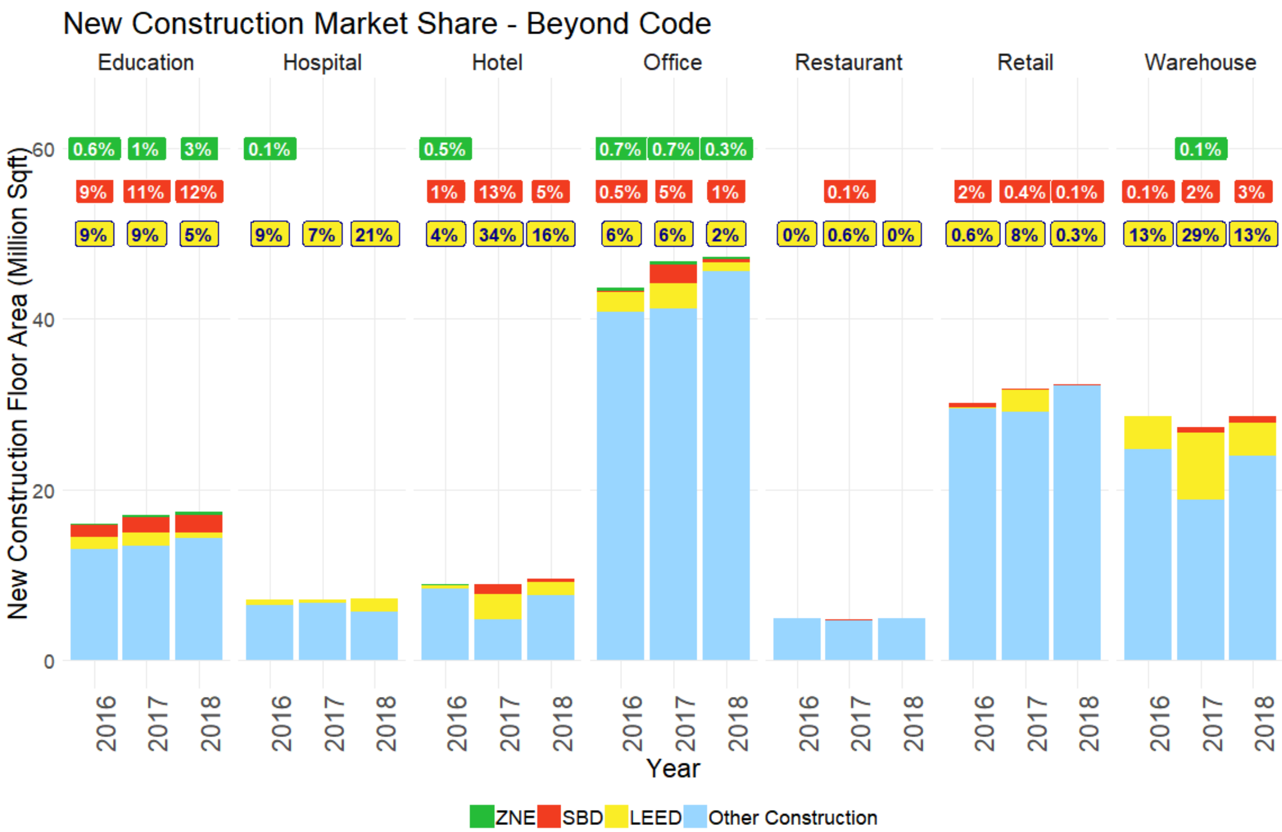
The team utilized several versions of LEED certifications in this analysis. All buildings labeled “New Construction” could be new construction or major renovations. Below we list LEED versions used in the analysis:

- LEED – New Construction 2.0
- LEED – New Construction 2.1
- LEED – New Construction 2.2
- LEED for Retail (New Construction) Pilot
- LEED v2007 (LEED for Schools)
- LEED – New Construction v2009 (also known as version 3)
- LEED – New Construction Retail v2009
- All LEED BD+C (Building Design & Construction – also known as version 4) except for BD+C CS (Core & Shell)

Building Types

The TRC team obtained building types from the California Watchlist, SBD dataset and LEED dataset. The team matched each building type to the building types in the CEC building forecast dataset by the first key term listed that corresponded to the building types in the CEC building forecast. This analysis did not consider building types that did not seem to fit any particular category provided in the CEC building forecast, such as those categorized as data centers or public assembly. Figure 98 shows the relative market shares of LEED certified and projects in SBD in five the most represented categories: Education, Hotel, Office, Retail and Warehouse.

Figure 98. New Construction Market Share for ZNE and Beyond Code Buildings



LEED and SBD buildings are taking a considerable share of the new construction market. LEED certified building penetrations seem especially high in the Hotel and Warehouse market, while SBD projects seem to have high penetration in the Education market. There is the least penetration in the Retail market.

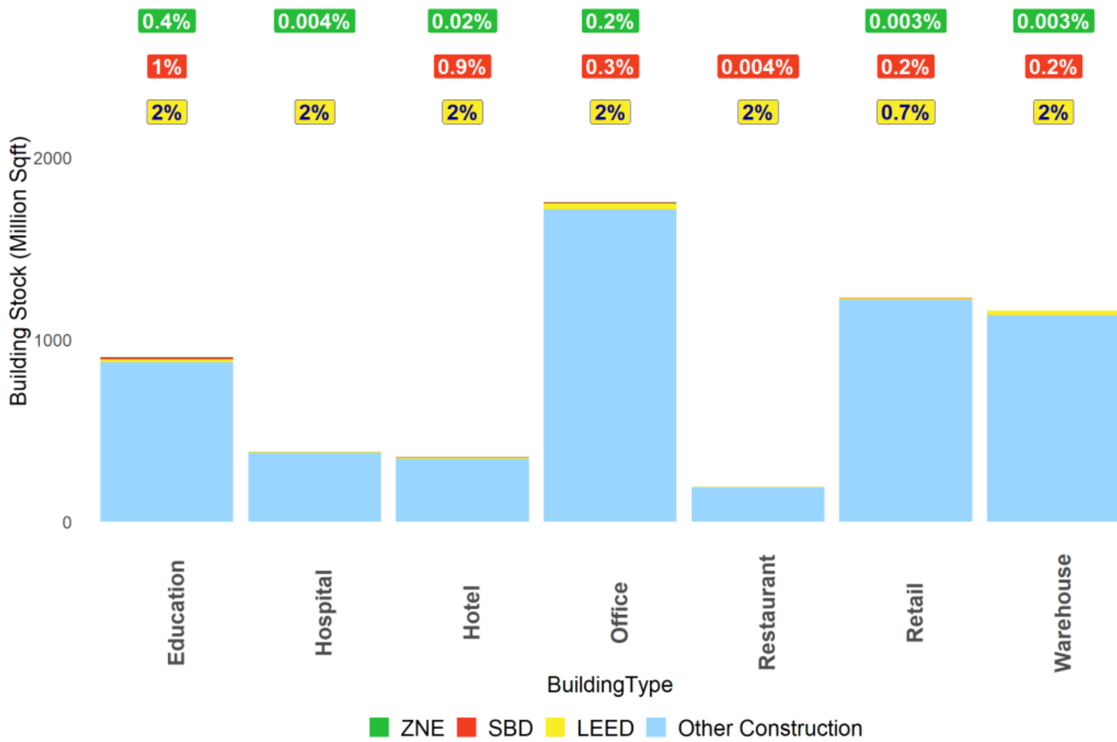
13.5.2 Market Share of ZNE, Ultra-efficient, and Beyond Code Buildings for Existing Stock

ZNE and Ultra-efficient building penetration is still in the innovators stage, making up about 0.1% of representative commercial building types. Beyond code building penetration is also relatively small, bordering between innovators and early adopters, across all building types except for office buildings, which are firmly in the early adopter stage.

This analysis used the same datasets as those in the new construction analysis. The team used total existing total building stock forecasts for 2019 from the CEC Floor Space Forecast.

In Figure 99, we graph market share of LEED and SBD buildings in comparison to total building stock. Penetration of ZNE and Ultra-efficient buildings were less than 1% for all building types, with the highest penetration being 0.4% education buildings.

Figure 99. Total Existing Building Market Share for ZNE and Beyond Code Buildings



13.5.3 Overlap of Building Labels

The team investigated overlapping certifications and program participation of buildings for the market share analysis. Most buildings seemed to participate in one certification or program. The majority of beyond code, ZNE and ultra-efficient buildings studied pursued one program or certification. However, about half of ZNE & Ultra-efficient buildings were also LEED certified.

Limitations

For the ZNE and ultra-efficient buildings, many projects in the TRC team's data set did not have addresses. Similarly, for the SBD projects, projects in the SDG&E region did not have addresses provided. The team could only match these projects between the data sets (SBD, LEED, ZNE and ultra-efficient buildings) by project names, which were sometimes very different across datasets. It is possible that some of these projects were the same but not matched in this analysis. For ZNE Performance and ZNE Emerging projects, the team also searched online to investigate overlaps with LEED certified buildings.

Methodology

In order to match project addresses and project names, the team used the Levenshtein distance metric, which is a measure of the minimum amount of insertions and deletions needed to transform one address or name into the other. For this analysis, the team marked any two buildings with addresses or names that had a Levenshtein distance between the two of less than 7, and then then sorted through all buildings manually to determine actual duplicates.

The team decided to use the Levenshtein distance because addresses had different abbreviations across datasets, so we could not find an exact match. The team also considered using a key term search, but this led to too many false matches within the dataset and it was beyond the scope of this project to manually check for duplications. A key term search omitting common terms and location names may be considered for a more stringent duplicate removal in the future. Overall, this analysis may have underestimated duplications among LEED, SBD, and the ZNE and ultra-efficient buildings data sets.

Figure 100. Number of Buildings Overlapping ZNE, SBD, and LEED

Building Type	Number of Buildings
LEED	1841
LEED & SBD	108
SBD	529
SBD & ZNE & Ultra-Efficient	11
ZNE & Ultra-Efficient	75
LEED & ZNE & Ultra-efficient	86
LEED & ZNE Emerging	66
LEED& ZNE Performance	20

Figure 101. Overlap of LEED, SBD and ZNE Buildings Used in Analysis

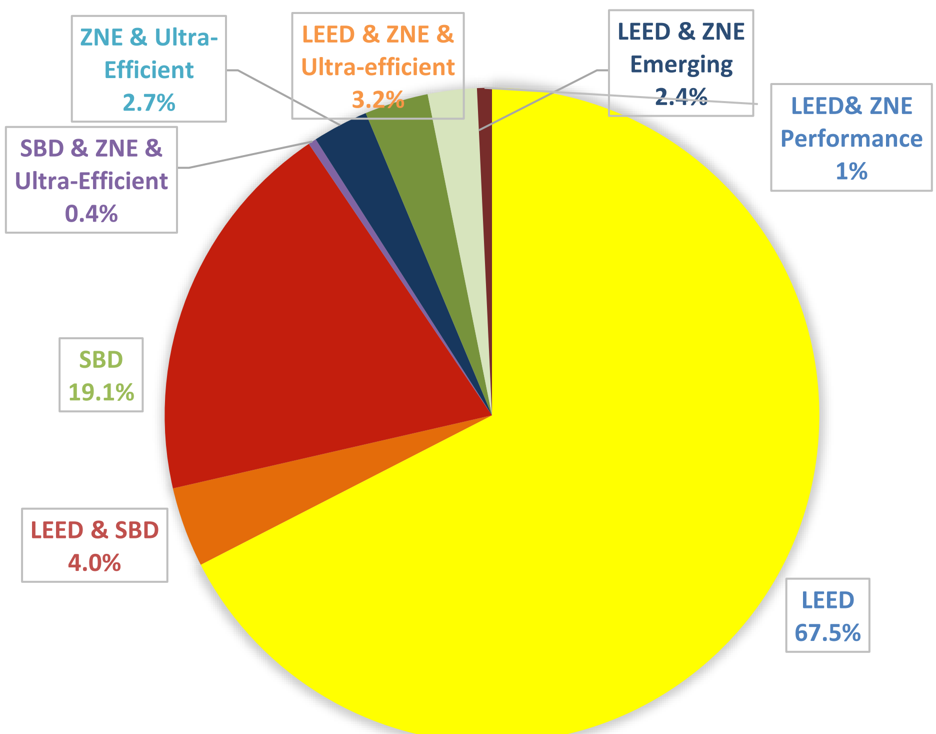


Figure 100 and Figure 101 show the overlaps of programs and certifications. About a fifth of SBD projects were also LEED certified projects, but the majority of LEED and SBD projects were either just in the SBD program or LEED certified. In contrast, many ZNE buildings, especially ZNE performance buildings, were also LEED certified. 20 out of 26 ZNE performance buildings were LEED certified buildings and 66 out of 230 ZNE emerging buildings were also LEED certified.

13.5.4 Penetration of Solar PV in ZNE, Ultra-efficient, Beyond Code, and Total Stock

The TRC team investigated penetration of Solar PV in the market to investigate potential for more PV and ZNE projects in the market.

Data Sources:

- The team used overall commercial market solar PV data from the California Distributed Generation Statistics website[47]. This analysis used the website's "Currently Interconnected Data Set". For LEED certified buildings, the team looked at whether a LEED building had points attributed to their EAc2 credit (name may vary between versions) which indicates whether or not the building utilized on-site or off-site renewables. The team estimated total commercial market number of buildings using the CEC building stock forecasts. CEC building stock forecasts only had square footage of building forecasts by building type. Therefore, the team estimated the number of buildings by dividing the square footage in the building forecasts with the average square footages calculated with the CBECS dataset.

Methodology:

The team analyzed PV penetration of the market over the last three years (between 2016 to 2018). For each type of building, the team found the number of new buildings with Solar PV that year, the number of buildings with Solar PV before the given year and compared this to the total number of buildings of that type in the market.

LEED buildings:

The downloadable dataset provided on the LEED website did not have EAc2 points readily available, although this data is made publicly available on their website. Therefore, the team web-scraped a sample of EAc2 points off of the website to produce estimates of PV penetration.

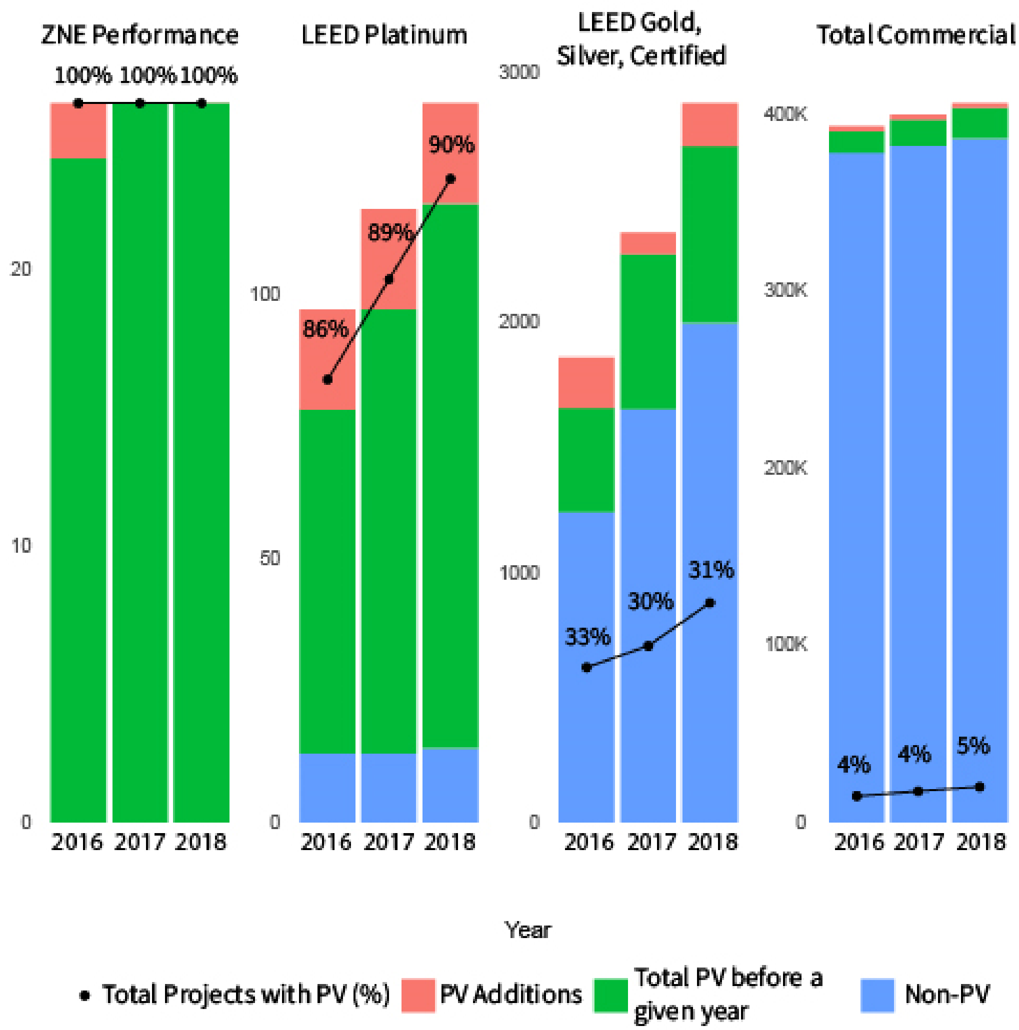
The team took 4 samples, where each sample was designed to achieve approximately 90% confidence 10% precision:

1. LEED Platinum sample – New Construction (2016-2018)
    a. 58 buildings total
    b. All were analyzed (no sampling)
2. LEED Gold, Silver and Certified sample – New Construction (2016-2018)
    a. 371 buildings total
    b. 65 building sampled
3. LEED Platinum sample – all years for New Construction, Core & Shell, Existing Building programs
    a. 78 buildings as of 2016
    b. 47 buildings sampled
4. LEED Gold, Silver and Certified sample – all years and all versions for New Construction, Core & Shell, Existing Building programs
    a. 1159 buildings as of 2016
    b. 53 buildings sampled

The team used the first two samples to get estimates of new Solar PV added to the market every year for the years of 2016 through 2018. The latter two samples were used to estimate the total number of LEED certified buildings with renewables as of the year 2016. For each year, the sample had standard error estimated at less than 10%, with the exception of LEED non-Platinum for 2018 (standard error was 14%).

[47] California Distributed Generation Statistics https://www.californiadgstats.ca.gov/charts/

Figure 102. Solar PV Penetration of ZNE, LEED and Overall Market



The analysis shows that in the overall market, the penetration of Solar PV in the commercial market has grown to about 5%. In addition, Solar PV is making a considerable penetration in LEED Certified buildings, especially buildings that were certified LEED Platinum. As expected, all ZNE projects have PV.

13.5.5 Measured vs Modeled EUI for ZNE Projects

The TRC team compared measured (i.e., measured) energy use with modeled energy use for ZNE and ultra-efficient projects for which we had both data sets. The following figure shows modeled and measured consumption – energy use (without energy generation from renewables such as PV. The black dashed line shows the ideal "Modeled = Measured Consumption" line. **Although there are many buildings that fall close to this line, there can be wide discrepancies between modeled and measured consumption EUI**. The blue line shows the linearly fitted line to the data with a significance level of at least .01 (high significance). However, it is hard to derive many conclusions from this fit. There are a few points that may be outliers which have high influence over this trend line. If the analysis had not included one of those buildings, the trend line could be quite different.

Figure 103. Measured vs. Modeled Consumption EUI for ZNE & Ultra-Efficient Buildings

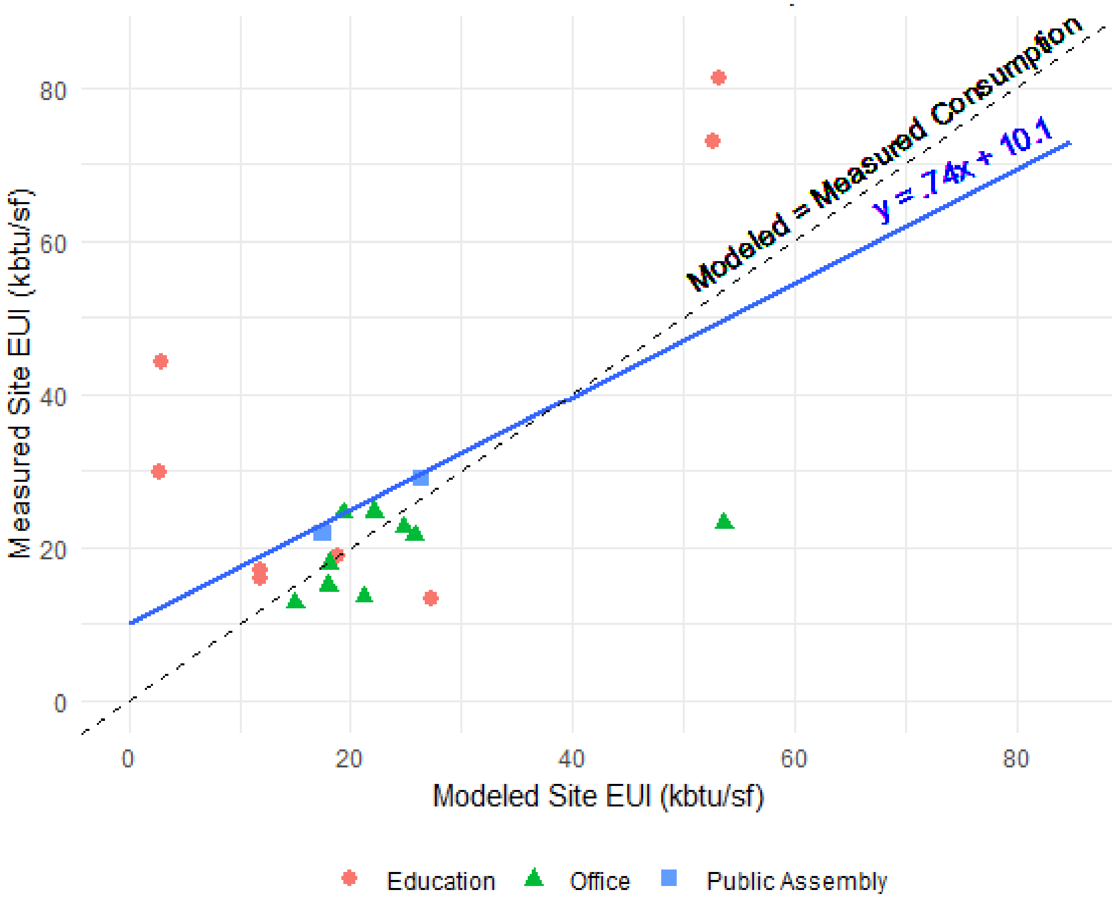


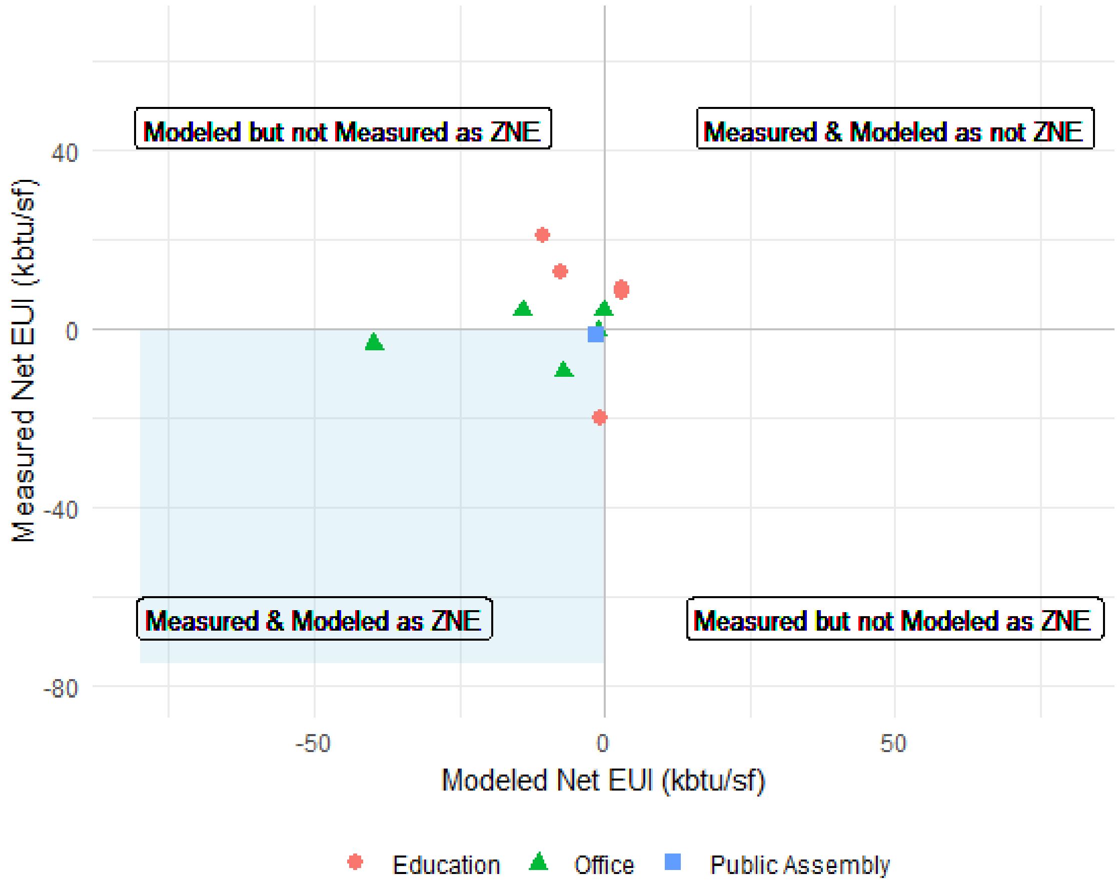
Figure 104 presents modeled versus measured site EUI for the buildings that were the most egregious outliers (i.e., had the furthest deviation from the trendline in Figure 103). The first two buildings had significantly lower modeled EUI compared with measured, while the remaining three had higher modeled than measured EUI.

Figure 104. Outlier Buildings for Measured vs. Modeled Comparison

Modeled Site EUI	Measured Site EUI
2.98	44.1
2.78	29.8
52.8	73.1
53.2	81.2
53.6	23.1

Figure 105 shows net measured versus net measured energy, which reflects both efficiency and on-site energy generation (mostly solar PV). **The TRC team found no correlation between measured and modeled net energy**, and therefore the figure does not include a trendline. **There was no clear trend in whether measured performance exceeded modeled performance**. Some projects were modeled as ZNE and perform as ZNE (bottom left quadrant); others were modeled similarly but did not perform as ZNE (top left quadrant).

Figure 105. Measured vs. Modeled Net EUI



13.5.6 Relative Energy Savings and PV Credits in CA LEED Projects

This analysis investigated the EUI of LEED Platinum buildings to understand if the majority of these projects could be considered ultra-efficient. This was done because there is a lack of sources that track ultra-efficient buildings. For example, there are no buildings identified in the NBI Watchlist as "ultra-low" for the past three years (2016-2018). If this analysis found that LEED Platinum projects have a much lower EUI than Title 24-2019 requirements, it would indicate that LEED Platinum projects could be a tracking source for ultra-efficient buildings.

Public LEED data did not have EUI or energy consumption data. However, the USGBC databases did provide how many EAc1 (Energy & Atmosphere Credit 1) points and EAc2 (Energy & Atmosphere Credit 2) points each project achieved. EAc1 points provided how much each building was modeled to perform better than the ASHRAE 90.1 standard (percentages and standard year dependent on version). EAc2 points provided how much on-site or off-site renewables each building was modeled to utilize.

For methodology, the team used the samples also used in the PV penetration analysis to obtain proportions of EAc1 and EAc2 credit points achieved. Figure 106 and Figure 107 provide box plots of the proportions of EAc1 and EAc2 credit points achieved and a comparison between buildings certified LEED Platinum and buildings certified LEED Gold, Silver or Certified.

Figure 106. Proportion of LEED EAc1 Points: 2016-2018 New Construction

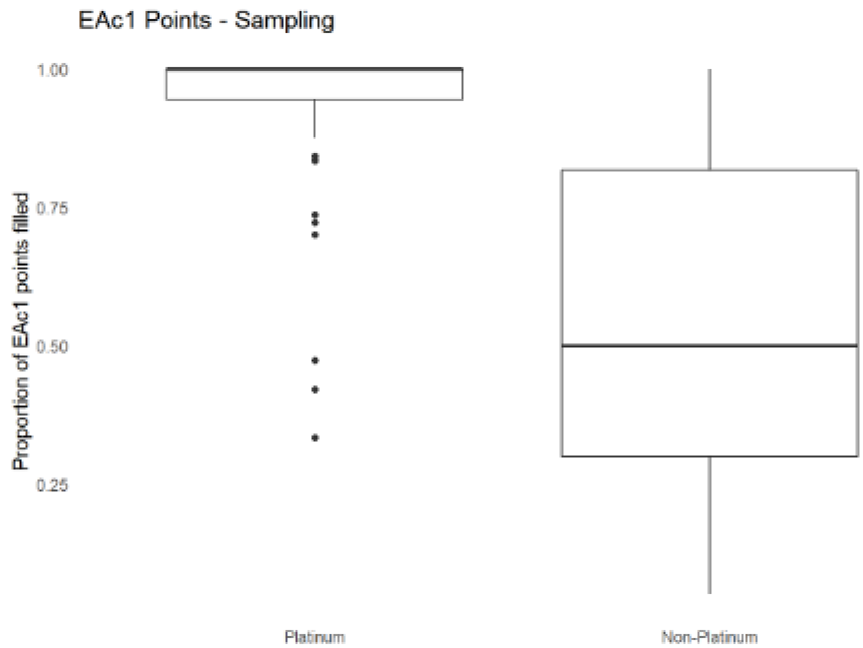


Figure 107. Proportion of LEED EAc2 Points: 2016-2018 New Construction

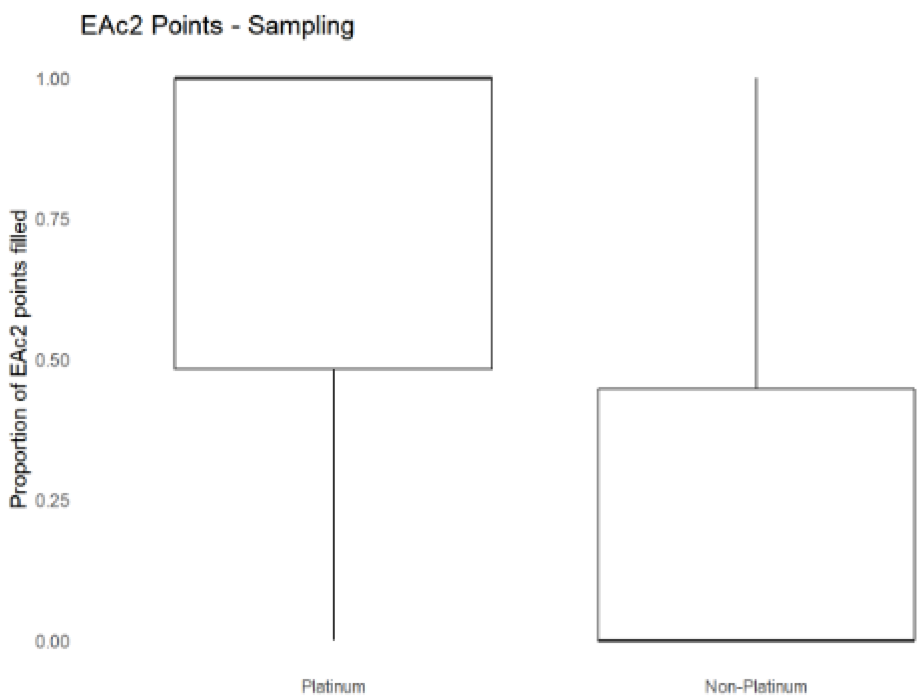
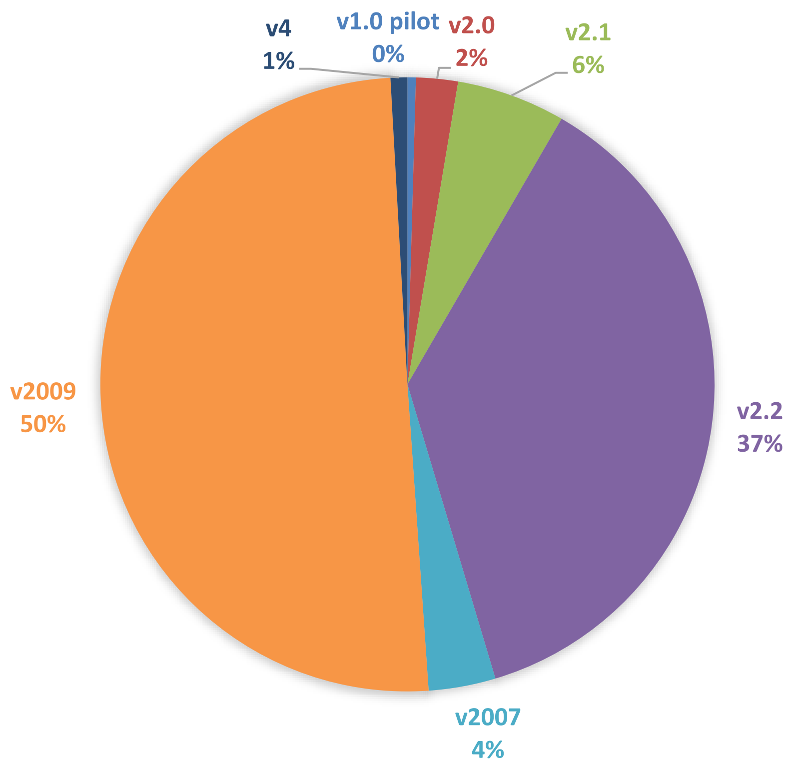


Figure 106 and Figure 107 show that for both EAc1 and EAc2 points, many buildings certified LEED Platinum are achieving maximum EAc1 and EAc2 points available, indicating high performance in terms of energy efficiency and utilizing renewables. On the other hand, the analysis shows that LEED Gold, Silver and Certified buildings are achieving far fewer credits in the energy modeling section (EAc1) utilizing less (or no) renewables (EAc2). This indicates there is a significant division in net modeled energy use between buildings certified to LEED Platinum vs. other LEED certifications. This is to be expected – but not a given – because LEED allows projects to earn credits in various categories beyond energy.

The next set of analysis considered how these energy credits might translate to EUI.

Figure 108 shows the breakdown of versions used by LEED Platinum new construction (certified 2016 to 2018) projects. As shown, most projects obtained certification under version 2009 or version 2.2.

Figure 108. LEED Platinum New Construction Certification Versions



To further analyze the performance of LEED Platinum buildings, the team estimated the EUI of LEED Platinum buildings. The TRC team needed to make several assumptions for this estimate, including estimating the EUI achieved by meeting the ASHRAE baseline (which varies by ASHRAE version. The team used modeled EUI values provided in RP 1651 (ASHRAE 2016) for ASHRAE versions 2004 and 2010 and values provided in an ASHRAE study by PNNL (PNNL 2011) for ASHRAE versions 2004 and 2007. Figure 109 shows the estimated EUI for the ASHRAE 90.1 baseline that were used in the LEED Platinum projects certified between 2016-2018. This analysis used the average of two sources if there were two sources for the ASHRAE baseline EUI.

Figure 109. Estimated ASHRAE Baseline EUI

		ASHRAE Baseline EUI													
LEED Version	**ASHRAE Version**	**Apartment High Rise**	**Hospital**	**Hotel Large**	**Hotel Small**	**Office Large**	**Office Medium**	**Office Small**	**Out Patient Health Care**	**Restaurant Sit Down**	**Retail Standalone**	**Retail Stripmall**	**School Primary**	**School Secondary**	**Warehouse**
v2.2	2004	48.9	155.65	158.4	76.4	43.1	49	40.3	162	396	73.6	77.8	72.4	64.65	25.75
v2007	2004	48.9	155.65	158.4	76.4	43.1	49	40.3	162	396	73.6	77.8	72.4	64.65	25.75
v2008	2007	-	152	148.2	71.2	38.9	44.5	38.6	155	378	64.7	69.2	66.6	59.1	25.2
v2009	2007	-	152	148.2	71.2	38.9	44.5	38.6	155	378	64.7	69.2	66.6	59.1	25.2
v4	2010	47.2	124.7	111.3	65.1	52.7	37.1	32.9	122	357	51.5	58.7	54.6	44.45	18.6

The next figure shows the estimated EUI for LEED Platinum buildings that achieved maximum energy efficiency performance – so the estimated EUI for a project that achieved 100% of EAc1 points under different version of LEED. Note that LEED EAc1 points are based on *cost* energy savings. **This analysis assumes that the cost energy savings used in the EAc1 credit is equal to energy savings.** This is an oversimplification, but since actual EUI is not available, the TRC team needed to make this assumption to complete analysis. As shown in Figure 110, **achieving all EAc1 points reduces modeled energy use by approximately 42-50% for new construction and 35-48% for major rehabilitation projects**.

Figure 110. LEED EAc1 Credit and Estimated EUI

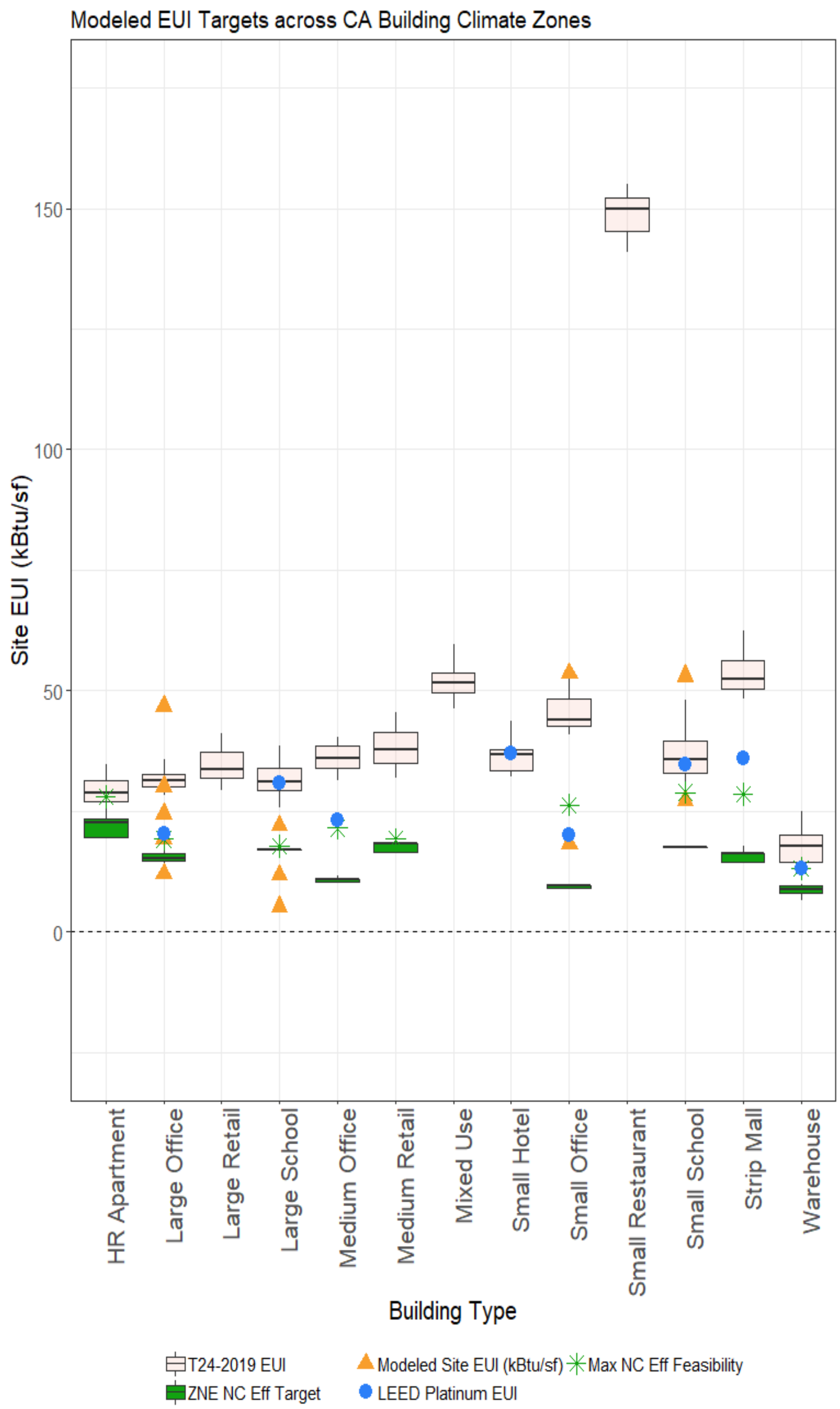
				LEED EUI after improvement over ASHRAE Baseline													
Version	**Maximum energy performance Improvement over ASHRAE Baseline - New Construction**	**Maximum energy performance Improvement over ASHRAE Baseline - Major Renovation**	**ASHRAE Version**	**Apartment High Rise**	**Hospital**	**Hotel Large**	**Hotel Small**	**Office Large**	**Office Medium**	**Office Small**	**Out Patient Health Care**	**Restaurant Sit Down**	**Retail Standalone**	**Retail Stripmall**	**School Primary**	**School Secondary**	**Warehouse**
v2.2	42%	35%	2004	28.4	90.3	91.9	44.3	25.0	28.4	23.3	94.2	229.4	42.7	45.1	42.0	37.5	14.9
v2007	42%	35%	2004	28.4	90.3	91.9	44.3	25.0	28.4	23.3	94.2	229.4	42.7	45.1	42.0	37.5	14.9
v2008	47%	-	2007	NA	80.6	78.5	37.7	20.6	23.6	20.5	82.1	200.1	34.3	36.7	35.3	31.3	13.4
v2009	48%	44%	2007	NA	79.0	77.1	37.0	20.2	23.1	20.1	80.5	196.4	33.6	36.0	34.6	30.7	13.1
v4	50%	48%	2010	23.6	62.4	55.7	32.6	26.3	18.5	16.5	60.9	178.7	25.7	29.3	27.3	22.2	9.3

Because the California building code does not use ASHRAE 90.1 as its basis, the TRC team then compared the estimated average EUI for the LEED Platinum projects with Title 24-2019 EUIs. The team calculated the EUIs using the analysis above, by taking into account the average EUI based on proportions of LEED Platinum certifications under each version, the weighted average EAc1 points earned by LEED Platinum projects, and the resulting EUI according to each version. Again, given the number of assumptions used, these results are rough estimates.

Figure 111 shows how these LEED Platinum buildings map to Title 24-2019 compliant buildings. As shown, the modeled EUI performance of LEED Platinum buildings compared to Title 24-2019 varies by building type. Based on this comparison, LEED Platinum office buildings and strip malls have a significantly lower EUI than Title 24-

2019 compliant buildings, but LEED Platinum schools, hotels and warehouses are roughly equivalent to Title 24-2019 buildings. **Because not all building types were performing significantly better than the Title 24-2019 baseline, this study did not consider LEED Platinum as ultra-efficient for market size analysis. However, the analysis shows that for select building types, LEED Platinum buildings do have modeled energy use that could be considered ultra-efficient.** Particularly since almost all LEED Platinum buildings have renewable energy, the modeled net energy use of LEED Platinum buildings is likely lower than all Title 24-2019 buildings, and much lower than Title 24-2019 compliant retail and office buildings.

Figure 111. LEED Platinum EUI Compared to T24 and Efficiency Targets



14 Appendix C: ZNE Terminology

The following provides more detailed descriptions of terminology related to ZNE and ultra-efficient buildings:

14.1 Additional ZNE Terms

The following terms are sometimes used in policy discussions.

- **ZNE Site** – A building designated as ZNE Site is a building that offsets its annual energy use expressed in terms of site kBtu (site energy) with renewable energy generated on site also expressed in terms of site kBtu (site energy). A ZNE Site building could be designated ZNE Site - Design if the designation is based on predicted performance or ZNE Site - Performance if based on actual observed building energy use and renewable generation.

- **ZNE Source** – This definition is like the ZNE Site definition, except the metric used is a source kBtu (source energy) that accounts for energy required to extract and transport the raw fuel and losses associated with conversion, transmission and distribution to the point of use (building). This is typically achieved by multiplying site energy values with a multiplier that then generates the source values. These site-to-source conversion factors vary by fuel (electricity, natural gas, propane) as well as the electricity generation mix for a given utility or region. This report uses national average values for site-to-source energy as used by the US Department of Energy (DOE) for the DOE Common Definition for Zero Energy Buildings[48], EnergyStar and Portfolio Manager initiatives. This enables the values to be comparable across the various states and utility territories across the country.

- **IEPR ZNE Code** – This definition of ZNE is specific to California and is unlike the definitions of ZNE used elsewhere. ZNE Code is a design rating since it is based on predicted energy performance. Specifically, the 2015 Integrated Energy Policy Report (2015 IEPR) spells out the ZNE Code definition as:

- A ZNE Code Building is one where the value of the energy produced by on-site renewable energy resources is equal to the value of the energy consumed annually by the building, at the level of a single “project” seeking development entitlements and building code permits, measured using the California Energy Commission’s Time Dependent Valuation metric. A ZNE Code Building meets an Energy Use Intensity value designated in the Building Energy Efficiency Standards by building type and climate zone that reflect best practices for highly efficient buildings.

- Note that this definition includes all fuels consumed onsite. In addition, as part of the “best practices for highly efficient buildings”, IEPR emphasizes that the project team is to install energy efficiency measures first before considering renewables.

- **2019 Title 24 ZNE Code** – This definition is specific to California and is a specific implementation of the IEPR ZNE Code and the EDR definitions. Currently in draft format and out for a required 45-day comment period, the 2019 Title 24 Standard Section 150.1(b) specifies the following:

- **Newly Constructed Buildings.** The Energy Budget for newly constructed buildings is expressed in terms of the Energy Design Rating, which is based on TDV energy. The Energy Design Rating (EDR) has two components, the Energy Efficiency Design Rating, and the Solar Electric Generation and Demand Flexibility Design Rating. The Solar Electric Generation and Demand Flexibility Design Rating shall be subtracted from the Energy Efficiency Design Rating to determine the Total Energy Design Rating. The Proposed Building shall separately comply with the Energy Efficiency Design Rating and the Total Energy Design Rating.

[48] https://www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

- EXCEPTION to Section 150.1(b)1. A community shared solar electric generation system, or other renewable electric generation system, and/or community shared battery storage system, which provides dedicated power, utility energy reduction credits, or payments for energy bill reductions, to the permitted building and is approved by the Energy Commission as specified in Title 24, Part 1, Section 10-115, may offset part or all of the solar electric generation system Energy Design Rating required to comply with the Standards, as calculated according to methods established by the Commission in the Residential ACM Reference Manual.

- **Additions and Alterations to Existing Buildings.** The Energy Budget for additions and alterations is expressed in terms of TDV energy.

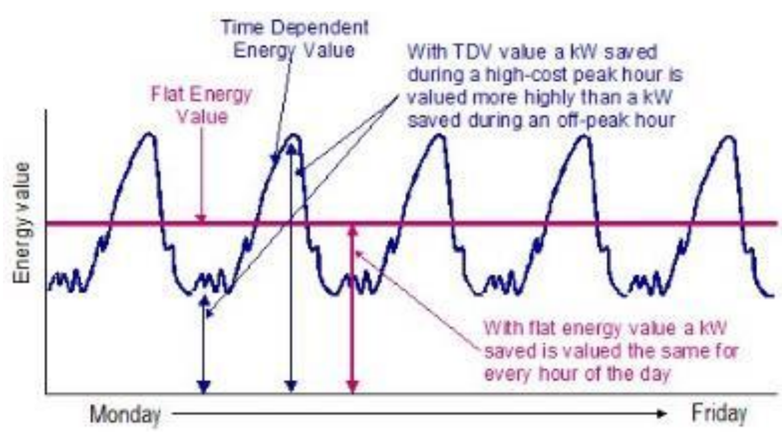
- **Zero Net Carbon** – Zero Net Carbon (ZNC) focuses specifically on carbon emissions related to building energy use, rather than energy use alone. Architecture 2030 defines ZNC as a "building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually". This definition allows for procurement of energy from off-site non-carbon renewable sources to offset building energy, rather than requiring all energy to be produced on-site. Carbon emissions and carbon equivalents are measured in CO_2. There is no accepted definition for ZNC within California, though the CEC, California Air Resources Board and CPUC are all working on developing carbon metrics that can be used towards zero carbon buildings. These need to account for not only site energy use but also the fuel mix used for the energy generation (onsite and offsite) as well as account for seasonal and hourly variations based on location and utility.

14.2 TDV and EUI

The following provides more background on the terms TDV and EUI.

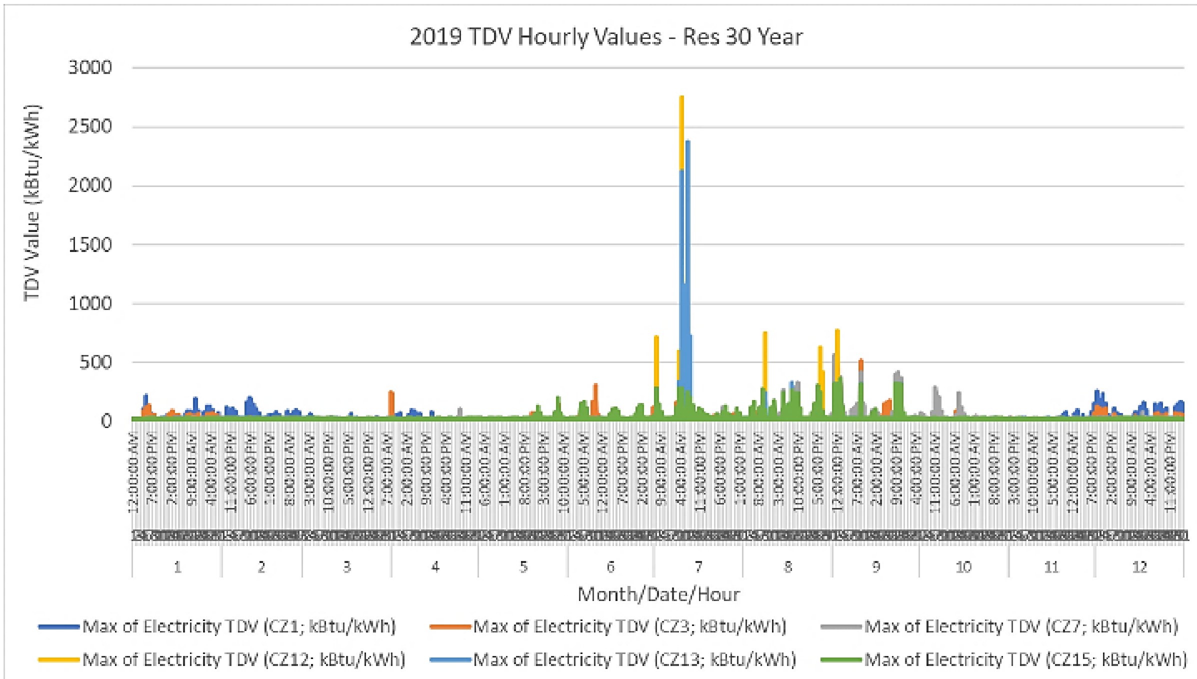
- **Time Dependent Valuation (TDV)** – TDV has been used to evaluate cost-effectiveness of energy efficiency and demand response measures for Title 24 since the 2005 Title 24 update. Prior to 2005, a flat value of source energy cost was used to evaluate the value of measures. Under TDV, energy is valued instead on an hourly basis that better reflects the actual cost of energy to the customers, to the utility system and to society. TDV values are calculated separately for the three primarily fuels used in buildings – electricity, natural gas and propane – as well as for the 16 California climate zones. Electricity values change by hour for each hour of the year while natural gas and propane values change by month.

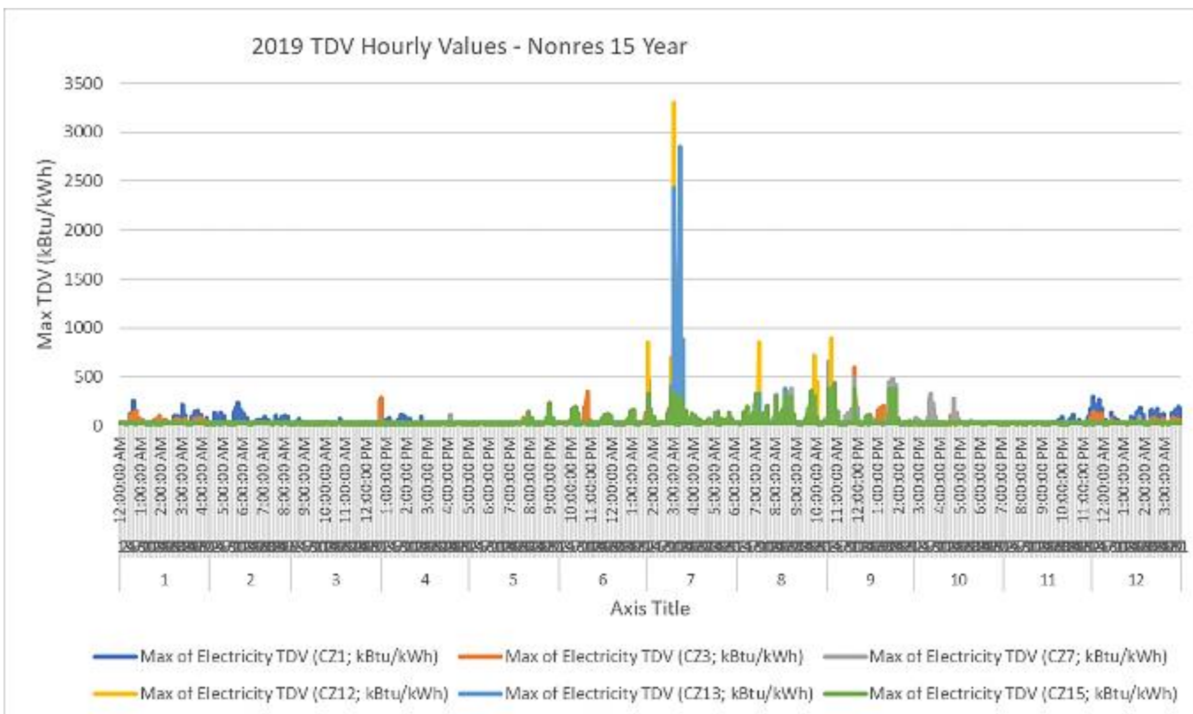
Figure 112. TDV Concept – "Flat" Valuation vs. TDV for Electricity Use



The TDV value of electricity is highest during summer peak periods when the overall grid is stressed to full capacity and there is need for additional generation resources. Thus, energy saved on peak carries a higher value than energy saved off-peak. As a result, residential air conditioning energy savings get higher benefit under TDV since air conditioning usage tends to coincide with current system peak and lighting savings get lesser benefits, since they tend to occur outside the system peak.

Figure 113. 2019 TDV Values Over the Year





- **Energy Use Intensity (EUI)** - The EUI is expressed as kBtu/sf/yr, and is a commonly used metric of a building's energy use or performance. To normalize the various fuels in a building, all the energy forms for both use and production/generation are converted to thousands (k) of British Thermal Units (Btu) and then divided by the square feet (sf) of the buildin

15 Recommendations Formatted for IOUs' "Response to Recommendations"

Figure 114. Recommendations Formatted to Facilitate the IOUs' Response to Recommendations Process

Recommendation	Program or Database	Summary of Findings	Additional Supporting Information	Recommendation	Recommendation recipient: Lead (Support)
1	EM&V	Since the study was scoped, the State has increased its focus on greenhouse gas (GHG) reduction.	For information on California policy related to ZNE see Section 6.3.4. For details on justification and recommendation see Section 11.2.1.	Revisit ZNE goals to meet GHG emissions and demand response needs • Investigate options for achieving ZNE in prototype buildings, and their impacts on GHG and demand. • Identify a new loading order for efficiency, renewables, and load management by building type and location.	IOUs (CPUC)
2	EM&V	Cost-effectiveness requirements prohibit aggressive action. Cost-effectiveness calculations are based on energy savings, but non-energy benefits (NEBs) can be significant.	For examples of non-energy benefits see Figure 15. For details on justification and recommendation see Section 11.2.1.	Monetize non-energy benefits (NEBs) • Quantify NEBs through literature review and program-incentivized occupant surveys. • Include customer and utility NEBs in cost-effectiveness calculations.	CPUC (IOUs)
3	EM&V	"Percent better than Title 24" does not track progress. A fixed performance baseline would enable comparison of efficiency levels across code cycles and among building types.	For definition of Energy Design Rating (EDR) see Section 6.3.4. For details on justification and recommendation see Section 11.2.1.	Develop Energy Design Rating (EDR) type metric for commercial buildings • IOUs should continue to support CEC in its development of a fixed performance metric, by helping to identify the baseline systems for each building type.	CEC (IOUs)
4a	Codes and Standards	Current trajectory is ~3% EUI reduction each Title 24 Cycle for commercial buildings.	For details on justification and recommendation and examples of codes and standards for EUI reduction see Section 11.2.2.	Accelerate net energy reduction each code cycle. Require deeper savings through greater prescriptive trade-offs	CEC (IOUs)

4b	Codes and Standards	Hospitals, hotels, and restaurants have large loads not regulated by Title 24 or Title 20.	For modeled EUI usage under Title 24 see Section 10.3.1. For details on justification and recommendation see Section 11.2.2.	Continue to investigate opportunities to bring more loads under Title 24 or Title 20 • Short-term: Shift to EDR-type metric • Long-term: Shift to outcome-based codes	CEC (IOUs)
4c	Codes and Standards	Five percent (5%) of the commercial buildings market had solar PV in 2018. Title 24-2019 requires that residential new construction (but not commercial) install distributed generation.	For approaches to distributed generation, see Section 9.2. For penetration of solar PV over time, see Section 10.2.3. For details on justification and recommendation see Section 11.2.2.	Add requirements for renewable energy and load management • Provide flexibility so project teams can meet the specific needs of each site	CEC (IOUs)
5a	Reach Code	New requirements can be more contested (and take more time for approval) than renewals.	For drivers and barriers to development and adoption of reach codes, see Section 9.3. For details on justification and recommendation see Section 11.2.3.	Update existing reach code requirements separately from new developments.	Local Jurisdictions (IOUs, through Reach Code Programs)
5b	Reach Code	Projects may not complete plan review goals.	For examples of enforcement mechanisms, see Section 9.3. For details on justification and recommendation see Section 11.2.3.	Impose enforcement mechanism, such as a deposit that is refunded if goals are met.	Local Jurisdictions (IOUs, through Reach Code Programs)
5c	Reach Code	Cost effectiveness limits scope of reach codes	For examples of commercial reach code requirements, see Figure 28. For details on justification and recommendation see Section 11.2.3.	Establish voluntary standards to encourage deeper energy savings or reach retrofits.	Local Jurisdictions (IOUs, through Reach Code Programs)
5d	Reach Code	Offering “carrots” will increase participation in voluntary pathway	For details on justification and recommendation see Section 11.2.3.	Encourage participation of voluntary standards through rewards, such as density bonuses or tax incentives.	Local Jurisdictions (IOUs, through Reach Code Programs)
6a	Building Performance Standards	California has no policies to directly regulate energy performance and is not on track to meet 2030 statewide goals.	For California policy related to ZNE see Section 6.3.4. For current ZNE market penetration, see Section 10. For details on justification and recommendation see Section 11.2.3.	Convene a statewide meeting to develop a framework for Building Performance Standards.	CPUC & Local Jurisdictions (CEC, CARB, IOU Reach Code Staff)

6b	Local Ordinance	Building Performance Standards may be more feasible at the local jurisdiction level than statewide.	For details on justification and recommendation see Section 11.2.3.	Local jurisdictions should initiate implementation of Building Performance Standards.	CPUC & Local Jurisdictions (CEC, CARB, IOU Reach Code Staff)
7a	Savings by Design replacement program	The replacement program to Savings by Design (SBD) could help address first cost barrier, which market actors identified as a barrier to ZNE and ultra-efficient buildings.	For incremental cost estimates see Section 8.1. For role of financing in efficiency see Section 9.1.6. For details on justification and recommendation see Section 11.2.4.	Couple financing offering with the incentive in the SBD-replacement program. • Recommend the On-Bill Financing (OBF) program as a resource (in addition to the SBD-replacement program) for retrofit projects. • Offer a financing option in addition to other program incentives for new construction.	IOUs
7b	Savings by Design replacement program	ZNE operations and maintenance cost may be high for some strategies	For operation and maintenance cost estimates see Section 8.2. For details on justification and recommendation see Section 11.2.4.	Offer optional post-occupancy support in the SBD-replacement program.	IOUs
7c	Savings by Design replacement program	SBD had variations on data tracked between IOUs	For information on SBD data tracking see Section 13.5.1. For details on justification and recommendation see Section 11.2.4.	Require documentation of predicted energy use and savings in the SBD-replacement program.	IOUs
7d	Savings by Design replacement program	Post-occupancy incentives will encourage metered energy savings. Actual energy use may also exceed modeled predictions.	For comparisons of modeled and metered data, see Section 10.3.4. For details on justification and recommendation see Section 11.2.4.	Use a partial “pay for performance” incentive structure or require projects to provide 12 to 24 months of post-occupancy data in replacement program.	IOUs
7e	Savings by Design replacement program	Indoor environmental quality (IEQ) is a common ZNE driver. However, there is a lack of documented occupant benefits with some measures.	For examples of IEQ ZNE drivers, see Section 7.3.1. For details on justification and recommendation see Section 11.2.4.	Offer incentives for administering an IEQ survey of occupants in replacement program.	IOUs

8a	Valuation of ZNE	Market actors cite non-energy benefits as drivers to ZNE.	For non-energy benefits, see Figure 15. For details on justification and recommendation see Section 11.2.4.	Emphasize NEBs to project teams using outcome of Recommendation 2.	IOUs
8b	Valuation of ZNE	Incremental costs are low for ZNE and ultra-efficient buildings, and sales and rental premiums should provide high Return on Investment (ROI).	For incremental cost estimates of ZNE see Section 8.1. For valuation of ZNE, see Section 8.3. For details on justification and recommendation see Section 11.2.4.	Highlight high ROI, particularly for privately-owned buildings.	IOUs
8c	Valuation of ZNE	Market actors commonly cite marketability as a driver to ZNE. There is also generally high participation of buildings in LEED than SBD, and much higher penetration of LEED and SBD than ZNE buildings.	For market penetration of LEED and SBD buildings, see Section 10.2. For valuation of LEED buildings, see section 8.3. For examples of improved marketability, see Section 13.2.5. For details on justification and recommendation see Section 11.2.4.	Consider providing a ZNE recognition program for companies and buildings that achieve ZNE. • To identify projects for recognition, leverage those identified by NBI or that participated in the Living Futures Institute or LEED-ZNE programs.	IOUs
9a	WE&T	Integrated design helps achieve ZNE and reduce cost.	For usage of integrated design in ZNE, see Section 9.1.1. For details on justification and recommendation see Section 11.2.5.	Continue to provide training on integrated design and compare curriculum to high priority technologies presented in Itron (2019) study.	IOUs
9b	WE&T	Several trainings requested are already provided through Workforce Education and Training (WE&T).	For requested assistance from market actors see Section 7.3.3. For details on justification and recommendation see Section 11.2.5.	Use the upcoming WE&T Market Assessment to parse out actual training needs vs. participation challenges. • Identify opportunities to increase participation in trainings • Identify needs, audiences, and delivery methods for coursework that can build the business case for ZNE	IOUs
10	Mandated training	Mandated training would reach a much larger audience, but California governors have rejected continuing education requirements.	For details on justification and recommendation see Section 11.2.5.	Convene a statewide forum to discuss requirements for continuing ZNE and GHG education.	CPUC (IOUs)

11	Long Term Research	Benchmarking was recently mandated for large buildings. Compliance software does not accurately capture some advanced strategies.	For summary of ZNE and GHG related policies, see Figure 11. For comparisons of modeled and metered data, see Section 10.3.4. For details on justification and recommendation see Section 11.2.6.	Allow 3rd parties access to modeling (in addition to benchmarking) data, to allow for improvements in model accuracy. • Compare modeled and actual energy use. • IOUs can help prioritize modeling improvements by identifying common strategies in their custom programs.	CEC (IOUs)
12	Long Term Research	Statewide ZNE progress is not tracked.	For sources of ZNE projects, see Section 13.5.1. For details on justification and recommendation see Section 11.2.6.	Track ZNE claims in a central registry. Consider creating an internship program to create the registry.	CPUC (CEC)
13a	Long Term Research	Actual energy use varies by operation and occupant behavior. Facility operators are in a good position to identify opportunities for improvement.	For discussion of occupant behavior, see Section 13.2.6. For details on justification and recommendation see Section 11.2.6.	Provide an industry competition for strategies to improve operations and occupant behavior.	IOUs
13b	Long Term Research	Most ZNE project teams track building performance	For percent of buildings with performance tracked, see Figure 14. For details on justification and recommendation see Section 11.2.6.	Ask ZNE contacts for methods to reduce occupant energy use. Methods can be publicized through social media, short videos, or case studies.	IOUs
14	Building Technology Recommendations	Itron (2019) recently published a study that identified high priority technologies	For more detail on the Itron (2019) report, see section 9.1.7. For details on justification and recommendation see Section 11.2.7.	IOU programs, codes and standards, and policies should continue to encourage adoption of the high priority technologies.	IOUs (CPUC and CEC)
15	Building Technology Recommendations	Data centers were not studied, because there is no data center prototype.	For building types in past CEC studies, see Figure 7. For details on justification and recommendation see Section 11.2.7.	Improve tracking of building stock and EUI for data centers. • Use results as initial step to identify savings opportunities • Track data centers as a separate category in the next building stock or energy use survey	CEC (IOUs)