# The Road to ZNE

## Mapping Pathways to ZNE Buildings in California

### Main Report

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# Table of Contents

1. ACKNOWLEDGEMENTS....6

2. EXECUTIVE SUMMARY....7

2.1 Background....7
2.2 Goals and Objectives of the 'Road to ZNE' Study....8
2.3 Limitations of Project Scope....8
2.4 Study Findings....10
2.5 Policy and Regulatory Recommendations....19
2.6 Policy and Research Next Steps....26

3. INTRODUCTION....31

4. GOALS AND OBJECTIVES....33

4.1 Objective....33
4.2 Limitations of Project Scope....33

5. METHODOLOGY....35

5.1 Research Approach....35
5.2 Primary Research....35
5.3 Secondary Research....35
5.4 Coordination with Other Efforts....36

6. RESEARCH FINDINGS....38

6.1 ZNE Goals will Help Achieve California Greenhouse Gas Reduction Goals....38
6.2 ZNE Goals Are Not Mandated....38
6.3 The ZNE Market is Early in its Development, with Significant Remaining Uncertainties....38
6.4 Deep Energy Efficiency Should be the Foundation of ZNE....39
6.5 The Breadth of ZNE Planning is Very Expansive and Will Require a High Level of Coordinated Effort....41
6.6 ZNE Policy Framework....65
6.7 Cost Effectiveness Framework for ZNE....85
6.8 Grid Implications of ZNE Goals....104
6.9 Potential Impact of ZNE on Building Energy Related Emissions....120
6.10 Current ZNE and High Performing Building Energy Characteristics....122
6.11 Impacts of Building Operations, Maintenance, and Occupants....130

7. STUDY RECOMMENDATIONS ........ 140
7.1 ZNE Path Forward ........ 141
7.2 Policy and Regulatory Recommendations ........ 150
7.3 Next Steps ........ 163
8. REFERENCES ........ 167
9. APPENDIX A: GOALS AND OBJECTIVES ........ 185
9.1 Study Goal ........ 185
9.2 Study Objectives ........ 185
9.3 Study Process ........ 187
9.4 Limitation of Project Scope ........ 187
10. APPENDIX B: ASSESSING MARKET ATTITUDES TOWARDS ZNE GOALS ........ 188
10.1 Market Actors ........ 188
10.2 Summary of Market Actor Interviews ........ 191
10.3 Priority Commercial Markets for ZNE Adoption ........ 196
11. APPENDIX C: ROLE OF BUILDING OPERATORS AND OPERATIONS ........ 199
11.1 Impacts of Building Operations, Maintenance, and Occupants on Building Energy Use ........ 199
11.2 Key Findings from Literature Review on Role of Building Operations, Maintenance, and Occupants ........ 230
12. APPENDIX D: RESIDENTIAL ZNE PV CAPACITY CALCULATION ........ 232
12.1 PV Capacity Needed Under the Site Energy Definition ........ 232
12.2 PV Capacity Needed Under the Source Energy Definition ........ 236
12.3 PV Capacity Needed Under the TDV-based Definition ........ 236
13. APPENDIX E: GREENHOUSE GAS EMISSIONS ........ 237
13.1 Marginal and Average Emissions Rates of Electricity in California ........ 237
13.2 Lifecycle Greenhouse Gas Emissions ........ 240
14. APPENDIX F: KEY ASSUMPTIONS FOR LEVELIZED COST OF ENERGY OF PV SYSTEMS ........ 241
15. APPENDIX G: NONRESIDENTIAL BUILDING EUI ANALYSIS ........ 243
15.1 Existing Building EUI Data ........ 243
15.2 New Buildings – California LEED NC Rated Building Data ........ 257
16. APPENDIX H: RESIDENTIAL EUI AND RASS ANALYSIS ........ 275
16.1 Whole Building Energy Use ........ 275

16.2 UECs by Climate Zone ..... 277
16.3 UECs by Building Size ..... 279
16.4 UECs by Construction Year ..... 281
16.5 Title 24 Regulated Loads ..... 283
16.6 Unregulated Loads ..... 286

17. APPENDIX I: BUILDING RATING SCHEMES AND INITIATIVES ..... 287
17.1 Asset Ratings ..... 287
17.2 Operational Ratings ..... 289
17.3 Building Labeling Initiatives ..... 291
17.4 Green Building Rating Programs ..... 297

18. APPENDIX J: ROOF SPACE NEEDED FOR SOLAR PV IN RESIDENTIAL SINGLE FAMILY BUILDINGS ..... 300

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# 2. Executive Summary

## 2.1 Background

The California Long Term Energy Efficiency Strategic Plan (the Strategic Plan) includes four "big bold" programmatic goals to guide market transformation efforts in the state of California. These "big bold" goals include:

- All new residential construction in California will be zero net energy by 2020
- All new commercial construction in California will be zero net energy by 2030
- Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate
- All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020

This report focuses on the first two "big bold" goals related to zero net energy (ZNE) buildings which are clearly ambitious; both from the technical and building market perspectives.

The California Public Utilities Commission (CPUC) has been working with various stakeholders during and since the writing of the Strategic Plan to promote the ZNE goals through various regulatory and voluntary methods.

The California Energy Commission (CEC) has likewise adopted the ZNE goals as part of their long term planning through the Integrated Energy Policy Report (IEPR). For the purposes of this report these jointly agreed upon goals between these state agencies will be referred to as the "ZNE goals."

The California Investor Owned Utilities (IOU) have been active in pursuing the ZNE goals outlined in the Strategic Plan and the IEPR. As part of these efforts, the IOUs have been supporting ZNE demonstrations, providing energy efficiency incentives and conducting studies to assess the ZNE goals.

One such effort is PG&E's Zero Net Energy Pilot program (ZNE Pilot) – a non-resource program in the 2010-2012 portfolio of PG&E's energy efficiency programs. This 'Road to ZNE' report is a program deliverable for the ZNE Pilot program that is jointly funded by the four IOUs – Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E) and Southern California Gas Company (SCG). The report was funded through and overseen by the IOU Evaluation, Measurement and Verification (EM&V) staff. The study was coordinated with, and overseen by, the Energy Division at the CPUC.

## 2.2 Goals and Objectives of the 'Road to ZNE' Study

The goal of this study is to identify:

- Pathways to achieving ZNE for new construction residential buildings by 2020
- Pathways to achieving ZNE for new construction commercial buildings by 2030

This study has three main objectives:

- Objective I: Establish Framework for ZNE Research
- Objective II: Perform Market Assessment that Identifies Market Intervention Strategies
- Objective III: Identify pathways to ZNE for Residential and Commercial New Construction

For a detailed explanation of these objectives, please refer to Appendix A.

This study has established a ZNE framework to understand what progress has been made toward the ZNE goals, as well as what remains unknown about whether the ZNE goals can be achieved. Relevant issues and potential pathways for pursuing the ZNE goals have been flagged, such as codes and standards, IOU programs, workforce education and outreach, among others.

While residential and commercial sectors are addressed independently and the differences between the two are outlined where necessary, this report outlines a single set of pathways to pursuing the ZNE goals.

## 2.3 Limitations of Project Scope

The Road to ZNE project has the following limitations to its scope and recommendations:

- While this study identifies potential pathways to the ZNE goals, it does not prescribe specific regulatory language. The intent of this study to provide a framework that will highlight issues and point out policy choices to be made, rather than suggesting prescriptive regulatory recommendations.
- This study focused more on the new construction ZNE goals relative to the retrofits/renovation ZNE goals due to time and budget constraints.
    - The study findings and recommendations are thus more focused on new construction though many of these apply to retrofits as well. However, barriers and opportunities unique to retrofits are not addressed in this report.
- This study performed an assessment of the early adopters of ZNE to identify market intervention strategies, but this is not a market characterization study. This early assessment provides recommendations on future research needs, such as a thorough market characterization.
- This study did not conduct research on the interactions of electric vehicles charging at homes and work places on the achievement of ZNE goals. This study also did not research the impacts of electric vehicle charging on the need for grid and renewable generation nor did it look at the impact of vehicle charging on the grid.
- This study did not conduct an exhaustive research on the renewable options available to meet ZNE. We provide high level information on the most widely used renewable – solar photovoltaic – in this report but it is not intended to be a detailed market study of solar. There are several other worthy renewables technologies that can be used in place of, or along with, solar but this study did not investigate them in detail.
- This study does not include analysis of energy storage solutions for renewables.

In a similar vein to the caveat above, the study does not answer each and every question that arose during the course of our research. Our approach was to identify research questions that need further study in our recommendations. This project thus serves as a gateway to prioritize ZNE research needs and questions to be answered.

## 2.4 Study Findings

### 2.4.1 ZNE Goals will Help Achieve California Greenhouse Gas Reduction Goals

The ZNE goals will play a significant role in allowing regulatory agencies and the utilities to promote efforts for meeting the state's greenhouse gas reductions goals. The ZNE goals will help spur efforts to promote greater energy efficiency in buildings as well as distributed renewable generation in buildings and/or communities. Both energy efficiency and renewable energy generation will help the state meet its 2050 greenhouse gas emissions goals.

The ZNE goals have also been identified as supporting the state's clean energy jobs growth efforts and thus serve an important economic function.

### 2.4.2 ZNE Goals Are Not Mandated

It is important to note that the ZNE goals identified in the Strategic Plan and the IEPR are aspirational goals that provide a long term target for the CPUC and CEC, respectively. The general concept of ZNE is currently not mandated in any form. Moreover, from a legal perspective, there are no legal consequences for the state if the ZNE goals are not met.

Regulatory agencies are bound by their respective rules of cost-effectiveness to balance a given policy's potential benefits against its potential costs and unintended consequences. The ZNE goals are no exception to these rules. Thus meeting the ZNE goals is not a foregone conclusion if ZNE does not meet the cost effectiveness criterion used by each regulatory agency – which currently differs by agency – to make policy decisions.

The findings and recommendations from this study therefore do not presume that the ZNE goals will be achieved. Our findings and recommendations are intended to inform and assist future policy decisions to be made by regulatory agencies IF they want to meet their stated ZNE goals.

### 2.4.3 The ZNE Market is Early in its Development, with Significant Remaining Uncertainties

There is a virtual consensus among stakeholders that California is not currently on the correct trajectory to meet the 2020 and 2030 ZNE goals. Several significant outstanding questions about the potential impacts of the ZNE goals must be addressed regarding: the potential impacts of the ZNE goals on the electrical grid; the amount of distributed generation needed to achieve the ZNE goals; the costs of achieving the ZNE goals; and whether the ZNE goals are the most cost-effective method to achieve greenhouse gas reductions in the state.

The immediacy of the 2020 residential new construction ZNE goal emphasizes the need for state agencies to address these significant outstanding questions soon.

The sum of the literature review, interviews and analyses conducted for this study point to a decidedly mixed picture about the status of the ZNE goals in the state.

On the positive side, the ZNE goals continue to garner attention from various market actors and there are several early adopters who are boldly experimenting with various methods of pursuing the general concept of ZNE. For example, California currently has the highest number of ZNE Site buildings of any other state in the country – and the diversity of ZNE Site buildings is growing. The explanation for ZNE Site is discussed in Section 6.6.2.

Many of the early adopters see the ZNE goals as an inevitable outcome in the future and want to be ahead of the curve to differentiate themselves from others who may soon follow. At the same time, cost, technology and policy challenges faced by these early adopters need to be addressed in a timely manner if others are to be encouraged to follow in their footsteps.

On the flip side, the market is still in a 'proof-of-concept' stage in terms of experimenting with the ZNE goals. The number of ZNE buildings is still tiny compared to the overall rate of construction (even with the economic downturn that has resulted in historically low construction starts). It is important to remember that the motivations of the early adopters are inherently different than those of the rest of the market. Our research indicates that those designing ZNE buildings are doing it for various reasons but they all share one thing in common – they are willing to experiment and try new ideas.

The essential challenge for achieving the ZNE goals is to learn from the experiences of the early adopters and apply those lessons learned to motivate, and if needed, mandate changes. We say this because achieving the ZNE goals will require the type of rapid changes in current industry practices for design, construction and operation that cannot be achieved through incentives alone.

Relative to many other industries the construction industry as a whole is not an industry that innovates at a fast pace on a large scale. Our interviews with stakeholders demonstrate that the majority of the construction industry will only adopt any ZNE metric as a construction practice once two things are clear: (1)there is a sustained market demand for that metric of ZNE; and (2) the resulting buildings are deemed cost-effective and 'feasible' by market actors and building owners/operators.

### 2.4.4 Deep Energy Efficiency Should be the Foundation of ZNE

As a guiding principle for this project, the ZNE goals will be most beneficial to California if a proper loading order is established for pursuing any metric of ZNE for a given building. This will ensure that regardless of the metric used, the efforts towards achieving that metric are all moving in the same direction and towards a common goal.

The loading order or 'steps to ZNE buildings' includes:

- Minimizing building loads
- Optimizing system efficiency based on equipment efficiency and use
- Using highest efficiency appliances
- Optimizing building operations to better meet occupant and energy efficiency needs
- Improved occupant interactions with the building
- Renewable power generation when feasible and as a last step for a ZNE building

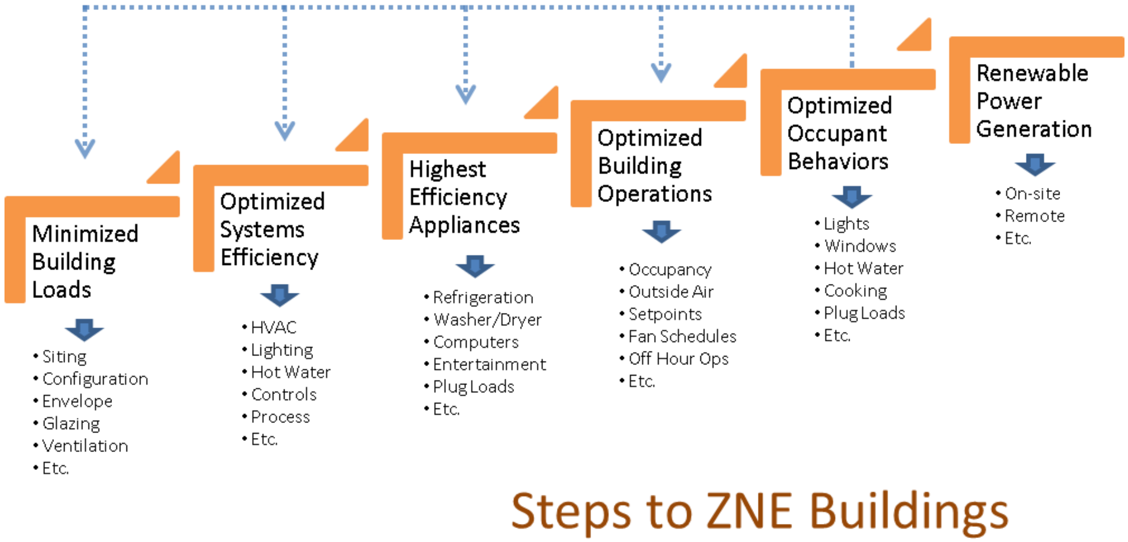



*Figure 1: Steps to Achieving ZNE Designs for Individual Buildings*

It should be noted that the steps above are not prescriptive in nature and that there are several overlaps among the steps. With each step and as a whole, a ZNE building will be driven by what is technically feasible and in the case of many building owners, what is cost-effective. There may be tradeoffs made between the categories and steps shown above for a given building based on these criteria.

The basic tenets of these steps to ZNE buildings apply across all buildings. There are certain common truths about ZNE that all stakeholders we interviewed agreed on:

- A ZNE building should be a highly efficient building in terms of how it is designed and operated,
- A ZNE building should reduce customer electricity bills, and
- ZNE buildings should create societal benefits in terms of carbon emission reductions and reduced need for electricity generation facilities.

Thus we conclude that specific energy efficiency targets – energy use intensity (EUI) in terms of kBtu/sf/yr consumed onsite – should be established for various building types and by climate zone to provide a common reference point for different ZNE metrics. The Technical Feasibility Study will provide valuable data to support the creation of such energy efficiency targets and state agencies should look to its findings as a starting point for establishing those targets.

Once the EUI targets are established for various building types, they can become the rallying point for the targeted efficiency level regardless of the specific ZNE metric chosen. Thus, a building designed using the TDV metric or a building designed using site energy metrics should target the same site EUI in terms of kBtu/sf/yr.

However, it is equally important that the different ZNE metrics are marketed and used appropriately. This means that it is not important just to say ZNE but to specify which ZNE metric is being used such as 'ZNE TDV' or 'ZNE Equivalent' versus 'ZNE Site'. Further discussion on ZNE metrics can be found in Sections 2.4.6 and 6.6.2.

### 2.4.5 Reducing Costs of Renewables is Necessary

Renewables will play a critical role in achieving ZNE goals; however, there are outstanding questions about how much renewable generation is needed, which energy uses this generation offsets (electricity, natural gas or both) and where the renewables should be located in a ZNE building or community. We outline these issues in Sections 6.7.4 and 6.8 of this report.

A key determinant of the cost-effectiveness of ZNE buildings is tied to the cost of rooftop solar PV, since rooftop solar PV is currently the most common and lowest-cost form of renewable self-generation for most buildings. In this report, we do not try to forecast whether solar PV is likely to be cost-effective for ZNE buildings by 2020 or 2030. Rather, we discuss the factors that will influence solar PV costs, highlight the uncertainties around future costs of solar, and emphasize the importance of continuing to achieve cost reductions of solar PV over time as a key element of achieving the ZNE goals.

### 2.4.6 One ZNE Metric May Not Prevail but Common Goal is Critical

The ZNE goals outlined in the Strategic Plan and IEPR and subsequent discussions have revolved around the concept of defining what ZNE means for policy makers. There are at least three approaches being proposed to or by regulatory agencies –

Strategic Plan – *A ZNE home employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid. ZNE is defined on a "project" basis and not "building" basis.*

IEPR – *The Energy Commission and CPUC should work jointly on developing a definition of ZNE that incorporates the societal value of energy (consistent with the time dependent energy valuation approach used for California's Building Energy Efficiency Standards)*

Findings from ZNE definitions group – *ZNE Equivalent defined as a property that achieves the societal value of energy (TDV energy) equivalent of ZNE with consideration of off-site renewable resources, or other factors to be determined by California policy makers.*

These discussions around 'definitions' conflate two separate but related ideas – a definition that defines the goal and metrics that are used to measure or quantify or translate the goals in practice.

From a definitional standpoint, the concept of equivalency that allows the building to meet the ZNE goals makes the most sense for the regulatory agencies since it:

- Addresses the need for promoting energy efficiency and renewables
- Addresses constraints on renewable energy generation, and
- Promotes whole building and community solutions that may lead to better greenhouse gas reductions

This report focuses on the metrics for quantifying ZNE goals, and outlines (as have many others before us) the various metrics for the ZNE goals, along with their relative strengths and weaknesses. We are fully aware that the regulatory agencies are working cooperatively to address any differences in their perspectives on the ZNE metrics. We encourage them to continue to do so and expedite these coordination efforts since they are foundational to their pursuit of the ZNE goals.

At the same time, we do not think it is a catastrophe if one metric for ZNE is not agreed upon by all concerned. Indeed it may be counter-productive to force a given metric on market actors who don't find the metric beneficial.

Conversely, we do not advocate an 'anything goes' approach to ZNE. If different metrics are claiming to do the same thing then there will be confusion in the market place and will cause more harm than good.

A single metric has proven elusive because each of the market actors - be they regulators, utilities or building developers/owners/operators - have different reasons and motivations for pursuing the ZNE concept:

- CEC – Promote cost-effective energy efficiency and renewables in buildings through codes when using the modified participant cost test metrics (namely TDV). A TDV-based metric of ZNE also requires less self-generation of renewable energy than all other ZNE metrics. CEC pursues the ZNE goals since they have societal benefits in terms of reduced emissions and need for fewer power plants.
- CPUC/Utilities – Promote cost-effective energy efficiency and renewables in buildings through programs and codes that meet the ratepayer benefit tests (PCT, TRC). ZNE goals help reduce greenhouse gas emissions through increased penetration of energy efficiency and renewables. CPUC pursues ZNE goals for the same reasons as the CEC, but additionally ZNE goals must also meet the needs of the IOU ratepayers.
- Developers/Building Owners – Early adopters of ZNE pursue ZNE goals in order to differentiate new construction or retrofit projects from the glut of existing buildings available for sale/lease. Any consideration for defining a ZNE building includes more self-reliance and comfort for its occupants while lowering the customer's utility bills – which should add to the building valuation. Most developers and building owners interviewed for this study prefer a simple metric for ZNE that is easy to measure and market.
- Occupants – Occupant perspectives on ZNE are still nascent as there is not a lot of experience with living or working in ZNE buildings. Regulators and developers are projecting that occupants will find that ZNE is good for the occupants' bottom-line in terms of lower utility bills, increased comfort and being 'good for the environment.' ZNE is often discussed by market actors (with limited input from actual occupants) as 'zero net energy bills' for building owners/occupants.

Our proposed solution to address this issue is to make sure that the metrics are structured and promoted in a manner than distinguishes them from each other so it is clear how a given ZNE building is designed or operated to perform. Below we provide more details on this proposed solution.

**Mandate** → **Voluntary**

| | CEC: ZNE TDV | CPUC: ZNE Equivalent* | Market: ZNE Site |
|---|---|---|---|
| *Fuels Covered* | Electricity + Natural Gas | Electricity + Natural Gas | Electricity + Natural Gas |
| *Asset Value* | Yes | Yes | N/A |
| *Performance Index* | N/A | N/A | Yes |
| *Energy End Uses* | Regulated Only | Regulated and Unregulated | Regulated and Unregulated |
| *Cost-effectiveness Tests Required* | CEC TDV Test | CPUC Tests (e.g. TRC) | N/A |
| *Renewables On-Site* | Yes | Yes | Yes |
| *Renewables Off-Site* | Yes | Yes | N/A |
| *ZNE Equivalencies* | Allowed | Allowed | N/A |
| *EUI Target* | TDV/sf/yr equivalent to a kBtu/sf/yr target. Will vary by building type and climate zone. Could be expressed as HERS 0 or BEARS 0. | X Btu/sf/yr **including** approved Equivalencies. Will vary by building type and climate zone. | kBtu/sf/yr Will vary by building type and climate zone. |

* ZNE Capable as an alternative

Regulated End Uses → All End Uses

*Figure 2: Proposed ZNE Metric Taxonomy*

We recommend the following taxonomy from the perspective of the principal market actors as a starting point:

- **ZNE TDV (CEC)** – a building designed to meet the TDV based definition for ZNE preferred by the CEC that includes all cost-effective energy efficiency that is allowable through the codes and standards update process. This is inherently an asset rating since it is done prior to occupancy. A relationship needs to be established between code ratings (HERS and BEARS scores) and absolute EUI targets for ZNE. ZNE TDV buildings may incorporate renewables but only after all cost-effective and optimal levels of energy efficiency are achieved. Equivalency metrics for renewables that allow tradeoffs against locational efficiency may be explored.
- **ZNE Equivalent* (CPUC)** – a building that meets the energy efficiency EUI goals but does not mandate onsite or community renewable generation. Instead other factors such as offsite renewable generation, renewable energy offsets/credits, tradeoffs with transportation energy are allowed to achieve equivalency. The regulatory agencies and other stakeholders need to identify specific criteria that would allow this trade-off while ensuring that the equivalency is genuinely necessary and is of the correct magnitude.

  ***** As an alternative to ZNE Equivalent, a ZNE Capable building definition could be adopted by the CPUC which allows for similar levels of energy efficiency. Further discussion on this topic is in Section 6.6.2.
- **ZNE Site Building (Market)** – a building designed to match the amount of energy (electric & gas) used onsite or at a community level to energy generated onsite. This is a *performance* metric which would only be realized after there is at least a years' worth of

energy use and distributed generation (DG) output to compare. A ZNE Site building may not meet cost-effectiveness tests used by the CEC/CPUC but since this is a voluntary level beyond code/CPUC program requirements, a building's noncompliance with those tests should not deter those who are truly committed to this definition.

It is possible for the ZNE TDV metric and the ZNE Equivalent metrics to converge depending on future efforts and coordination between the CEC and CPUC respectively which will significantly help the ZNE discussion by allowing one regulatory metric – ZNE Equivalent and one market metric – ZNE Site.

It is important to note that meeting a ZNE TDV or ZNE Equivalent target should not preclude someone from also pursuing a ZNE Site metric if they so choose. They would need more renewables on site and perhaps more energy efficiency, but it is technically and realistically feasible. The market may indeed prefer this arrangement since ZNE TDV or ZNE Equivalent buildings still leave some room in the market for those who want to differentiate their buildings from those that 'just meet the regulatory requirements.'

We expect further discussion among stakeholders and regulators to develop a more comprehensive taxonomy.

### 2.4.7 Understanding Social Science Perspectives on ZNE is Critical for Success

If good ZNE buildings are to be achieved relatively cost-effectively, and if they are to appeal to prospective buyers, building users need to be incorporated into the design of ZNE buildings realistically, rather than focusing on technology without examining assumptions about what users want or will do. This requires formal observation of how people use buildings and consideration of new ways to incorporate this information. The following areas stand out as especially important for research and policy attention:

- **Realistic behavior description and feedback to design**. Improve understanding and description of what occupants in homes and commercial buildings do with respect to energy. Improve how behavior and its variability are reflected in building and technology design, research, and policy development.

  Energy-using systems in buildings may often not be used as designed or as assumed in policies. Improved descriptions of user behavior that better match actual use can lead to better building design and performance. In conventional construction, designers and users may eventually adapt to each others' expectations, but this feedback loop is uneven and can take many years. Given the aggressive ZNE market goals and the likelihood of innovative systems used in ZNE construction, this process could be accelerated by ensuring careful assessment and feedback on actual use and potential improvements in design as well as occupant education. Not doing so can lead to sub-par energy performance and occupant/buyer dissatisfaction, with potentially adverse effects on market growth.
  Further, better acknowledgement of the innate variability of behavior can help build more realistic expectations of building performance, versus the current use of synthetic "averages" in building energy policies (codes, programs etc.).

- **Building operations.** Address the human side of building management and operations. In commercial buildings, building operations and management are key determinants of building energy use, but are often forgotten in the focus on technologies and occupant actions. Understanding why buildings are operated as they are can help support more realistic ZNE designs and reveal ways to reduce energy waste, e.g., by better incenting such reductions.

- **Influencing building users**. Improve the quality and delivery of education and energy use feedback to building users.

  Providing information to building users will not necessarily have a major impact on what all building users do. But more attention to the process of helping occupants learn about using the buildings they inhabit, and continued work on developing more useful forms of energy use feedback for ZNE designs, taking realistic account of why users do what they do, can help reduce energy use and improve user satisfaction with ZNE homes and buildings.

- **Automation vs. manual control.** Use observation and experimentation to improve automation and balance automatic versus manual control strategies.

  In part due to the unpredictability of user behavior, the building industry overall has embraced automation as a means of reducing energy waste. However, development and evaluation of automation has not adequately accounted for building users' desire for control or the potential energy savings from manual versus automated control. Better integrating the human dimension in designing and selecting automation in energy service provision can help lead to lower energy use as well as more satisfied users.

- **Occupant satisfaction and building evolution**. Track occupant experience in ZNE buildings.

  If policy is to promote ZNE construction, it is important to help ensure – rather than simply assume -- that policies do not make the prospective occupants of these buildings worse off, e.g., through poorer air quality, inhospitable acoustic conditions, poor levels of control, etc. This will require evaluation of user experience and indoor environmental conditions, e.g., through post-occupancy evaluation and satisfaction assessments. High occupant satisfaction in ZNE buildings can help bolster the market case for ZNE. Assessment should also track how building users change the building, e.g., what systems they override or replace, and what uses they add.

- **Market.** Pay attention to what current and prospective ZNE buyers and building occupants want.

  Who buys, who occupies, who builds, and why, and what can be learned about the nature of future markets for ZNE homes and buildings? Rather than assume that the benefits of ZNE promoted in policy, research, and industry are also the hooks for potential buyers, use research to better determine what appeals about ZNE construction, what does not appeal about ZNE construction, perceived risks among buyers, and how buyer and occupant experience feeds back to the market.

### 2.4.8 The Breadth of ZNE Planning is Very Expansive and Will Require a High Level of Coordinated Effort

If the state regulatory agencies are to achieve the ZNE goals, they will need an extensive set of both policy and market intervention tools to help make the aspirational goals a reality. In this section, we outline the pathway elements available to put the state on the path to pursuing the ZNE goals. Pathways in this instance refer to strategies, policies and activities that are under the purview of state regulators to move the market towards pursuing the ZNE goals. Further, there are multiple parallel pathways to get to the same goal and each has a particular appeal to specific market actors. The complexity of the pathway elements will require integrated planning and coordinated implementation.

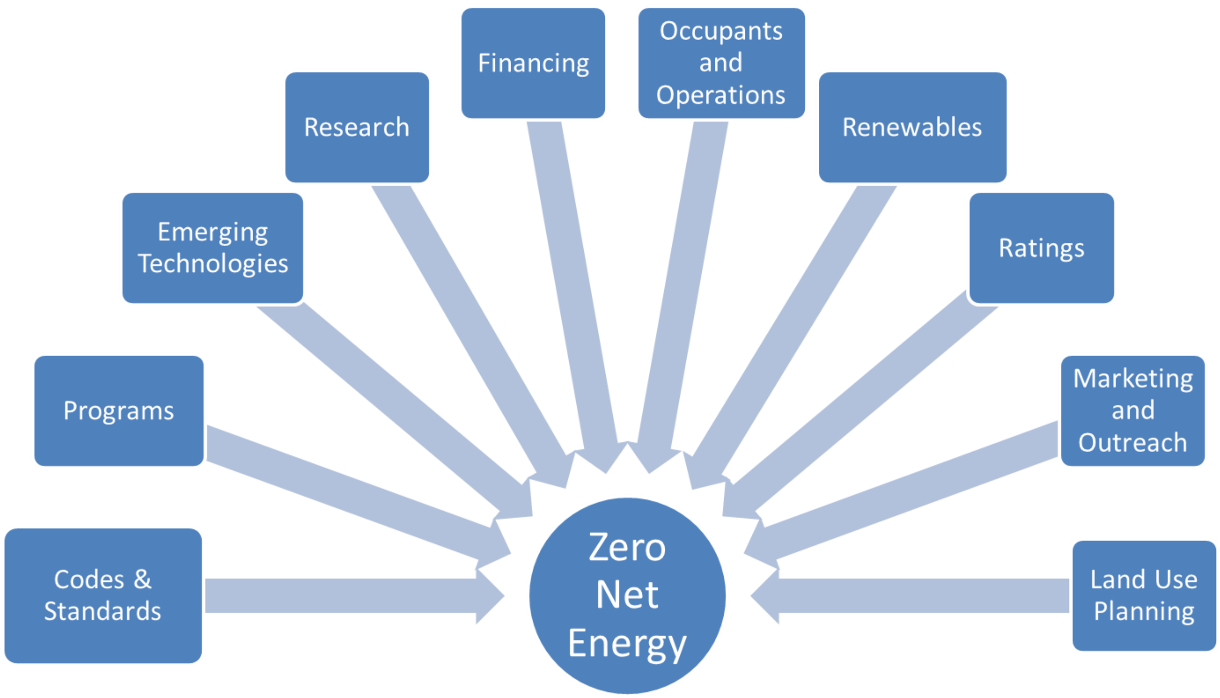
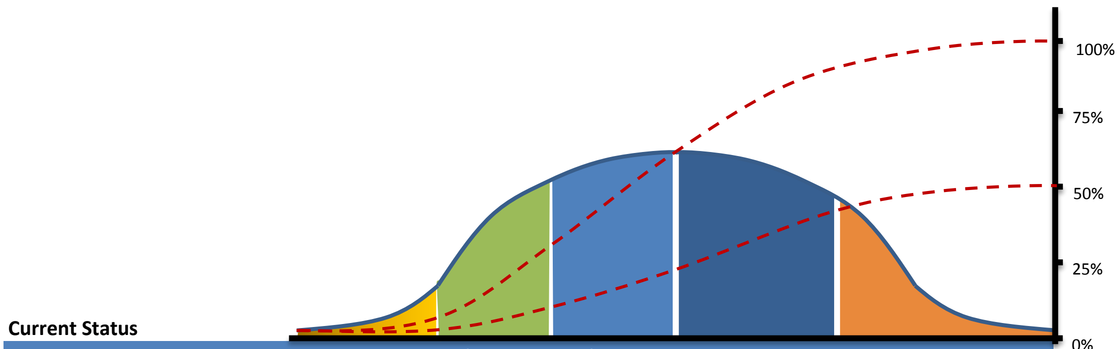



*Figure 3: Multiple but Supportive Paths to ZNE*

Comparing the pathways to the Diffusion of Innovation curve[1] Figure 3 shows where the various pathways are currently aligned to the market and ZNE goals. Most of the early efforts are focused on early adopters largely through a combination of incentives and research efforts. In this graphic, a capital "X" denotes where the pathways are currently most aligned with the market actors along the innovation curve, whereas a "Y" denotes where the pathway has some potential to influence the market as of the writing of this report.

[1] Diffusion of Innovation, E. M. Rogers, 1962




| Pathways | Innovators | Early Adopters | Early Majority | Late Majority | Laggards |
|---|---|---|---|---|---|
| Codes and Standards | | | Y | X | X |
| Programs and Incentives | | X | X | X | |
| Emerging Technologies | x | X | Y | | |
| Research | X | X | X | | |
| Financing | | Y | | | |
| Occupants and Operations | | | | X | X |
| Renewables | | X | | | |
| Building Ratings | | Y | Y | Y | Y |
| Marketing and Outreach | | X | | | |
| Land Use Planning | NA | NA | NA | NA | NA |

*Figure 4: Current Status of Pathways as Applied to ZNE.*

## 2.5 Policy and Regulatory Recommendations

Achieving the ZNE goals will require coordinated approaches from all parties to ensure that all energy efficiency, demand response and renewables policies are aligned with the ZNE goals. In this section we outline the specific policy approaches that the CPUC and CEC would need to address to pursue their ZNE goals.

### 2.5.1 Critical Planning Issues Must be Addressed to Achieve the ZNE Goals

The ZNE goals outlined in the Strategic Plan and the IEPR are policy goals to inform long term planning. However, if they are to be achieved, the ZNE goals can no longer be considered long term goals as 2020 is only eight years away. The CPUC and CEC need to set specific priorities for their respective efforts and make regulatory decisions with the ZNE goals in mind if they are to be realized.

#### Recommendation: Establish a Memorandum of Understanding around ZNE Goals

Though the CPUC and CEC have the policy tools available to pursue the ZNE goals, there is a need for an ongoing forum to evaluate the complex set of issues and recommendations presented in this report and those that will no doubt arise in the years to come. We therefore suggest that the CPUC and the CEC consider a process of evaluating the issues and policies around ZNE separate from, and in addition to, the more voluntary efforts of the ZNE champions network. One such approach – short of a formal rulemaking – is to institute a memorandum of understanding (MOU) between the CPUC and CEC that provides a venue where all ZNE related issues can be addressed dispassionately and with a focus on providing concrete policy directions.

## Recommendation: Use Cost Effectiveness to Inform ZNE Policy

There are many important differences regarding how the cost-effectiveness of ZNE projects and programs are likely be evaluated by the CEC, the CPUC and the private sector (market). These differences are captured by the different cost tests described in Section 5.5 (TRC, PACT, PCT, TDV, etc.) and outlined in the Figure below.

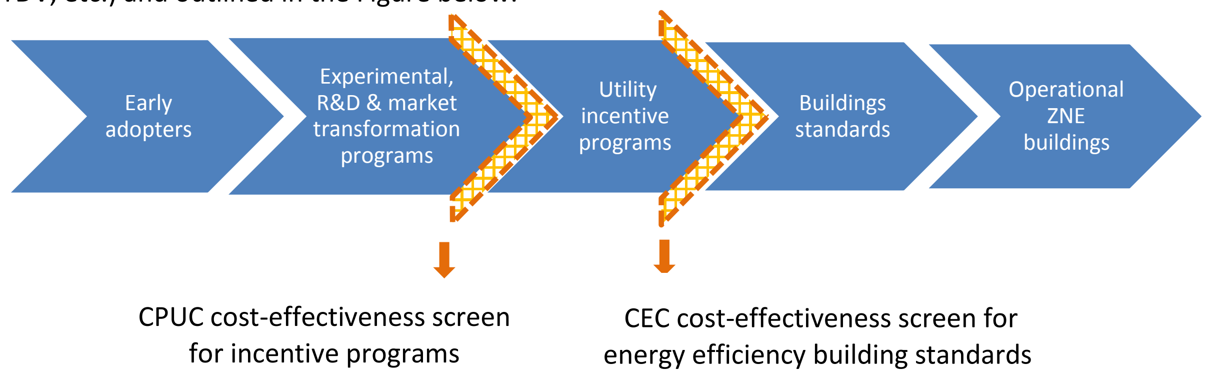



*Figure 5: Cost-Effectiveness Screens to ZNE Goals*

While a single definition of cost-effectiveness is not appropriate or needed, the differences between agencies and the market in evaluating cost-effectiveness may increasingly cause confusion as policies and programs are developed in pursuit of the ZNE goals unless there are concerted efforts to a) understand the differences, b) explain the differences and c) align targets for energy efficiency between agencies/approaches.

Better tools are needed by building designers to evaluate the tradeoffs inherent in ZNE building design, including the cost-effectiveness of different design choices. Likewise, policymakers need to have a better understanding of the costs and benefits of ZNE policy choices they will face over the years between today and 2020 and 2030.

A particular challenge on cost-effectiveness is that with each successive code cycle, there will be fewer savings to be achieved per building than the previous cycle and the savings that can be achieved will likely entail higher costs. There is a real risk that a ZNE Site level performance may not meet the current cost-effectiveness metrics for both the CPUC and CEC.

Given current uncertainty around renewable energy policies and incentive structures, there is a risk that rooftop PV will not be cost-effective in 2020 using a participant cost test metric or the TRC or TDV cost-effectiveness metrics. Although there are many uncertainties regarding the future cost of solar PV, this possibility must be accounted for in designing a roadmap to achieve the state's ZNE goals. State policies, such as market transformation programs, that help incentivize continued reductions in the cost of both renewable distributed generation and energy efficiency are needed to help bring down the cost of ZNE buildings.

California policymakers have encouraged "market transformation" of the rooftop solar PV market through the use of incentives: the California Solar Initiative, the New Solar Homes Partnership and net energy metering rules. As a result of the market transformation goal, these programs have not been constrained by cost-effectiveness tests. A similar market transformation approach could be applied to the development of ZNE buildings, by developing policies to continue to bring down the cost of renewable distributed generation as well as energy efficiency.

There is significant uncertainty looking forward to 2020 and beyond regarding key policies and regulations which will influence the cost-effectiveness of ZNE going forward, particularly in the areas of retail rate design and net energy metering policies. As these policies are being reconsidered in current CPUC proceedings, the ways that these policies will influence both the utility business model, as well as the future achievability of the state's ZNE goals, should be factored into the decision-making process.

In addition, the competing needs for rooftop space on buildings, and the limited availability of appropriate rooftop space for PV on some buildings, including in high-density developments, imply that some flexibility may be needed regarding where a ZNE building's source of self-generation is physically located.

Larger distributed PV systems tend to be lower cost on a per unit basis than smaller systems. This implies that the cost of achieving ZNE targets could be lowered by utilizing renewable generation from a single project across multiple buildings. However, current solar PV incentives and most existing policies are not designed to encourage larger, non-rooftop distributed generation projects. Policies could be developed to encourage "ZNE communities" rather than simply "ZNE buildings." If correctly designed, this option could open community renewables to other customers in a way that does not shift costs to nonparticipants in the policy's market intervention.

A building that is a net exporter of electricity to the grid falls under the "net surplus power" rules of net energy metering (NEM), such that the building owner is compensated for their surplus power at a market price for power, rather than the wholesale retail rate. This means that building owners have little economic incentive to offset their natural gas use with onsite electricity generation. Rather than encouraging all-electric buildings or onsite electricity production to offset a building's natural gas usage to achieve a ZNE Site building, other options, such as the use of biogas offsets may be better alternatives to explore under a ZNE Equivalent scenario.

Designing "ZNE Capable" or "ZNE Equivalent" buildings with higher levels of energy efficiency may be a more important and more practical policy goal than achieving a ZNE target with on-site renewable generation. Distributed renewable generation should not need to be physically located on a building's lot in order to meet a "ZNE Equivalent" definition.

## Recommendation: Develop Equivalency Metrics for ZNE Goals

This study recommends that the concept of ZNE Equivalency is critical to making the ZNE goals feasible and addressing valid concerns about requiring renewables onsite for each and every building. A number of equivalency metrics have been proposed by others and we have outlined them above. We recommend that the CPUC and CEC collaborate on developing the parameters of the equivalency metrics – be they renewable credits, locational efficiency or vehicular miles traveled.

A particular area of research relevant to ZNE Equivalency is to evaluate the feasibility and metrics for community scale solar and community scale ZNE 'projects' as opposed to ZNE buildings.

Another issue where equivalency metrics may make sense is for offsetting natural gas energy use in buildings. A potential equivalency would be to allow a building owner to purchase biogas credits to offset the building's natural gas consumption. Currently, it is not feasible to deliver biogas to most California customers, but biogas offsets, not necessarily delivered biogas, could provide a way for a building to achieve ZNE in a more cost-effective way than offsetting natural gas use with on-site solar PV generation. The use of biogas offsets for natural gas use does not appear to be a part of the current understanding of ZNE buildings, however, policymakers may want to investigate this option as a potential way to lower the cost of achieving ZNE equivalency.

## Recommendation: Evaluate Grid Impacts of ZNE buildings

Meeting the 2020 ZNE residential goals will most likely require a dramatic increase in the PV installation rate, above and beyond the state's "million solar roofs" goal. The amount of new solar PV needed to meet the state's residential ZNE goal could be between 5,000 MW and 11,000 MW by 2030, depending on the definition of ZNE, as well as other factors. 11,000 MW of distributed PV development is of a similar magnitude as the total amount of new solar that is currently estimated to come on-line to meet the state's 33% renewable portfolio standard by 2020. Achieving the state's 2020 residential ZNE goals will likely require new policies to support onsite and community solar PV installations, since rooftop solar PV may not be cost-effective without incentives or other policy support by 2020.

Importantly, the total amount of PV that would be needed in 2020 to meet the ZNE goal depends greatly on the level of energy efficiency improvements achieved in ZNE residential buildings. In this report, we have assumed that fairly aggressive levels of energy efficiency improvements can be achieved in residential buildings by 2020 based on the findings of the Technical Feasibility study. If these "exemplar" levels of energy savings are not achieved, more solar PV would be required to meet the ZNE goals.

More research is needed into the grid impacts of achieving the state's ZNE goals. At currently low levels of PV penetration, the grid impacts of ZNE are less about technical challenges than about the need for more clarity regarding the cost and allocation of potential distribution grid upgrades. Small numbers of ZNE homes in a neighborhood pose limited grid integration challenges, but very high penetrations of ZNE Site buildings on single substations would require:

- More flexible interconnection screening rules or a more streamlined interconnection review process, (progress is currently underway through recent and planned reforms to Rule 21);
- Investment in new or upgraded distribution equipment for voltage regulation, fault detection, and anti-islanding;
- Installation of smart inverters on PV systems and regulatory changes to allow smart inverters to provide voltage regulation services.

The short-term flexibility requirements of distributed PV systems on ZNE homes are expected to be less pronounced than those associated with the central station renewable plants anticipated to meet the 33% RPS. However, additional quantitative analysis of system flexibility for distributed solar is still needed. While ZNE PV systems may contribute to future transmission network costs and upgrades associated with high penetration distributed generation, there is no clear quantitative analysis of these effects to date.

### 2.5.2 Internalize ZNE Goals in Portfolio Planning

There are a variety of ways that early market activity can be stimulated and supported. Policies and programs need to actively support market activity to create a more robust set of ZNE buildings if the ZNE goals are to be realized.

#### Recommendation: Support and Learn from Early Adopters

If the ZNE goals are to be achieved, early successes should be rewarded through recognition and marketing support to spread the message of the benefits these early adopters have realized. The efforts of these early adopters and their successes and failures need careful follow-up to understand the technological and policy approaches required to move the rest of the market. The essential challenge for achieving the ZNE goals is to learn from the experiences of the early adopters and apply those lessons learned to motivate and as needed require those not naturally inclined to change. We say this because achieving the ZNE goals will require changes in current industry practices for design, construction and operation.

#### Recommendation: IDSM Strategies Will Assist Meeting ZNE Goals

The CPUC is well-suited to provide leadership on the integration of energy efficiency, demand response and renewables into a common set of programmatic activities. Integrated Demand Side Management (IDSM) strategies have been piloted in the 2010-2012 IOU portfolios of programs. Indeed the ZNE Pilot program, for which this study is a deliverable, is part of this IDSM strategy.

To achieve ZNE goals will require careful coordination of the EE, DR and DG programmatic activities including incentive levels, application processes, savings claims, marketing and outreach as well as project financing. An integrated approach through the IDSM process will play a crucial role in providing the right resources to early adopters and the early majority to achieve building designs and EUI performance levels that meet the ZNE definitions put forth in this report, all of which include EUI metric targets. Further we encourage the IOUs and CPUC to orient the IDSM offerings to a common goal of encouraging ZNE Equivalent buildings.

#### Recommendation: Target ZNE through Programmatic Activity

Starting with the 2013-2014 portfolios of programs, we encourage the IOUs and CPUC to identify specific pathways to encourage ZNE performance through programs. For new construction programs in particular, we encourage setting ZNE performance thresholds, based on EUI targets that are matched with appropriate design assistance and incentive levels. We further encourage new construction programs to target a broader implementation of the ZNE Pilot Program's efforts by highlighting early successes and promoting efforts of early adopters.

#### Recommendation: Take a Longer-Term View of Cost-Effectiveness for ZNE Elements of New Construction Programs

The pathway to increasing market penetration of the energy efficiency component of any ZNE definition (i.e. the EUI metric targets) will likely require an explicit focus on developing and transforming the new construction market. As such, it may not be appropriate to hold programs that target the ZNE goals to current CPUC program cost-effectiveness standards. The California Solar Initiative (CSI) and New Solar Homes Partnership (NSHP) programs could be used as models, including these programs' use of pre-planned and progressive reductions in incentives over time to encourage early adoption and to create a sense of urgency for project developers who want to qualify for the higher incentives early in the program.

Measure cost-effectiveness assessments are unlikely to be appropriate for new construction ZNE buildings, or for deep retrofits to achieve ZNE. Rather, a portfolio-level or whole buildings approach may be needed to evaluate cost-effectiveness.

#### Recommendation: Focus on Target Markets that have Multiple Reasons to Pursue ZNE Goals First

For commercial buildings, target both program activities and codes to advancing the "more interested" markets, such as schools and other publicly owned buildings. The commercial buildings market is extremely diverse, and ZNE goals are both more attractive and more feasible in some sub-markets for reasons of low cost of ownership, demonstration of leadership, or alignment with carbon reduction goals.

For the residential markets, market research is needed to identify the motivations and definitions of target buyers to assist the development community in effectively reaching the more interested markets.

#### Recommendations: Conduct Research to Overcome Technical Barriers

The systems being used in some of the early ZNE Site buildings are innovative and there is limited market experience with the systems. Further, some of these systems need more maturation before they can be adopted on a larger scale. Continued efforts are needed to evaluate promising technologies through emerging technologies programs and other research efforts. This includes developing appropriate system-specific performance metrics, developing controls protocols, developing installation protocols and validating the effectiveness of the technologies. The Technical Feasibility study also identifies key starting points for research efforts on technical barriers.

### 2.5.3 Define a Codes and Standards Path to ZNE

Codes and Standards programs at the CEC and the IOUs (under CPUC oversight) will play a pivotal role in achieving the ZNE goals. Of all the pathways available to the regulators, codes and standards offers the most direct method to mandate new construction measures capable of achieving ZNE EUI metric targets for buildings. In order to do so however, codes and standards need to evolve as follows:

#### Recommendation: Make Quality Construction the Foundational Element of Title 24

In order to meet the ZNE goals, construction quality must be of the highest standard and both building envelope and systems must be installed as designed/intended. There are a number of measures assessing construction quality that Title 24 must include as requirements. Title 24 already includes a number of these measures such as heating, ventilation and air-conditioning (HVAC) refrigerant charge testing, acceptance testing and fault detection and diagnostics. However, there is still a need for substantial improvement to Title 24 to address quality construction such as (but not limited to):

- Framing: Reduce thermal bridging in construction through advanced framing techniques
- Insulation: require QII (Quality Insulation Installation)
- HVAC installation standards

- HVAC diagnostics standards
- Compact and efficient domestic hot water (DHW) designs

### Recommendation: Move to a EUI Target for Codes

The language typically used to express code changes is in terms of percent improvements over the previous standards. This language is counter-intuitive to achieving the ZNE goals. Since we have only two code cycles to 2020, and another three until 2030 each successive code update must target a greater portion of the regulated energy use of the building than the previous standard. However, the absolute magnitude of savings (TDV, kWh, Therm) may actually be lower in each successive code update. Thus a percent better than previous code language is actually misleading and may lead to confusion at best and opposition at worst. Instead, laying out a clear goal of a code performance target has the advantage of simplicity and ease of comparison to other ZNE metrics.

Using an energy use target metric for ZNE buildings (instead of a more prescriptive approach) will give the right signals to the market to innovate and find lowest-cost solutions. The Technical Feasibility Study results will provide valuable data to support the creation of such energy efficiency targets.

As outlined in Section 7.1.2 we recommend that the code metrics be aligned with ZNE EUI metrics by providing a clear path from ZNE TDV buildings to ZNE Capable, Equivalent, and Site buildings.

### Recommendation: Evaluate TDV Metric to Better Account for Increased Penetration of Distributed Renewables Generation

As the contribution of PV self-generation to overall electricity generation increases, there will be fundamental changes to the marginal value of electricity generation which in turn will affect the TDV values used for codes. We recommend that the Codes and Standards roadmap scheduled to be started by the CPUC and CEC in 2013 should focus on this issue to identify future directions for TDV. The use of TDV to value renewable self-generation may also need to be reconsidered if the state's net energy metering policies change significantly.

### Recommendation: Identify Ways to Overcome Federal Pre-Emption

As outlined in section 5.3.1, a number of states and the IECC have adopted innovative methods to overcome federal preemption of appliance efficiency. We encourage the CEC to consider these approaches as part of the Codes and Standards roadmap and 2016 Title 24 process.

### Recommendation: Address Increasing Plug Loads and Appliances Energy Use

The direct path to addressing plug loads and appliances is through codes and standards (Title 20 for appliance efficiency and Title 24 for controls and integration into ZNE building codes). As explained in section 6.5.1 there are challenges in doing so due to federal preemption but there are also several potential approaches to navigate around the preemption barrier. We recommend that the CEC explore these approaches starting with the 2016 Title 24 updates.

However, codes and standards alone cannot make headway towards the ZNE goals without assistance from voluntary efforts aided by utility and third-party incentive programs. New construction programs could potentially include incentives for high-efficiency plug loads and appliances subject to verification of the same. Some programs already have pre-requisites on plug load and appliance efficiency such as requiring EnergyStar rated appliances. These approaches could be expanded through new construction programs for both residential and commercial buildings.

Regulatory agencies and the utilities could also work in collaboration with national appliance and plug load rating initiatives such as EnergyStar to ensure that these ratings target the 'best in class' systems based on their energy efficiency performance.

Finally, and perhaps most urgently, is the need for better information on where, when and how much energy is used by plug loads and appliances in buildings. Current datasets are limited in their predictive capabilities and their estimates of energy use based on limited field data. We recommend that the CPUC and CEC respectively fund studies to evaluate the current 'baseline' conditions for plug loads and appliance energy use in residential and commercial buildings including time of use and energy use data.

## 2.6 Policy and Research Next Steps

In this section we present policy recommendations for meeting the 2020/2030 goals. For the sake of brevity we do not repeat the overall recommendations made in Section 7.2 but highlight a few key decisions that need to be made in the short term:

### 2.6.1 Recommendation: Develop a Codes and Standards Roadmap to Achieving ZNE

The CEC and CPUC are set to begin this roadmap in 2013 for residential buildings. We encourage the agencies to expand the roadmap to include nonresidential buildings as well and outline specific milestones that apply to codes and standards development.

Most importantly we encourage the agencies to identify how the other pathways identified in Figure 7 need to be aligned to meet those goals. Section 7.2 provides suggestions on this.

### 2.6.2 Recommendation: Align the New Construction Program Portfolio to ZNE Equivalency Goals

New construction programs are currently active in promoting the general ZNE concept. However, these efforts are in the pilot stages and need to be substantially enhanced in 2013-2014 onwards to reach a broader section of the market.
As part of this effort, we recommend that programs use ZNE EUI metric targets for buildings to achieve in order to meet the ZNE goals. Results from the Technical Feasibility study would be useful to establish these targets.
A significant challenge is the cost-effectiveness of programs which will be adversely affected by these enhanced incentives and support. However, if the ZNE goals are to be achieved, we recommend that the IOUs and CPUC to keep the broader market transformation goals in mind when funding and evaluating new construction programs.

### 2.6.3 Recommendation: Align Emerging Technologies Programs to ZNE Goals

Though it is challenging to predict when technologies may develop and what new technologies may arrive in the market place, it is possible to outline the needs of a ZNE building by any definition using the results of the Technical Feasibility study and this study to identify a roadmap for the emerging technologies programs. As an example, there are several codes and standards proposed measures that need further laboratory and field testing such as evaporative cooling systems. In other cases, there are technology needs that are not met – such as smaller air conditioning systems with higher efficiency levels. Beyond technologies themselves, much more information needs to be collected on the occupant interaction with systems and controls. These needs should form the basis of emerging technologies research roadmap.

### 2.6.4 Recommendation: Develop and Encourage Financing of ZNE Buildings

The CPUC has initiated efforts to create policies that encourage private lending institutions to value and support energy efficiency efforts. These policies should be aligned with the ZNE goals. Specific efforts must be undertaken to align building ratings and labels to the needs of financial institutions when they compare buildings for loan appraisals.

### 2.6.5 Recommendation: People and Technology are Intertwined and their Interactions Need to be Better Understood

Interdisciplinary (technology, social sciences, design, engineering, etc.) perspectives on building energy use prediction and assessments of actual building energy use are necessary if the policy goals are to meet reality.

There is variability in energy use in buildings but policy is currently driven by assumptions about 'average' or 'idealized' energy use patterns and behaviors. People will adapt the building, systems, controls and features to their needs and wants. This is not to say that they will adversely affect the carefully crafted building and system designs, but they will make things work *for them* if they can. There is little basis to assume that people will act in accordance with design assumptions or with instructions on proper use if there do not seem to be enough advantages to doing so from the occupants' perspective. But people can and do adapt to new designs and learn how to use buildings. Therefore, strategies for educating occupants on how to maximize their building's energy efficiency attributes should be developed and shared with ZNE building occupants.

If is often assumed that providing more control to building users will result in energy use penalties or inefficiencies in building operation. Regulatory efforts are thus structured to promote automation and centralized controls over distributed controls or occupant control. This assumption is an oversimplification based on limited data on the variability of human interactions with buildings. Careful assessment of how specific design assumptions work in practice, feeding back to changes in designs and design assumptions, as well as user education and expectations, can lead to ZNE designs that support ZNE performance but are not seen by users as major compromises.

Further research is needed on the variability of energy use and the 'how' and 'why' occupants use energy in buildings. Research is needed on how much energy use patterns and behaviors can be influenced by policy approaches (programs, codes, marketing, etc.). Research is needed on how to incorporate occupant expectations and behavior into programmatic approaches.

### 2.6.6 Recommendation: Research is needed into Customer Decision-making

It should not be assumed that ZNE homes and buildings have innate appeal to all prospective buyers and occupants. Rather, research into why people invest in ZNE homes and buildings now, and why they do not, can help build ZNE market intelligence, e.g., on market segments, on features and storylines that appeal to potential buyers, and on how buyers see risks and costs. This study did not conduct research into this important aspect of ZNE goals. This study recommends that market characterization studies are necessary to understand the motivations and barriers to a 'demand' for ZNE buildings.

### 2.6.7 Recommendation: Research Needed on Existing ZNE Buildings

The early adopters have taken the risks needed to design and construct buildings that meet the various ZNE definitions outlined in this report. Field research on these buildings is required to answer a number of questions still outstanding including:

#### *Field Performance Assessments*

ZNE is inherently a performance concept in the minds of most stakeholders and as such there is interest and value is looking at the early adopters of ZNE to evaluate how the ZNE designs are working in practice. There are individual efforts being conducted by utilities and private entities to evaluate how the combination of technologies and strategies are working in practice. These efforts need to be expanded and standardized so as to enable comparison of predicted performance with actual performance across buildings, climate zones and ownership/tenancy structures.

#### *Occupant Interaction with Buildings*

Investigate how occupants interact with ZNE buildings as related to energy use and occupant experience, including assessing the heterogeneity of these interactions with respect to different social contexts and building designs, and better accounting for use/users as a source of uncertainty.  Further evaluate the degree of energy impacts of interventions such as education and energy use feedback devices, recommend improvements, and characterize limitations. Investigate tradeoffs between automated and manual control of energy-using devices and systems, both in terms of energy use and occupant experience, and use results to improve design.

#### *Plug and Miscellaneous Loads*

Evaluate how plug loads and miscellaneous loads contribute to building energy use and affect achievement of the various ZNE definitions. Variability in user choice and user interactions with the building may have a proportionately larger influence on the energy use of ZNE buildings versus conventional buildings, as the energy efficiency of the building envelope and systems in ZNE buildings are higher.

### 2.6.8 Recommendation: Research Needs for ZNE Grid Impacts

The grid interconnection costs for high penetration distributed PV systems on ZNE buildings are still largely unknown.  While it may be impossible to predict these costs until California experiences high penetration distributed PVs, we have identified some specific areas of research that would provide guidance going forward.

- *Local voltage stability.* Although it is not anticipated that distributed PV systems will lead to rapid short-term fluctuations in California's net load, it is possible that local distribution systems will experience transient voltage behavior that compromises the performance of local electronic devices. ZNE community pilot projects present unique opportunities to investigate these transient voltages and their impacts if voltages are recorded with high temporal resolution over various load and renewable conditions throughout the local distribution system. ZNE community pilot projects should also provide a unique test bed for smart PV inverters that are capable of mitigating these voltage fluctuations.

- *Operational flexibility.* New modeling methods will be required to determine if California has enough operational flexibility to meet demand with high penetrations of renewables. These methods must include adequate treatment of sub-hourly load and renewable fluctuations, renewable forecasts, imports, hydropower flexibility, renewable curtailment, and alternative scheduling algorithms to identify whether flexibility can be achieved through operational changes or will require procurement of new flexible capacity. Quantification of flexibility requirements is not only an important step toward meeting the 33% RPS, but it will also provide a baseline for examining the incremental flexibility need associated with the ZNE goals.

- *Interconnection cost data availability.* The local grid impacts of ZNE can likely be managed with upgraded distribution equipment. This means that in a future with high penetration of distributed PVs, interconnection costs may increase and the allocation of these costs may need to be considered in the context of evaluating the cost effectiveness of ZNE communities. Currently there is very little standardized interconnection cost data available, partially because there are relatively few completed interconnection studies for ZNE communities and partially because each system has unique distribution engineering considerations. Going forward, it would be useful to create a standard method for utilities to characterize and report interconnection costs so that the grid impact costs and implications of ZNE can be better understood.

- *Allocation of distribution upgrade costs and benefits.* Currently, renewable generation interconnection costs, that are identified prior to project approval, are incurred by the project developer, increasing the project cost. Small residential systems typically do not require distribution equipment upgrades at the time the system is installed, so there is essentially no direct cost of interconnection. If distribution upgrades are required after the distributed generation is in place, these costs will eventually be collected from all utility ratepayers through retail rates. As the penetration of PV systems increases, however, distribution upgrade costs are likely to become more frequent and more costly, making cost allocation a more important issue. Under the current interconnection tariff, interconnection costs will be disproportionately allocated to the first developer that fails the interconnection screens in an area, while later developers may reap the benefits of an upgraded distribution circuit for free. This may introduce an additional barrier to adoption for early ZNE communities. In anticipation of these cost and benefits allocation issues, policy makers should explore new models for distribution upgrade cost allocation.

- *Transmission system effects.* There is concern that high penetration distributed generation may lead to poor utilization of the transmission infrastructure and congestion on specific lines containing both high penetrations of distributed generation and load pockets, potentially requiring transmission infrastructure upgrades. However, there is a need for more quantitative evidence of the thresholds at which these issues arise. Research should be directed toward determining if there are critical ZNE or distributed generation build-out scenarios that give rise to transmission effects, quantifying the potential costs of these effects, and exploring different cost allocation options.

# 3. INTRODUCTION

The California Long Term Energy Efficiency Strategic Plan (the Strategic Plan) goals for zero net energy (ZNE) buildings are clearly ambitious; both technically and from a building industry change perspective. The California Public Utilities Commission (CPUC) has been working with various stakeholders during and since the writing of the Strategic Plan to promote the ZNE goals through various regulatory and voluntary methods. The California Energy Commission (CEC) has likewise adopted the ZNE goals as part of their long term planning through the Integrated Energy Policy Report (IEPR). For the purposes of this report these jointly agreed upon goals between the state agencies will be referred to as the "ZNE goals."

The California Investor Owned utilities (IOU) have been active in pursuing the ZNE goals outlined in the Strategic Plan and the IEPR. As part of these efforts, the IOUs have been supporting ZNE demonstrations, providing energy efficiency incentives and conducting studies to assess the ZNE goals.

One such effort is PG&E's Zero Net Energy Pilot program (ZNE Pilot) – a non-resource program in the 2010-2012 portfolio of PG&E's energy efficiency programs. This report is a program deliverable for the ZNE Pilot program that is jointly funded by the four IOUs – Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E) and Southern California Gas Company (SCG). The report was funded through and overseen by the IOU Evaluation, Measurement and Verification (EM&V) staff. The study was coordinated with the Energy Division at the CPUC.

This report lays out the strategies and next steps needed for meeting the long term goals outlined in the Strategic Plan. Through the course of this study, we explored a wide variety of topics including:

- What does it mean to have a ZNE building? What is the definition of ZNE?
- Who are all the market actors that will influence or will be affected by the ZNE policies and implementation?
- What energy use targets should be used when setting the ZNE goals? How do these vary by location and building type?
- How does user interaction and feedback impact the design, operation and maintenance of buildings and how does that impact ZNE designs?

The technical challenge is to develop cost-effective and scalable strategies for building or renovating large numbers of buildings, both residential and nonresidential, in all California climate zones, which achieve the high levels of efficiency and performance to become ZNE. This will require sophisticated systems integration, as well as optimized operations and user interaction and feedback.

The industry challenges are likely to be more difficult. In many ways, the process of designing, building and renovating buildings is optimized to current market conditions. These include the ways:

- Zoning, regulations and sites constrain building layouts,
- Design teams are hired and structured,
- Building trades and contracting practices operate,

- Materials and equipment suppliers choose to stock their warehouses,
- Financing and lease arrangements determine physical and operational patterns, and
- User interaction and feedback shape energy demand.

The user interaction and feedback specifically will become an increasing influence on a ZNE building where the time of use and quantity of appliances, plug loads and entertainment/productivity devices will start representing a larger portion of the building energy use as the building envelope and systems are optimized for energy efficiency.

Changing the optimum of these factors to favor ZNE buildings will require encouraging new ways of making buildings, at all levels. We are not talking simply about making more efficient buildings. Rather we are talking about taking the entire building industry to new levels of design and operational practice.

This is an industry that collectively represents the largest slice of economic activity in California, and it is the most heterogeneous industry of all. It is made up of thousands of product manufacturers, wholesalers and distributors; tens of thousands of tradespeople and specialty installers; thousands of contractors and builders; thousands of designers (architects, mechanical engineers, lighting designers, etc.); untold numbers of builders and owners, many of whom only build once or twice in their lifetimes; building operators and maintenance staff who are often undertrained on sophisticated building systems; and financing sources with a strong propensity toward standard practice and avoidance of risk. Changing practices and standards for the building industry is much more challenging than changing, for example, vehicle mileage standards or power plant designs, because those are done by comparatively centralized industries.

To achieve the necessary change in construction practices and encourage common goals and objectives towards ZNE will require coordination between various entities described above.

The central tenet of this study is to identify connections between the various entities, understand the barriers and opportunities for these entities and prioritize solutions and next steps for taking the state on the road towards achieving our ZNE goals.

The HMG team has built this study on the knowledge gained from our past experiences as well as current efforts being paid through the California Public Utilities Commission (CPUC), California Investor Owned Utilities (IOU) and the California Energy Commission (CEC). As a starting point, we understand the Strategic Plan goals and are aware of the challenges and opportunities for meeting those objectives. One of the specific studies we have coordinated with closely is *The Technical Feasibility of Zero Net Energy Buildings in California* (formally known as the Technical Potential Study)[1] that was conducted concurrently by another team. The Technical Feasibility study has modeled exemplar residential and commercial buildings as the research team can best project them to exist in 2020 and used those models to estimate the technical potential for ZNE buildings in CA in 2020. The Road to ZNE study has proposed pathways for market actors to follow and support in pursuing the end goal of ZNE buildings in CA as modeled in the Technical Feasibility Study.

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[1] The Technical Feasibility of Zero Net Energy Buildings in California, 2012, conducted by Arup for the California Investor Owned Utilities

# 4. Goals and Objectives

The goal of this study is to identify:

- Pathways to achieving ZNE for new construction residential buildings by 2020
- Pathways to achieving ZNE for new construction commercial buildings by 2030

This study has established a ZNE framework to understand what progress has been made toward the ZNE goals from, as well as what remains unknown about whether the ZNE goals can be achieved. Relevant issues and potential pathways for pursuing the ZNE goals have been flagged, such as codes and standards, IOU programs, workforce education and outreach, among others.

While residential and commercial sectors were addressed independently and the differences between the two are outlined where necessary, this report outlines a single set of pathways to pursuing the ZNE goals.

## 4.1 Objective

This study has three main objectives:

- Objective I: Establish Framework for ZNE Research
- Objective II: Perform Market Assessment that Identifies Market Intervention Strategies
- Objective III: Identify pathways to ZNE for Residential and Commercial New Construction

For a detailed explanation of these objectives, please refer to Appendix A.

## 4.2 Limitations of Project Scope

The Road to ZNE project has the following limitations to its scope and recommendations:

- While this study identifies potential pathways to the ZNE goals, it does not prescribe specific regulatory language. The intent of this study to provide a framework that will highlight issues and point out policy choices to be made, rather than suggesting prescriptive regulatory recommendations.
- This study focused more on the new construction ZNE goals relative to the retrofits/renovation ZNE goals due to time and budget constraints.
  - The study findings and recommendations are thus more focused on new construction though many of these apply to retrofits as well. However, barriers and opportunities unique to retrofits are not addressed in this report.
- This study performed an assessment of the early adopters of ZNE to identify market intervention strategies, but this is not a market characterization study. This early assessment provides recommendations on future research needs, such as a thorough market characterization.
- This study did not conduct research on the interactions of electric vehicles charging at homes and work places on the achievement of ZNE goals. This study also did not research the impacts of electric vehicle charging on the need for grid and renewable generation nor did it look at the impact of vehicle charging on the grid.

- This study did not conduct an exhaustive research on the renewable options available to meet ZNE. We provide high level information on the most widely used renewable – solar photovoltaic – in this report but it is not intended to be a detailed market study of solar. There are several other worthy renewables technologies that can be used in place of, or along with, solar but this study did not investigate them in detail.
- This study does not include analysis of energy storage solutions for renewables.

In a similar vein to the caveat above, the study does not answer each and every question that arose during the course of our research. Our approach was to identify research questions that need further study in our recommendations. This project thus serves as a gateway to prioritize ZNE research needs and questions to be answered.

# 5. METHODOLOGY

## 5.1 Research Approach

A large body of research has already been completed in each of the specific focus areas covered by this study. This study therefore is a meta-analysis that builds on this existing work. A thorough literature review and analysis of ZNE and high performing buildings is the foundation of the project. In addition, data collection includes individual communications, structured interviews with market actors, and analysis of building energy consumption data.

In our analysis, we strived to understand the connections between the various inputs and studies, as well as the connections and interactions between different market actors.

This section contains an abbreviated overview of our methodology. A more detailed explanation in included in the appendices for reference.

## 5.2 Primary Research

As a team, we created a market actor matrix. We focused on key players and early adopters. This matrix contains a list of market actors, their roles, and their likely incentives and barriers to achieving ZNE designs. From this list, we then conducted 40 formal interviews, in addition to a number of informal discussions.

To expand on the limited amount of ZNE and high performing building energy data in the literature, the team also analyzed data from:

- LEED: >400 LEED buildings
- NBI ZNE Data on about 100 buildings
- RASS: >20,000 anonymous samples

## 5.3 Secondary Research

In order to answer research questions and set a direction for the future, one must understand past and current practices, and must know the policy, building, economic and political implications of these practices. Literature review which is our secondary research activity formed the basis for most of the analysis as well as guided the development of our primary research. As a team, we reviewed over 225 sources covering topics such as:

- ZNE Definition
- EUI Targets
- Fuel Mix Metrics
- Grid Challenges
- Certifications and Ratings
- User Interaction and Feedback
- Building or Project Design and Construction

- Building Operations and Maintenance

The literature review was targeted to studies deemed relevant to the study and was guided by inputs from the IOUs, CPUC and public comments on the study work plan.

## 5.4 Coordination with Other Efforts

### 5.4.1 Project Advisory Group (PAG)

Including opinions and suggestions from key decision-makers and market actors on the project research and recommendations ensures that results from this project are meaningful, address market actor concerns and provide the best opportunity for success in achieving the ZNE goals.

To help guide the data collection and analysis efforts, Energy Division created and led a Project Advisory Group (PAG). The goal of this group was to regularly brief Energy Division on the status of the ZNE studies and collect input for consideration on major project milestones.

### 5.4.2 Technical Feasibility Study

For each of the data collection and analysis elements, there was constant communication within the team and with the utilities/CPUC and advisory groups. The ZNE Technical Feasibility Study was a parallel effort to this project and provided details on specific strategies and measures needed to achieve ZNE goals. The study team lead attended bi-weekly conference calls with the utilities and the team lead from the Technical Feasibility study. These bi-weekly meetings were a venue to highlight relevant questions and seek inputs from the utilities on specific tasks. In addition, email communications happened regularly throughout the project with various market actors to ask questions, review information and conduct discussions as necessary.

### 5.4.3 Codes and Standards Action Plan

The study coordinated with the early efforts in developing a C&S action plan being led by CPUC. This effort was useful to identify the challenges, barriers and opportunities for C&S to support and lead ZNE efforts in the state. Discussions around the role of C&S in relation to other efforts such as programs, emerging technologies and market initiatives supported the findings outlined in this report regarding pathways to ZNE. We hope that the recommendations from this study will serve to further enhance and add to the action plan discussions in the future.

### 5.4.4 Strategic Plan Updates

The Strategic Plan update process is a key input to the Road to ZNE study since a number of key decision-makers and opinion leaders on ZNE policy have been engaged in the Strategic Plan updates since 2010. Their collective expertise and deliberations provide a foundation for the additional market and technical research conducted by this study. At a minimum, we avoid duplicating discussions and work already done by these stakeholders, but on a strategic level, the results of this study should feed in directly into the future updates to the Strategic Plan.

### 5.4.5 National/Regional ZNE Efforts

In general, the effort in California is the most advanced in the country, but there are elements of other programs that are worth noting. This study has included the lessons learned and current direction of these efforts as part of our data collection and analysis efforts.

*Zero Energy Commercial Buildings Consortium (CBC)*

Nationally, the Zero Energy Commercial Buildings Consortium (CBC) works to coordinate a broad-based industry/ government collaborative of about 500 organizations to move the commercial sector to ZNE levels of energy performance. The CBC, which is managed by the National Association of State Energy Officials (NASEO), was funded by a three year grant from the U.S. Department of Energy (DOE). The Steering Committee includes many national organizations and trade associations, such as AIA, ASHRAE, USGBC, ASE and NBI, as well as representatives from PG&E and the CPUC that represent California interests.

The initial work of the CBC included extensive committee process work that resulted in the development of two publications, one focused on technology needs and recommendations, and the second on market and policy gaps and recommendations. In 2012, NASEO and NBI produced a status report on ZNE in the country which reviewed the types, features and costs of ZNE commercial buildings. The study documented 21 ZNE buildings and an additional 39 potential ZNE buildings that were either still under construction or could not provide enough data to verify zero-energy performance. The initial DOE funding has nearly expired, and NASEO and NBI are working to develop other sources of funding to support ZNE related policy advancements at the state and local government level. Reports and more detailed information about the CBC are available at www.zeroenergycbc.org.

# 6. Research Findings

In this section of the report, we outline key findings that provide answers to several important questions regarding the policies, feasibility, challenges and opportunities for achieving the ZNE goals. Unless expressly noted, ZNE (the definition and the goal) refers to the Strategic Plan definition and goals.

## 6.1 ZNE Goals will Help Achieve California Greenhouse Gas Reduction Goals

ZNE goals will play a significant role in allowing regulatory agencies and the utilities to promote efforts for meeting greenhouse gas reductions goals for the state. ZNE goals will help spur efforts to promote greater energy efficiency in buildings as well as distributed renewable generation in buildings and/or communities. Both energy efficiency and renewable energy generation will help the state meet its 2050 greenhouse gas emissions goals.

ZNE goals have also been identified as supporting the state's clean energy jobs growth efforts and thus serve an important economic function.

## 6.2 ZNE Goals Are Not Mandated

It is important to note that the ZNE goals identified in the Strategic Plan and the IEPR are aspirational goals that provide a longer term target for the CPUC and CEC respectively. The general concept of ZNE is currently not mandated in any form. Moreover, from a legal perspective, there are no legal consequences for the state if the ZNE goals are not met.

Regulatory agencies are bound by their respective rules of cost-effectiveness to balance a given policy's potential benefits against its potential costs and unintended consequences. The ZNE goals are no exception to these rules. Thus meeting the ZNE goals is not a foregone conclusion if ZNE does not meet the criterion used by the regulatory agencies – which currently differs by agency – to make policy decisions.

The findings and recommendations from this study therefore do not presume that the ZNE goals will be achieved. Our findings and recommendations are intended to inform and assist future policy decisions to be made by regulatory agencies IF they want to meet their stated ZNE goals.

## 6.3 The ZNE Market is Early in its Development, with Significant Remaining Uncertainties

There is a virtual consensus among stakeholders that California is not currently on the correct trajectory to meet the 2020 and 2030 ZNE goals. Several significant outstanding questions about the potential impacts of the ZNE goals must be addressed regarding: the potential impacts of the ZNE goals on the electrical grid; the amount of distributed generation needed to achieve the ZNE goals; the costs of achieving the ZNE goals; and whether the ZNE goals are the most cost-effective method to achieve greenhouse gas reductions in the state.

The immediacy of the 2020 residential new construction ZNE goal emphasizes the need for state agencies to address these significant outstanding questions soon.

The sum of the literature review, interviews and analyses conducted for this study point to a decidedly mixed picture about the status of the ZNE goals in the state.

On the positive side, the ZNE goals continue to garner attention from various market actors and there are several early adopters who are boldly experimenting with various methods of pursuing the general concept of ZNE. For example, California currently has the highest number of ZNE Site buildings of any other state in the country – and the diversity of ZNE Site buildings is growing. The explanation for ZNE Site is discussed in Section 6.6.2.

Many of the early adopters see the ZNE goals as an inevitable outcome in the future and want to be ahead of the curve to differentiate themselves from others who may soon follow. At the same time, cost, technology and policy challenges faced by these early adopters need to be addressed in a timely manner if others are to be encouraged to follow in their footsteps.

On the flip side, the market is still in a 'proof-of-concept' stage in terms of experimenting with the ZNE goals. The number of ZNE buildings is still tiny compared to the overall rate of construction (even with the economic downturn that has resulted in historically low construction starts). It is important to remember that the motivations of the early adopters are inherently different than those of the rest of the market. Our research indicates that those designing ZNE buildings are doing it for various reasons but they all share one thing in common – they are willing to experiment and try new ideas.

The essential challenge for achieving the ZNE goals is to learn from the experiences of the early adopters and apply those lessons learned to motivate, and if needed, mandate changes. We say this because achieving the ZNE goals will require the type of rapid changes in current industry practices for design, construction and operation that cannot be achieved through incentives alone.

Relative to many other industries the construction industry as a whole is not an industry that innovates at a fast pace on a large scale. Our interviews with stakeholders demonstrate that the majority of the construction industry will only adopt any ZNE metric as a construction practice once two things are clear: (1)there is a sustained market demand for that metric of ZNE; and (2) the resulting buildings are deemed cost-effective and 'feasible' by market actors and building owners/operators.

## 6.4 Deep Energy Efficiency Should be the Foundation of ZNE

As a guiding principle for this project, the ZNE goals will be most beneficial to California if a proper loading order is established for pursuing any metric of ZNE for a given building. This will ensure that regardless of the metric used, the efforts towards achieving that metric are all moving in the same direction and towards a common goal.

The loading order or 'steps to ZNE buildings' includes:

- Minimizing building loads
- Optimizing system efficiency based on equipment efficiency and use
- Using highest efficiency appliances
- Optimizing building operations to better meet occupant and energy efficiency needs
- Improved occupant interactions with the building
- Renewable power generation when feasible and as a last step for a ZNE building

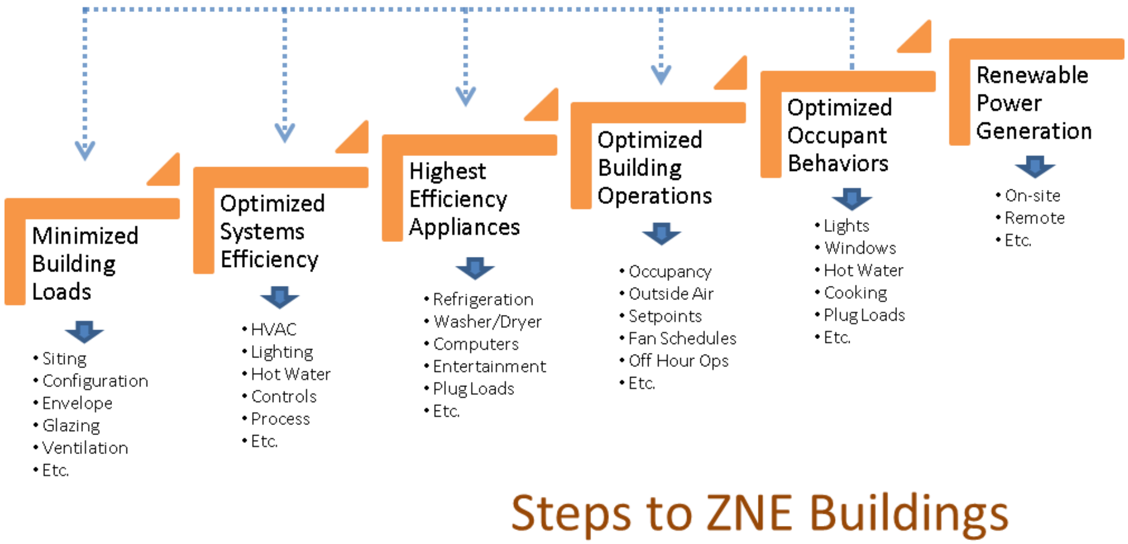



*Figure 6: Steps to Achieving ZNE Designs for Individual Buildings*

It should be noted that the steps above are not prescriptive in nature and that there are several overlaps among the steps. With each step and as a whole, a ZNE building will be driven by what is technically feasible and in the case of many building owners, what is cost-effective. There may be tradeoffs made between the categories and steps shown above for a given building based on these criteria.

The basic tenets of these steps to ZNE buildings apply across all buildings. There are certain common truths about ZNE that all stakeholders we interviewed agreed on:

- A ZNE building should be a highly efficient building in terms of how it is designed and operated,
- A ZNE building should reduce customer electricity bills, and
- ZNE buildings should create societal benefits in terms of carbon emission reductions and reduced need for electricity generation facilities.

Thus we conclude that specific energy efficiency targets – energy use intensity (EUI) in terms of kBtu/sf/yr consumed onsite – should be established for various building types and by climate zone to provide a common reference point for different ZNE metrics. The Technical Feasibility Study will provide valuable data to support the creation of such energy efficiency targets and state agencies should look to its findings as a starting point for establishing those targets.

Once the EUI targets are established for various building types, they can become the rallying point for the targeted efficiency level regardless of the specific ZNE metric chosen. Thus, a building designed using the TDV metric or a building designed using site energy metrics should target the same site EUI in terms of kBtu/sf/yr.

However, it is equally important that the different ZNE metrics are marketed and used appropriately. This means that it is not important just to say ZNE but to specify which ZNE metric is being used such as 'ZNE TDV' or 'ZNE Equivalent' versus 'ZNE Site'. Further discussion on ZNE metrics can be found in Sections 2.4.6 and 6.6.2.

## 6.5 The Breadth of ZNE Planning is Very Expansive and Will Require a High Level of Coordinated Effort

If the state regulatory agencies are to achieve the ZNE goals, they will need an extensive set of both policy and market intervention tools to help make the aspirational goals a reality. In this section, we outline the pathway elements available to put the state on the path to pursuing the ZNE goals. Pathways in this instance refer to strategies, policies and activities that are under the purview of state regulators to move the market towards pursuing the ZNE goals. Further, there are multiple parallel pathways to get to the same goal and each has a particular appeal to specific market actors. The complexity of the pathway elements will require integrated planning and coordinated implementation.

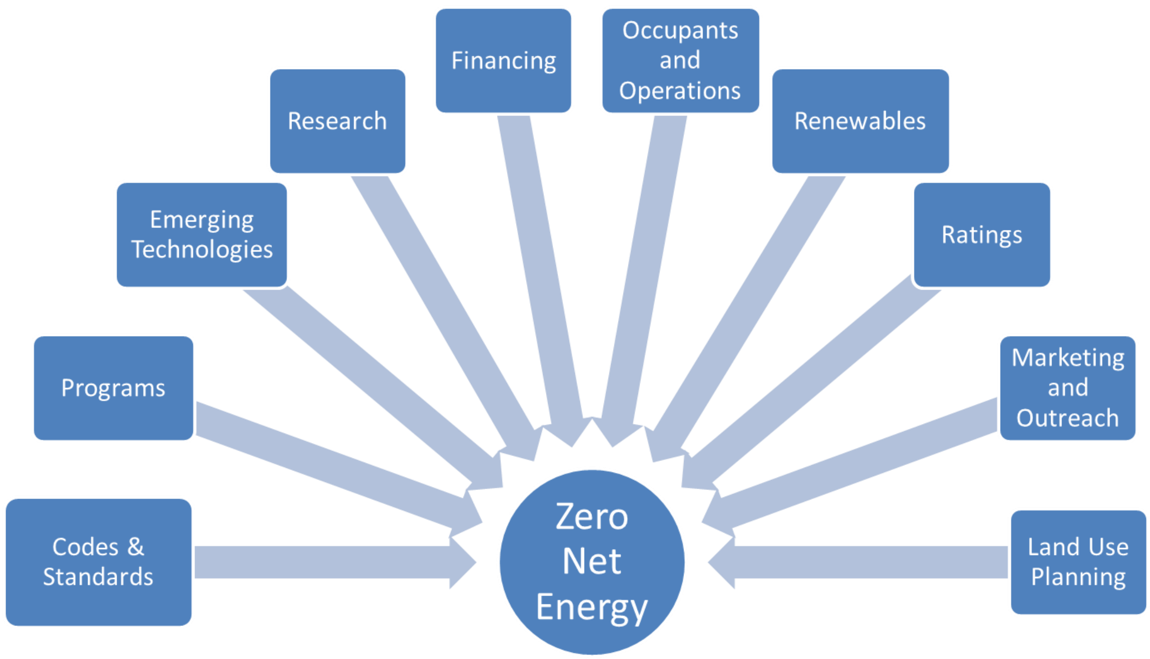
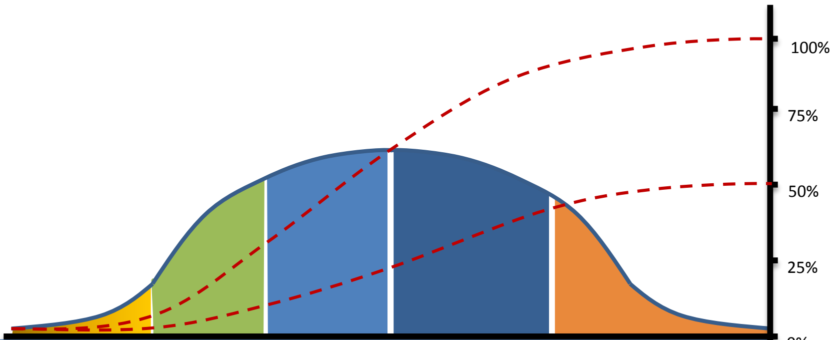



*Figure 7: Multiple but Supportive Paths to ZNE*

Comparing the pathways to the Diffusion of Innovation curve[1], Figure 8 shows where the various pathways are currently aligned to the market and ZNE goals. Most of the ZNE early efforts are focused on early adopters largely through a combination of incentives and research efforts. In this graphic, a capital “X” denotes where the pathways is currently most aligned with the market actors with the innovation curve, whereas a “Y” denotes where it does have some potential to influence the market as things currently stand.

[1] Diffusion of Innovation, E. M. Rogers, 1962




**Current Status**

| Pathways | Innovators | Early Adopters | Early Majority | Late Majority | Laggards |
|---|---|---|---|---|---|
| Codes and Standards | | | Y | **X** | **X** |
| Programs and Incentives | | **X** | **X** | X | |
| Emerging Technologies | x | **X** | Y | | |
| Research | **X** | **X** | X | | |
| Financing | | Y | | | |
| Occupants and Operations | | | | X | X |
| Renewables | | **X** | | | |
| Building Ratings | | Y | Y | Y | Y |
| Marketing and Outreach | | **X** | | | |
| Land Use Planning | NA | NA | NA | NA | NA |

*Figure 8: Current Status of Pathways as Applied to ZNE*

The following subsections outline why and how these pathways need to be involved in achieving our ZNE goals IF the ZNE goals are to be seriously taken.

## 6.5.1 Codes and Standards

Codes and standards are regulatory mechanisms that mandate energy efficiency features for buildings and appliances. In California, there is a rich history starting in the early 1970's for both aggressive and progressive standards for building (Title 24 Part 6) and appliance energy efficiency (Title 20).

In addition to these 'traditional' codes and standards efforts, there are now two other avenues available for improving the energy performance and renewable integration of buildings:

- The California Green Building Code (CALGreen) is formally Title 24, Part 11 and was first adopted in 2008. Since then it is being updated on a triennial cycle. The current CalGreen standards are the 2010 version of the standards and the next version will be the 2013 CalGreen standards. The Building Standards Commission (BSC) formally adopts the standards through a cooperative effort with the Department of Housing and Community Development (HCD), the Division of State Architect (DSA), the Office of the State Fire Marshal, the Office of Statewide Health Planning and Development (OSHPD) and the California Energy Commission (CEC).
- Separate from the statewide CALGreen effort, local jurisdictions can also adopt reach codes that go beyond the base Title 24 building standards.

The Title 24 Part 6 and Title 20 efforts are led by the CEC which was established by the Legislature in 1974 to address the energy challenges facing the state. Created by the Warren-Alquist State Energy Resources Conservation and Development Act[1] (Warren-Alquist Act) the CEC is the state's principal energy policy and planning organization.

The Warren-Alquist Act directs the CEC to "Prescribe, by regulation, lighting, insulation, climate control system, and other building design and construction standards which increase the efficiency in the use of energy for new residential and new nonresidential buildings." The Act also provides for similar directives for energy efficiency retrofits to existing buildings at the time of renovations, alterations and retrofits.

The Act also requires that the Standards be cost effective "when taken in their entirety and amortized over the economic life of the structure," and it requires that the Energy Commission periodically update the Standards and develop manuals to support the Standards. The Act directs local building permit jurisdictions to withhold permits until the building satisfies the Standards.

The CEC in coordination with industry and with strong support of the California Investor Owned Utilities (IOUs) has proven leadership in the country in moving the California market to efficient products and strategies. California has consistently updated its building energy efficiency standards (Title 24 part 6) and appliance efficiency standards (Title 20) at regular intervals through a rigorous and public process.

Traditionally, codes and standards have been focused on the laggards – at the tail end of the innovation curve – to move them to industry standard practices and eliminate energy waste. However, recent efforts have begun to focus on market actors further up the innovation curve as a means to move the market as a whole to greater efficiency.

### *CALGreen (Title 24, Part 11)*

Title 24 Part 11 – referred to as CALGreen henceforth – is a comprehensive set of 'green' measures including planning and design, energy efficiency, water efficiency, material conservation and resource efficiency and environmental quality. It is important to note that CALGreen applies to new construction only.

CALGreen has both mandatory requirements that are required across the state and voluntary provisions that could be adopted by local jurisdictions and which go beyond the mandatory requirements in their efficiency targets. The voluntary provisions are called as Tier 1 and Tier 2 where Tier 2 is intended to require greater levels of efficiency.

From a ZNE perspective, the most relevant provisions of CALGreen are the energy efficiency provisions contained within CALGreen in both the mandatory requirements and voluntary tiers. The mandatory energy efficiency provisions in CALGreen are essentially the current Title 24, Part 6 requirements whereas the voluntary Tiers are currently pegged at a percent beyond Title 24 (15% for Tier 1 and 30% for Tier 2). The CEC is responsible for the energy portion of the part 11 requirements.

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[1] http://www.energy.ca.gov/reports/Warren-Alquist_Act/index.html

For this reason, this report will combine the discussion of CALGreen energy requirements along with the Title 24, Part 6 requirements below.

## *Title 24 Part 6*

Title 24, Part 6 – referred to as Title 24 henceforth – primarily targets energy use (electricity, natural gas and other fuels) of buildings. Title 24 covers a broad range of buildings both residential and nonresidential including buildings that have either/both conditioned and unconditioned spaces as well as certain buildings with high process loads such as refrigerated warehouses. Title 24 however does not apply to California Building Code building group I, which includes hospitals, daycare, nursing homes, and prisons.

The CEC is the lead agency in charge of Title 24 development and conducts regular proceedings to update the Title 24 standards roughly on a three-year update cycle.

Title 24 Part 6 has three types of regulations:

- Mandatory requirements – minimum efficiency specifications that must be met by all covered buildings and end uses
- Prescriptive requirements – a check-list based approach where specific measures are required to be installed and limited substitutions are allowed
- Performance requirements – a energy simulation based approach where the overall energy use of the building is to not exceed the energy of a building built to the prescriptive requirements

The mandatory requirements are primarily targeted to the laggards who have shown no motivation to improve efficiency of their building and thus must be mandated to achieve a minimum level of efficiency. Prescriptive requirements on the other hand are often targeted at the late majority of adopters and form the 'baseline' for the performance approach. While the focus is on the late majority and laggards, however, there have also been several instances where the standards have promoted advanced technologies through compliance credits in the performance approach.

The Title 24 update process includes a formal rulemaking process where measures for proposed inclusion are analyzed for:

- Technical feasibility – can the measure be consistently applied to save energy and peak demand
- Cost-effectiveness – does the measure save energy and peak demand at a cost that meets the stringent cost-effectiveness criteria as outlined in Section 5.5 of this report
- Market feasibility – is there adequate experience in the market place for the installation, operation and maintenance of a measure being proposed for inclusion in the standards. This also includes that fact that a given technology being required or promoted by the standards is easily available from multiple manufacturers.

While the CEC is responsible for developing the building energy efficiency standards, the job of enforcing the regulations is up to the individual local building departments at each city and town. The persons responsible for enforcing the regulations have multiple other responsibilities in addition to enforcing the energy efficiency portion of the code. The rigor of enforcement of standards is thus highly dependent on the structure and staffing at local jurisdictions. Therefore a fourth – if informal – criteria has emerged over the years:

- Simplicity of the code – there is almost uniform agreement among local jurisdictions and construction industry professionals that Title 24 is difficult to enforce and is too complex due to the variety of energy efficiency measures incorporated in the standards.

Thus for Title 24 to adopt a measure/technology it by definition needs to be a mature technology that can have a broad distribution across the state and be easy to enforce.

Some exceptions to this enforcement model are:

- Schools – Compliance with Title 24 and other standards is overseen by the Division of State Architect (DSA)
- State buildings – these are overseen by the relevant state agencies including the DSA and Department of General Services (DGS)

In each of these and other similar building types, the enforcement is more or less centrally controlled by an organization that is responsible for compliance across the state. In these instances it is possible to maintain consistent protocols for compliance with the standards.

### *Suitability for ZNE*

Title 24, of all the pathways available, provides the most direct and sustained path towards the ZNE goals. Since Title 24 standards can mandate energy efficiency features and in the future may require certain renewables on or around buildings, Title 24 can ensure that all new construction projects – residential and commercial buildings that it covers – achieve a ZNE level design specification. Once a standard goes into effect it ensures that all construction following the adoption of standards continues to be specified at levels of efficiency (and potentially renewables) in the standard for perpetuity. Savings for every new construction building constructed to the Title 24 standards continue to accrue over the life of the building and equally important, savings continue to be achieved for buildings constructed every year since the standard is adopted. It thus has a broad and sustained reach above and beyond what the market can achieve through natural adoption rates.

The CEC has identified a path to ZNE as part of the Integrated Energy Policy Report (IEPR) by outlining Zero Net Energy as a policy goal as explained in Section 0 of this report. Beyond the general policy goal outlined in the IEPR, the CEC codes and standards staff leads have publicly expressed their goals for sustained improvement in the Title 24 standards in each consecutive update to the standards. Figure 4 shows the standards adoption cycles available between now and 2020. Essentially we have two code update cycles available each for Title 24 and CALGreen before we are to meet the 2020 residential ZNE goals.

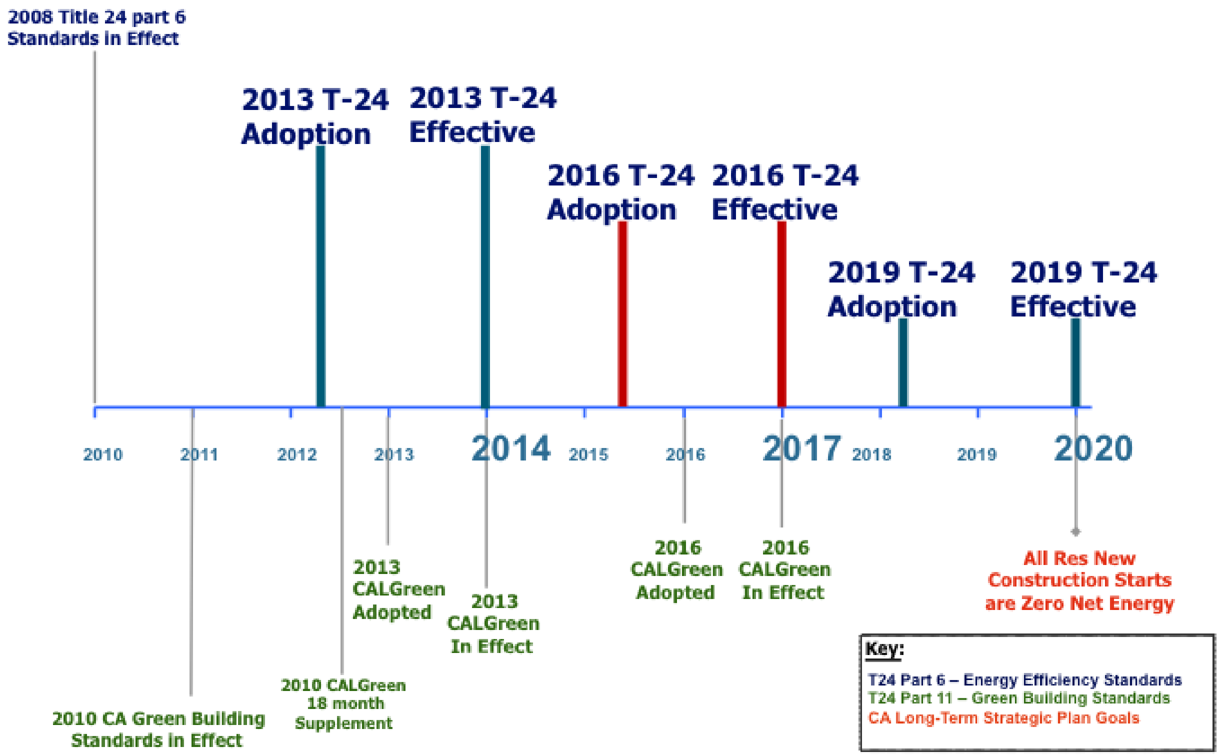


*Figure 9: Title 24 and CALGreen Update Cycles Through 2020*

It is however, important to note the following aspects of Title 24 which impact which portion of the innovation curve it can impact and therefore what measures it can target in the next two code cycles:

- Title 24 is a standard based on technical merit and rigorous cost-effectiveness analysis and is not a committee process as is the case with other standards such as 90.1
- Title 24 development is a formal rulemaking process that involves stakeholder engagement and feedback to ensure that requirements are not onerous and the market is amenable to the changes proposed – though this is not a consensus process.
- As explained in more detail below and in Section 6.5.1 of this report, Title 24 standards cannot be adopted unless the standards are cost-effective as a whole. In practice however, individual measures have been subjected to the cost-effectiveness test through the history of Title 24 development. As we move closer to 2020 (for residential) and 2030 (for commercial) ZNE goals, it is very likely that some measures may not be cost-effective on their own but still be cost-effective when packaged with other measures.
- Title 24 only affects that portion of the building energy use that is tied to the building envelope and systems that are installed at the time of initial occupancy. Thus there are several end-uses that Title 24 does not directly regulate such as portable lighting in homes, consumer appliances and many process loads.
- There are number of instances where Title 24 (and Title 20) are pre-empted by federal standards – more on this later in this section – so that there are limits to what efficiency levels it can propose for adoption for various appliances that it can regulate such as air conditioners and water heaters.

- The energy provisions of the CALGreen standards depend on the base Title 24 standards and are thus subjected to same set of criteria as the base Title 24 standards.

As a result of these factors, Title 24 has historically focused on the late majority and laggards as defined by Rogers in the market to establish a floor for the energy efficiency features in buildings.

### *Market Barriers to Increased Title 24 Stringency*

Due to the nature of Title 24 rulemaking process, measures need to be readily available and cost-effective on their own before a measure can be adopted into code. A number of measures needed for achieving ZNE goals or to be on the path to ZNE are measures that have limited traction in the market place and thus limited data on their viability.

An example of this is Codes and Standards Enhancement (CASE) proposal submitted by the California IOUs to update the residential roof insulation measures for 2013 Title 24[1]. This CASE report proposed several measures to increase the insulation in vented attics where the insulation was installed above the roof deck or just below the roof deck. Concerns were raised during the rulemaking process whether the roof deck insulation measures would create problems of moisture penetration through the roof deck or of creating moisture due to condensation on or below the roof deck. A study was commissioned by CEC to look into this and a report submitted by Building Sciences Corporation[2] using hygrothermal simulation analysis concluded that moisture was not likely to be a big concern in most all climate zones in California except the coldest. However, those opposed to the proposed requirements had a valid claim that no one had tried these installation techniques in the field and verified that the simulation results can be verified. Further, since no one had experience with roof deck insulation among the large home builders in the state, this uncertainty was a cause for concern. As a result of this, the 2013 standards backed away from roof deck insulation in favor of the more traditional attic insulation.

There are other examples such as Quality Insulation Installation (QII) where the measure itself is technically feasible and does not add significant cost to the construction. However, there is still limited experience with these techniques in the market place. Requiring QII would meet all of the technical criteria for standards improvement but due to the lack of experience in the market place, this measure was again not included in 2013 Title 24.

Another important barrier for codes to reach ZNE level performance specification is the cost of achieving ZNE. Current examples of ZNE buildings have substantial incremental costs associated with them - $50,000 to $100,000 per home according to a couple of early adopters. To put this in perspective, the average incremental cost increase for the 2013 standards was around $3000 in the central valley and this cost increase got pushback from the industry. For ZNE codes, the

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1 http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/2013_CASE_R_Roof_Measures_Oct_2011.pdf

2 http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/Hygrothermal_Analysis_of_California_Attics-BSC.pdf

costs of measures need to drop significantly and/or measure combinations need to have enough market traction for Title 24 to consider measures for adoption.

## *Limits to Title 24 Regulated Loads and Federal Preemption*

As outlined by McHugh in the Path to ZNE report[1] the percent of building energy use for residential buildings that is regulated by Title 24 is about half of the total building energy use. Using data from the Residential Appliance Saturation Survey (RASS), McHugh separates the energy end uses by those regulated by Title 24, those that cannot be regulated by Title 24 and those where federal preemption of California regulations limits what Title 24 can regulate as seen in Figure 10.

Over half of home electricity consumption <u>not</u> covered by T-24

| End-Use | kWh/yr | |
|---|---|---|
| **Not covered by T-24** | **3,612** | **54%** |
| Dryer | 187 | |
| Clothes Washer | 109 | |
| Dish Washer | 73 | |
| First Refrigerator | 707 | |
| Additional Refrigerator | 313 | |
| Freezer | 138 | |
| Range/Oven | 105 | |
| Television | 645 | |
| Microwave | 122 | |
| Home Office Equipment | 17 | |
| Personal Computer | 602 | |
| Well Pump | 28 | |
| Miscellaneous | 568 | |
| **T-24 + Preempted** | **1,106** | **17%** |
| Conv. Space Heating | 37 | |
| Heat Pump Space Heating | 13 | |
| Aux Space Heating | 0 | |
| Central Air Conditioning | 876 | |
| Room Air Conditioning | 47 | |
| Water Heating | 133 | |
| **T-24** | **1,927** | **29%** |
| Furnace Fan | 164 | |
| Attic Fan | 14 | |
| Evaporative Cooling | 43 | |
| Solar Water Heating | 0 | |
| Pool Pump | 234 | |
| Spa | 25 | |
| Outdoor Lighting | 284 | |
| Spa Electric Heat | 28 | |
| Lighting | 1,136 | |
| **Total** | **6,645** | |

| End-Use | Therm/yr | % |
|---|---|---|
| **Not Covered by T-24** | **51.4** | **14%** |
| Dryer | 16.2 | |
| Range/Oven | 31.7 | |
| Miscellaneous | 3.5 | |
| **T-24+ preempted** | **309.0** | **83%** |
| Primary Heat | 175.8 | |
| Conv. Gas Water Heat | 133.2 | |
| **T-24** | **10.2** | **3%** |
| Pool Heat | 5.6 | |
| Spa Heat | 2.9 | |
| Auxiliary Heat | 1.6 | |
| **Total** | **370.5** | |

**Not Covered by T-24**
Plug loads are installed after building inspection and are not covered by T-24

**T-24 + Preempted**
T-24 is preempted from requiring higher equipment efficiency but T-24 can impact the loads on equipment (envelope eff, controls etc.)

**Covered by T-24**
Loads and equipment efficiency can be regulated by T-24

*Figure 10: Percent Residential Energy Use Covered by Title 24*

Just over half of a home's electricity consumption is not covered by Title 24 regulations. In addition federal preemption of appliance efficiencies limits what Title 24 can regulate for another 17% of the home electricity use. Thus in effect, Title 24 can comprehensively impact just under a third of the total electrical use of a typical California home under the current rules.

Further, federal appliance standards set both the 'floor' and 'ceiling' for what appliance efficiency can be used in building energy efficiency standards as outlined in this ACEEE paper by Chase et al[2]. In this paper, Chase et al make the argument for why federal preemption is a barrier to building codes by outlining that the federal appliance standards are designed to

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[1] http://www.zne2020.org/PathToNetZero_v1.0.pdf

[2] http://www.aceee.org/files/proceedings/2012/data/papers/0193-000415.pdf#page=1

prevent “backdoor legislation” by requiring that state energy codes cannot require higher equipment efficiencies than NAECA requirements unless there is at least one or more optimal combination of measures that meet the state energy code requirements using the NAECA efficiency levels for appliances. Further the federal standard requires that any performance calculation approaches to meet the code (such as the performance path in Title 24) must use federally required efficiency of appliances as its baseline.

A number of alternatives have been tried by various jurisdictions in the past to get around this federal preemption. Chase et al outline a few of these in the paper and for the sake of readability, we are summarizing below:

- The most common path (and one California continues to apply) is to set state standards in advance of federal rulemaking. However, this path has limited success since the largest energy using appliances (heating, cooling, water heating) are already federally pre-empted.
- California has in the past sought a waiver from federal preemption such as that for a higher EER rating for air conditioners. However, this process is time consuming, costly and has almost always resulted in a rejection of the waiver request. This has led to costly lawsuits and other legal proceedings that take further time and money.
- In 2007, the City of Albuquerque adopted the 2006 International Energy Conservation Code (IECC) with local amendments. One of the local amendments was to prescriptively require higher equipment efficiencies than federal standards without any alternative paths for equipment with federal minimum efficiencies to meet the code. The Air Conditioning, Heating and Refrigeration Institute (AHRI) successfully sued the city and blocked the implementation of this energy code.
- IECC itself and a few other states have adopted an approach of using multiple pathways to compliance where for each approach that uses higher efficiency equipment, there must be another approach that uses standard efficiency equipment and uses similar amount of energy. The 2012 IECC, state of Washington and State of Oregon each have been successful in using such parallel path approaches.

## *Limitations of Assumptions in Title 24 Calculations*

It should be noted that Title 24 makes a number of assumptions about various appliance and end use operational schedules as well as energy use densities. Most of these are based on previous market studies that have developed synthetic averages of a broad range of variance in energy use patterns.

These assumptions are fine when comparing a proposed building with a hypothetical one that has the same geometry and equipment density (as in the Title 24 performance path) but when used for a truly performance-based metric such as ZNE Site there is a potential for significant divergence from the code projected energy use and actual energy use.

An example of this is discussed in Appendix C for residential thermostat energy use compared to Title 24 assumptions.

## *Title 20 Appliance Standards*

California's Appliance Efficiency Regulations (California Code of Regulations, Title 20, Section 1601-1608) or Title 20 in short for this report cover the efficiency and labeling of various appliances used in residential and commercial buildings.

## *Suitability for ZNE*

Unlike Title 24 which is updated on a triennial cycle, Title 20 is a continuous improvement model. The CEC is the agency responsible for updating Title 20 requirements and must conduct a public rulemaking process similar to Title 24. A growing sector of residential and commercial building energy use is plug loads – an area where Title 20 can show substantial leadership in the nation and assist achieving ZNE goals.

Chase et al present the following statistics in their paper on the amount of electricity and natural gas savings possible statewide if all appliances sold had the best possible technical performance (the 'max-tech' scenario or technical potential).

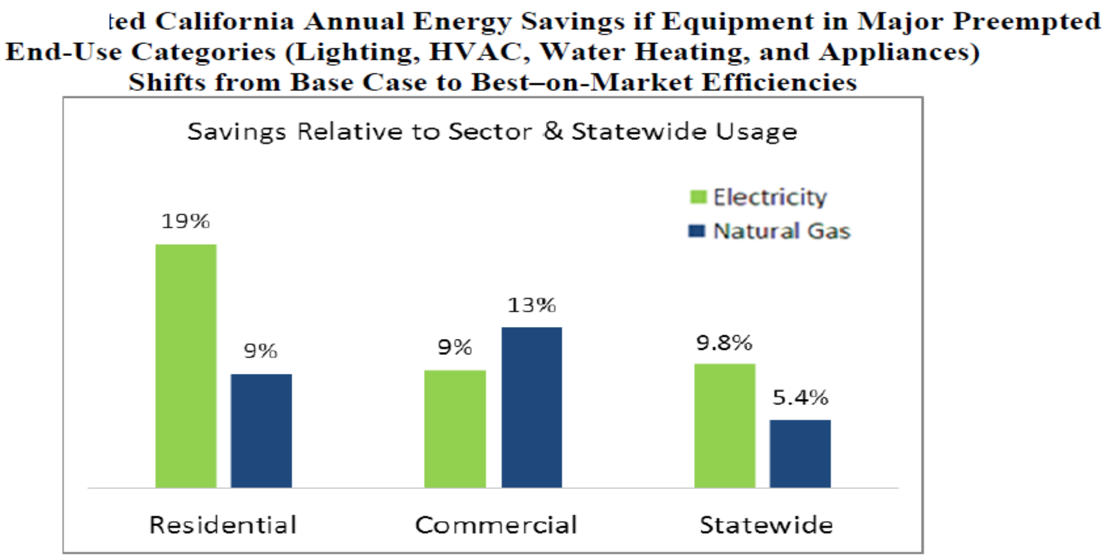



*Figure 11: Analysis of Projected Statewide Savings for Appliances Meeting Technical Potential*[1]

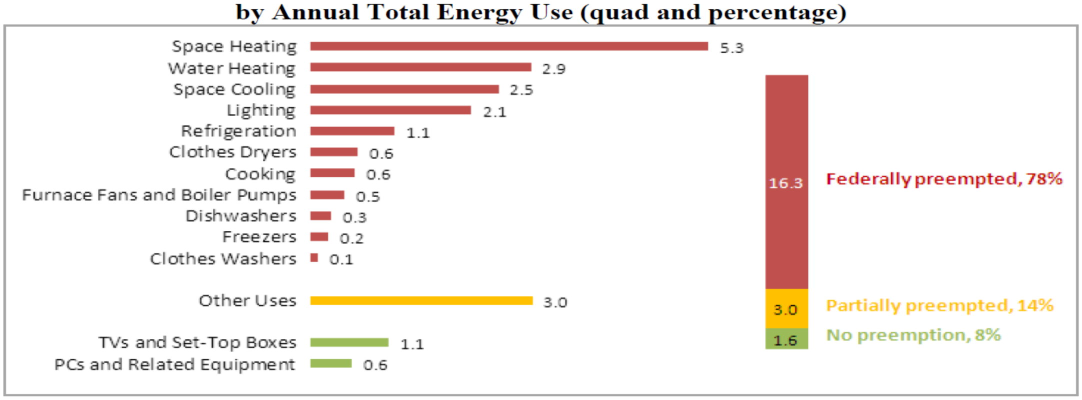
Chase et al project savings close to 20% of total residential stock electricity consumption and 9% natural gas savings. For Commercial buildings, the savings are projected to be 9% for electricity consumption and 13% for gas consumption. These are substantial savings opportunities, but one must be cognizant of the serious barrier to achieving this through Title 20 – namely federal preemption of appliance efficiency.

[1] http://www.aceee.org/files/proceedings/2012/data/papers/0193-000415.pdf#page=1

## *Federal Preemption*

To get a sense of the amount of appliance energy use that is federally preempted, we refer to the ACEEE report by Chase et al which shows the amount of US residential and commercial equipment stock that is covered by federal appliance standards under the auspices of the Department of Energy (DOE):

**U.S. Residential Equipment Stock, Covered and Uncovered by DOE, by Annual Total Energy Use (quad and percentage)**



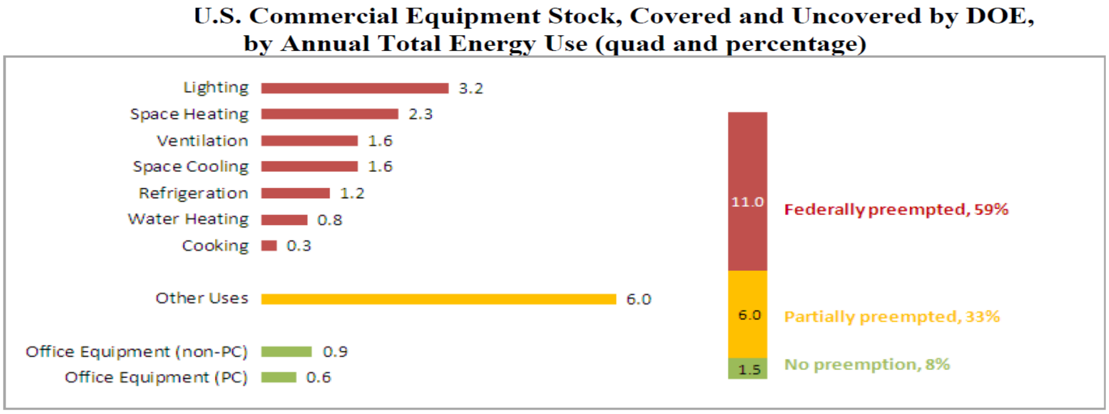

Source: Authors' analysis of the *Annual Energy Outlook 2011* (EIA 2011a). Quad values are for 2012. The major equipment types within the "Federally preempted" category are all preempted, but there may be some smaller loads that are not covered by DOE standards. For example, the lighting category includes some product categories that are not currently covered by DOE standards, such as multifaceted reflector lamps. The "Other Uses" category includes all products not included in the other categories, such as audio equipment, game consoles, vacuum cleaners, DVD players, coffee makers, etc.).

*Figure 12: US Residential Equipment Stock Covered by Federal Appliance Standards*

The overwhelming majority of equipment is federally preempted. The other uses constitute plug loads and small appliances – a rapidly increasing portion of the residential energy use. These end uses are considered partially preempted by Chase et al since they use components that have federal standards such as external power supplies. A small portion – 8% of household equipment stock in terms of its annual total energy use – is not covered by federal appliance standards for residential appliances. These include TVs and Set-Top Boxes and PCs and related equipment.

A similar story exists on the commercial side with about 80% of the energy use federally preempted from being targeted through more rigorous state codes as seen in Figure 13. The "other uses" in this instance is the largest energy using component and is potentially available for states to target. However, as the paper points out, this sector includes energy used for processes not amenable to standards such as combined heat and power and manufacturing performed in commercial buildings. The end uses available for state regulation include office equipment such as computers, servers, monitors and imaging equipment.

The CEC has moved aggressively to target the appliances that are currently not federally regulated. In 2009, CEC adopted the nation's first standards for TVs and DOE is not actively pursuing standards for TVs in 2013. Once those federal standards go into effect, California and other states would be barred from increasing the stringency of their state standards beyond the federal requirements.




Source: Authors' analysis of the *Annual Energy Outlook 2011* (EIA 2011a). Quad values are for 2012. The major equipment types within the "Federally preempted" category are all preempted, but there may be some smaller loads that are not specifically covered by DOE standards. The lighting category includes some product categories that are not currently covered by DOE standards (e.g., MR lamps). The "Other Uses" category includes equipment such as service station equipment, ATMs, telecommunications equipment, medical equipment, pumps, emergency generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings, plus residual fuel oil, liquefied petroleum gases, coal, motor gasoline, and kerosene.

*Figure 13: US Commercial Equipment Stock Covered by Federal Appliance Standards*

The CEC has initiated an Order Instituting Rulemaking (OIR)[1] in 2012 that outlines a three-phase plan for updates to Title 20 that address appliances currently not preempted by federal standards.

| Topic | Phase 1:<br><br>Short Term<br>(2nd Qtr 2012 – 2nd Qtr 2013) | Phase 2:<br><br>Mid Term<br>(2nd Qtr 2013 – 2nd Qtr 2014) | Phase 3:<br><br>Long Term<br>(2nd Qtr 2014 – 2nd Qtr 2015) |
|---|---|---|---|
| Consumer Electronics | Displays;<br>Game consoles;<br>Computers;<br>Set-top boxes | Servers;<br>Imaging equipment | Low power modes;<br>Power factor |
| Lighting | Dimming ballasts;<br>Multi-faceted reflector (MR) lamps;<br>Light-emitting diode (LED) lamps | EISA exempt lamps;<br>Lighting accessories;<br>Outdoor lighting | Linear fluorescent fixtures; |
| Water and Other | Commercial clothes dryers;<br>Toilets and urinals;<br>Air filter labeling;<br>Faucets;<br>Amend pools and spas standards<br>Water meters | Plug-in luminous signs;<br>Irrigation equipment | Commercial dishwashers;<br>Recirculation pumps;<br>Refrigeration condensing units |

*Figure 14: 2012 CEC OIR for Appliance Standards Proceedings*

Under Phase 1, CEC has initiated rulemaking proceedings on battery chargers and Light-emitting Diode (LED) lamp specifications. The LED rulemaking is being coordinated with the CPUC to

[1] http://www.energy.ca.gov/appliances/2012rulemaking/notices/prerulemaking/2012-03-14_Appliance_Efficiency_OIR.pdf

develop performance specifications for LED lamps to avoid the repeat of the CFL experience where the evaluations of incentive programs found poor performance of CFL lamps was a major impediment to greater market adoption of CFLs.

These efforts are certainly laudable and should be supported through CASE and other efforts. At the same time the larger issue of federal preemption still remains as a barrier to improving California's appliance stock.

### 6.5.2 Incentives and Rebates

California has an equally rich history of promoting energy efficiency and demand reduction through programs that provide monetary and other forms of assistance to new construction and existing buildings. The California Public Utilities Commission oversees majority of the state's energy efficiency programs that are implemented through the IOUs and 3rd party implementers. CPUC led programs go through a rigorous program design, implementation and evaluation process that is unparalleled in the country.

In addition to the CPUC overseen programs there are publicly owned utilities such as the Sacramento Municipal Utility District (SMUD) that run their own energy efficiency, demand response and renewable programs but these programs do not always use the same set of rules and cost-effectiveness metrics as the CPUC-led programs.

In this section of the report, we focus on programs led by the CPUC and specifically those programs that target new construction. These programs target a wide swath of the innovation curve – from early adopters through the late majority.

New construction energy efficiency programs are being run on a statewide basis in the 2010-2012 program portfolio with the goal of having uniform names, rules and regulations, incentive levels and delivery mechanisms. For single family residential buildings, there is the California Advanced Homes Program while Savings By Design (SBD) continues to be a statewide program for nonresidential buildings. In addition, there are various multifamily energy efficiency programs including 3rd party programs such as the California Multi-Family New Homes Program (CMFNH) and Energy Upgrade California.

A common thread to all of these new construction programs are the following elements:

- Energy savings targets based on a "percent better than code" approach – the currently enforced Title 24 code becomes the baseline compared to which the programs target specific efficiency levels – e.g. 15% better than code as the minimum efficiency threshold. This structure in principle is similar to the percent better than code targeted in reach codes (Tier 1 and Tier 2 for CALGreen and local reach codes).
- Financial incentives pegged to "percent better than code" – the incentive monies assigned to program participants are pegged at performance thresholds above code such that the greater the savings compared to code, greater the financial incentives.
- Project team design and energy analysis support – while there are variations across programs, each of the new construction programs offers support to the design teams and energy analysts by either providing direct financial assistance (e.g. SBD) or through design consulting (e.g. SBD, CMFNH)
- Trainings – each program conducts outreach and education efforts to educate the project teams, trades and interested parties on various topics including design, analysis, construction and maintenance of buildings.

## *Relevance to ZNE*

Energy efficiency programs provide a critical function in moving the early adopter and early majority spectrum of the diffusion curve towards higher levels of energy efficiency. Energy efficiency programs take concepts, strategies and technologies that have advanced beyond the proof of concept phase through the emerging technologies programs and other early innovation efforts and apply them to buildings in an integrated manner. The importance of integration of energy efficiency technologies into the overall building fabric cannot be emphasized enough especially for ZNE designs. The market assessment interviews conducted for this study highlight the importance of integrated design for ZNE and the ability of design and construction teams to integrate energy efficiency concepts from early design to construction completion. Energy efficiency programs provide a valuable support function in achieving these goals by providing monetary incentives for higher efficiency, but equally important is the design support and training that the program provides to participants.

Energy efficiency programs have proven to be a good conduit for measures to be included in codes and standards.  Some examples of this include daylighting controls in commercial buildings, high efficiency windows, advanced insulation techniques such as exterior insulation just to name a few. Programs offer an opportunity to evaluate both the efficacy as well as technical and market feasibility of measures in the context of whole building solutions. Further, program participants serve as an example for other market actors to adopt similar measures/strategies or savings targets by proving their viability.

## *Challenges*

The primary challenges for new construction programs from a ZNE perspective are:

- Cost-effectiveness of programs
- Lead time between design and construction
- Efficiency levels targeted through programs

Below we explore each of these challenges in brief.

New construction programs provide a higher degree of financial and training support to participants than many other utility or 3rd party programs due to the nature of new construction projects and the need to innovate beyond the baseline title 24 standards. As standards improve so do programs that target efficiencies beyond code, which means they are supporting efforts by design teams to identify and integrate innovative solutions. The cost of these innovative solutions and the knowledge of integration them into building designs are primary barriers to greater market adoption, and new construction programs need to address both of these barriers in order to succeed. New construction programs need to get involved at the early design stages in order to influence building design decisions and continue support of the design teams through construction.

At the same time, new construction programs need to balance these needs against the TRC metrics used for evaluating program viability. Residential new construction programs particularly find themselves well short of the TRC thresholds deemed sustainable for programs. As one looks ahead to programs supporting ZNE goals, there will be a need to provide even greater support to the design teams and greater incentive levels in order to move beyond the very early adopters currently active in the ZNE sphere. This will put greater strain on program cost-effectiveness and may influence decision-making by those involved with designing and evaluating cost-effective portfolios. The CPUC rules do allow flexibility for the utilities to design their portfolios such that programs with less than ideal TRC are still supported and enhanced by combining them with other programs that have high TRC. However, as we move towards 2020 and 2030, programs will be targeting smaller amounts of energy savings (as codes improve) while the monetary and educational challenges will become even more pronounced. Thus, there will be greater strains on the overall portfolio cost-effectiveness when new construction programs ramp up to meet the greater challenges of ZNE.

### *Lead Time between Design and Construction*

New construction projects have a long lead time between when the building design is initially conceptualized to when the building completes construction. The first challenge this presents is one of the time available between now and 2020/2030. Utilities and third party program implementers have already begun efforts to promote ZNE but they would need to enhance these efforts to reach a broader section of the market between now and 2015. This time horizon is critical to have enough experience built up for ZNE that codes and standards and other more top-down approaches could be applied in time to reach the 2020 residential ZNE goals.

The second challenge in terms of lead time is the timing of projects versus the timing of utility and 3rd party program cycles. Since programs typically run on a three year cycle and are evaluated on their performance during the cycle, it puts strain on the programs to target projects with longer lead times. Often program efforts in one cycle will not show impacts until the next program cycle kicks in. Thus continuity of programs, consistency in messaging and focus on a longer term goal is critical to ensure that ZNE projects – which will take more care and attention – get the proper assistance through programs but more importantly, they also ensure that the programs get due credit for their efforts towards the long term goals.

### *Efficiency Levels Targeted Through Programs*

New construction efficiency programs target efficiency levels in terms of ‘percent better than code’ and have minimum thresholds for program participation. On average new construction programs target efficiency levels between 10 and 30 percent beyond code. From a ZNE perspective, efficiency levels that need to be targeted are between 40-70 percent beyond current code – levels that are certainly being achieved on some current new construction program projects but not across the board. While there is value in continuing the lower performance levels for resource acquisition and moving the market, greater emphasis needs to be put on the higher performance levels required to reach ZNE.

Another challenge for new construction programs from a ZNE perspective is that codes only target certain building end uses whereas ZNE requires attention to all building end uses regardless of whether they are regulated or not. Thus a 50 percent better than code building may still have a lot of non-regulated loads that will make the ZNE goals hard to achieve.

A more sustainable solution may be for programs to target specific efficiency levels in terms of energy use intensity (EUI) for all end uses either in place of or in addition to the percent better than code approach. The results of the ZNE Technical Feasibility study should be useful to the utilities and 3rd parties in designing the EUI levels.

### 6.5.3 Emerging Technologies

Emerging technologies programs target the innovators and early adopters in the diffusion curve by assessing the technical viability of new technologies and strategies for energy efficiency.

The IOUs each run their emerging technologies programs under the auspices of the CPUC, while SMUD also has a very active emerging technologies program. The IOUs and SMUD together with CEC and CPUC coordinate a statewide initiative called the Emerging Technologies Coordinating Council (ETCC) that acts as a forum to discuss opportunities and findings from studies.

#### *Relevance to ZNE*

The emerging technologies programs strive to identify promising technologies that may have the potential to save energy through a series of activities. The activities of emerging technologies programs are varied but generally cover technology development support, technology assessments in laboratory and field settings, demonstration projects in the field and accelerating the path of innovative technologies into utility and 3rd party programs. The spectrum of efforts range from working with individual manufacturers to multiple customer participants in field studies to collaboration with laboratories, universities and standards organizations.

With respect to ZNE, emerging technologies programs have a critical and timely role to play. Many of the technologies needed to achieve ZNE level performance in buildings are still being developed and are in various stages of commercialization. Technologies used for the current crop of ZNE buildings – a limited number – are innovative and require care and attention in their design, installation and maintenance that is not likely to be available for all new construction projects. Efforts are therefore needed to identify methods of integrating these innovative technologies in the broader market. Improvements in technologies are needed to ensure that results from early examples can be translated to the broader market in a sustained manner. In other cases, such as the residential roof insulation measure discussed in earlier in this report, there are measures which are technically feasible but there are questions about their viability for energy efficiency due to other concerns such as moisture that need to be answered through laboratory and field studies. The emerging technologies programs are well suited to do this role and accelerate the adoption of measures into energy efficiency programs.

An area that emerging technologies programs are particularly well suited to address is development of technologies. Many ZNE buildings will require smaller HVAC systems that have variable speed compressors and fans. Currently available technologies in both residential and commercial buildings generally don’t offer smaller sizes of equipment at higher efficiencies required for ZNE. When smaller sizes are available, these units are less efficient than their larger counterparts. An example of this highlighted by the Technical Feasibility study is that of residential furnaces. These are not available in the smaller sizes required for ZNE homes and thus may push ZNE buildings to electrically heated solutions such as heat pumps. Heat pumps in turn don’t come in smaller sizes needed for small ZNE homes.

Another area where the emerging technologies programs have a role to play is to understand how occupants interact with these innovative systems. This is especially true of systems whose operation is tied to occupant interactions such as natural ventilation, fenestration daylighting controls, energy feedback devices and others. While improving technologies is critical, it is equally important to understand how the technologies will be used and how occupant preferences can be better accounted for in technology development.

### 6.5.4 Research

In addition to the utility emerging technology programs, there is a broader need for research with a longer term focus – the type of research typically funded through the public interest energy research (PIER) program. While the PIER program sunsets at the end of the year for electricity efficiency research, the Electric Program Investment Charge (EPIC) starts in 2013. The program will be overseen by the CPUC and administered through the IOUs and CEC respectively with the CEC getting the lion's share of the money. This PIER/EPIC research shares common elements with the emerging technologies programs but has the potential to offer specific benefits to ZNE as outlined below.

#### *Relevance to ZNE*

While the emerging technologies programs conduct technology specific research, the authors of this report believe that PIER and EPIC can play a complementary and expanded role in understanding the conditions that affect building energy use such as occupant behavior, feedback to energy use and market characteristics in addition to larger field based and laboratory based studies. An example of field-based studies as also of collaborative research is the Efficiency Characteristics and Opportunities for New California Homes (ECO) study[1] funded by PIER and co-funded by the IOUs through the codes and standards program. This study surveyed the construction features of recently constructed buildings with specific focus on residential air conditioning systems. Once the features were identified and potential problems documented, the study then also conducted follow-up field studies to implement energy efficiency upgrades to evaluate their feasibility and modality. These retrofits were then studied for inclusion in the 2013 Title 24 changes and many were successfully implemented in the standards. These types of research studies are best suited for PIER/EPIC since they cover large number of buildings, identify systemic challenges to building energy efficiency and identify solutions that can be translated to programs and codes and standards as well as emerging technology assessments.

Indeed there is still a lot unknown in terms of the performance of current ZNE buildings and lessons that can be learned from them. The PIER/EPIC programs are ideally suited to study the operation and maintenance of existing ZNE buildings and identify specific future emerging technologies and research needs.

Plug loads and plug load efficiency is another area that needs more research since this is a segment of the building energy use that is least understood but likely to become most important for ZNE buildings.

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[1] http://www.energy.ca.gov/2012publications/CEC-500-2012-062/CEC-500-2012-062.pdf

### 6.5.5 Financing

The inevitable question arises around the cost of doing the additional efficiency and renewables for ZNE buildings and who will pay for them. ZNE currently and will continue to cost more money upfront at the time of construction but may provide greater paybacks over the operation of the building. While the longer term benefits are tempting, there is still the challenge of getting the building constructed first.

The challenges are more severe for existing buildings where the efficiency upgrades are both a cost and cash-flow issue. For most all commercial and residential projects, financing is a foundational element that drives decisions about project features. For owner-occupied buildings, the decisions may be driven more by longer term benefits but for home built for sale and commercial buildings built for lease, the owner has less incentive to add costs to the construction of the building when they won't see the longer term benefits.

Thus there is a need to identify financing mechanisms that encourage energy efficiency and renewable investments in buildings. The CPUC and IOUs have long provided on-bill financing solutions for commercial customers and there are efforts currently underway to significantly expand financing opportunities for existing buildings both through CPUC funded mechanisms as well as leveraging the private lending market. Privately owned financial institutions (banks, funds and other financial entities) are increasingly showing interest in energy efficiency upgrades as a business opportunity.

On January 10, 2012, CPUC Administrative Law Judge Julie Fitch filed a Ruling on Energy Efficiency Finance[1] that proposes the development of a larger efficiency financing program supported with both ratepayer funds and private capital funds. The ruling includes staff proposal to significantly increase financing opportunities budgeted at a total of $180 million over two years including:

1. Development of an on-bill repayment (OBR) mechanism where customers can get loans from private entities but still repay the loans through monthly utility bills.
2. Development of ratepayer-supported loan products to selected customer segments and for specified purposes, including use of OBR.
3. Continuation of utility on-bill financing until on-bill repayment becomes more widely available.
4. Collecting and sharing aggregate loan and project data with lenders to build a knowledge base and inform project risk analyses.

Similar efforts are needed on the new construction side to fund the increased costs of energy efficiency of ZNE buildings.

[1] http://www.cpuc.ca.gov/NR/rdonlyres/183F35A6-7E21-4349-9EB9-997705F94203/0/ALJRuling.zip

### 6.5.6 Building Rating Schemes

The market is expecting ZNE to be a performance metric. At the end of the year, the expectation is that the building will net a 'zero' for something – whether it is site energy or energy bill or societal costs. However, our policy tools starting with codes and standards and then utility programs that target performance better than standards are largely geared towards asset rating for buildings as opposed to performance guarantees. This is largely due to the fact that our policy tools are normally applicable during the planning/design/permitting stages and it is impossible to provide a performance guarantee for a building when much is unknown at the time of design and construction about who will occupy the building and how they will use the building energy systems.

A number of asset ratings have been implemented or are currently under development. For example, the European Union, the US Department of Energy (DOE), the Massachusetts Department of Energy Resources (DOER), and the American Society and Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) are developing asset rating systems (Crowe, et al 2010). In California, the California Home Energy Rating System (HERS) is currently being used for residential buildings, while the California Commercial Building Energy Asset Rating System (BEARS) is being developed by the California Energy Commission for commercial buildings. Detailed explanations of each of these asset ratings are included in Appendix I: Building Rating Schemes and Initiatives.

Asset ratings can be a powerful tool to compare the efficiency potential between buildings, as designed and to track progress towards the ZNE new construction goals. However, it is also important to understand how the building is actually performing when in operation. This is an especially crucial task in ZNE buildings, when unknown factors like installation quality, plug loads, operational methods and occupant behavior can greatly affect whether the building is reaching ZNE targets. This is where operational ratings of buildings come into play.

There is currently one performance rating metric with significant traction – namely the Energy Star Portfolio Manager (ESPM) which provides building ratings by comparing a given building to its peers when accounting for location, climate and building type/size. There are limitations to the ESPM tool from a ZNE perspective – namely that it covers a limited set of buildings but more important, the maximum rating possible in ESPM (100) is NOT a ZNE building but rather the most efficient building in the peer group. The California Building Energy Use Rating Tool (CBEURT) is being developed by the CEC to provide operational ratings for commercial buildings in California. "The CBEURT utilizes the same information as the ESPM to generate a rating that is based on California specific metrics and referenced to net zero source energy consumption" (Regnier 2012). In contrast to the ESPM rating, where higher scores are better, in the base rating scale of CBEURT, "an EUI of zero yields a rating of zero, while an EUI equal to the median value for a particular building type will always yield a rating of one hundred" (Regnier 2012).

One emerging opportunity to bridge the divide between predicted (design) building energy use verses actual operational energy use in ZNE buildings are evolving building energy labeling and reporting requirements across the state that are encouraging building owners and operators to disclose building energy performance ratings. A detailed description of the emerging labeling and ratings schemes is provided in the appendices.

A building labeling system could be leveraged to set building energy performance goals during the planning and entitlement phases of the building lifecycle and provide a uniform mechanism for tracking performance as the project moves through various stages of the building lifecycle. However, there is no well-established mechanism to track these performance goals from the entitlement stage through the design stage to actual operation. It is critical that the building performance labeling system have both an asset (design) and operational rating to enable this transition from entitlement to operation.

Building energy labeling is still a "work in progress" with multiple disparate initiatives and a patchwork of requirements emerging. ZNE stakeholders will need continued and strong involvement in the development and implementation of these building labeling initiatives. For further discussion on building rating schemes, see Appendix I: Building Rating Schemes and Initiatives.

## 6.5.7 Outreach and Training

There is a need for sustained efforts to provide information about the benefits of ZNE, convey the basics of ZNE effectively and train those who will be involved with designing, constructing and maintaining ZNE buildings.

### *ZNE Marketing and Messaging*

In the minds of some of the early adopters, ZNE touches on the core values of energy independence (on a building or community level), energy cost savings and societal good. However, the devil is in the details – what metrics are used for evaluating ZNE, the costs of doing ZNE and the benefits of ZNE.

There are disagreements over the definition of ZNE and other details which need to be resolved soon. However, these differences should not be a reason to prevent the market actors from promoting the benefits of ZNE. The common goals of ZNE – energy efficiency and utility bill reductions – do not change between the different approaches, just their mix. Messaging should thus be built on these common elements. Early adopters – especially on the residential side – have commented on the lack of consumer demand for ZNE as a barrier. Thus a bottom-up effort to promote the benefits of ZNE is needed to generate more interest for ZNE and in the process encourage people beyond the early adopters to embrace the ZNE concepts.

### *Workforce Education*

Another important barrier to overcome is the nature of the construction industry with its multiple trades and their relative lack of coordination and training. ZNE construction will require attention to quality of construction, coordination of the trades (electrical, plumbing, roofers, HVAC, framers and insulation installers for instance for residential) and learning new skills (due to use of new and innovative technologies). As the ECO study referenced in Section 6.11 identified, we do not currently do quality construction for things that are common construction techniques, let alone innovative techniques. If ZNE is understood as a performance metric, quality construction is an absolute must to achieve ZNE performance levels.

Current utility programs do include workforce training components and these need to be enhanced to educate a larger portion of the workforce in more depth on measures needed for ZNE.

### *Building Operator/Occupant Education*

Lastly, but perhaps most important, the performance of a ZNE building will ultimately depend on how the building is operated. But this is not just a case of 'getting people to do the right thing'. Rather this involves understanding how people use building and how operators operate buildings. Research strategies as outlined in section 6.11 are critical to understanding occupants/operators. Lessons learned from these studies need to be widely disseminated so that future building occupants and operators can learn from the lessons of the early adopters and equally important, technology developers and promoters can design offerings that take advantage of occupant preferences.

### 6.5.8 Land Use Planning

Land use planning refers to the activities that happen prior to a building is even designed or imagined – including zoning of available land for residential/commercial/mixed use, size/location/orientation of lots and provision of basic services (utilities, roads) among other things. These set of activities have their own set of stakeholders – most of whom do not participate in the building energy efficiency or renewables proceedings.

#### *Relevance to ZNE*

Land use planning is currently an under-utilized pathway for energy efficiency in general and ZNE in particular. There have been various studies that have shown the correlation between density of development, proximity of services and other land-use planning aspects to energy use. Four different aspects of land use planning often get lumped together in discussions about energy use and ZNE:

- Density of development – how many units of residential or commercial buildings are on a given lot
- Impact on transportation – mixed-use developments or transit-oriented developments that reduce use of automobiles
- Orientation of individual lots in a subdivision – the impact of street layouts and thus lot layouts on building energy use and PV output
- Infill growth versus greenfield development – the challenges of incorporating energy efficiency and PV in infill developments where orientation and size options are limited. Another aspect is the types of developments allowed in infill versus greenfield development

A number of prominent researchers including David Goldstein of the Natural Resources Defense Council (NRDC) have made arguments for looking at ZNE from a holistic perspective of building and transportation energy use that address all four of these aspects of land use planning.

McHugh presents the following graphic adapted from a 2002 paper by Holtzclaw et al[1] that shows how energy use reduces between a single family home and a multifamily dwelling as well as the overall building energy use including transportation when buildings are smaller and located in more dense neighborhoods closer to public transit.

[1] Holtzclaw, John; Clear, Robert; Dittmar, Hank; Goldstein, David & Peter Haas (2002). Location Efficiency: Neighborhood and Socio-Economic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles and San Francisco. Transportation Planning and Technology Volume 25, Issue 1, 2002

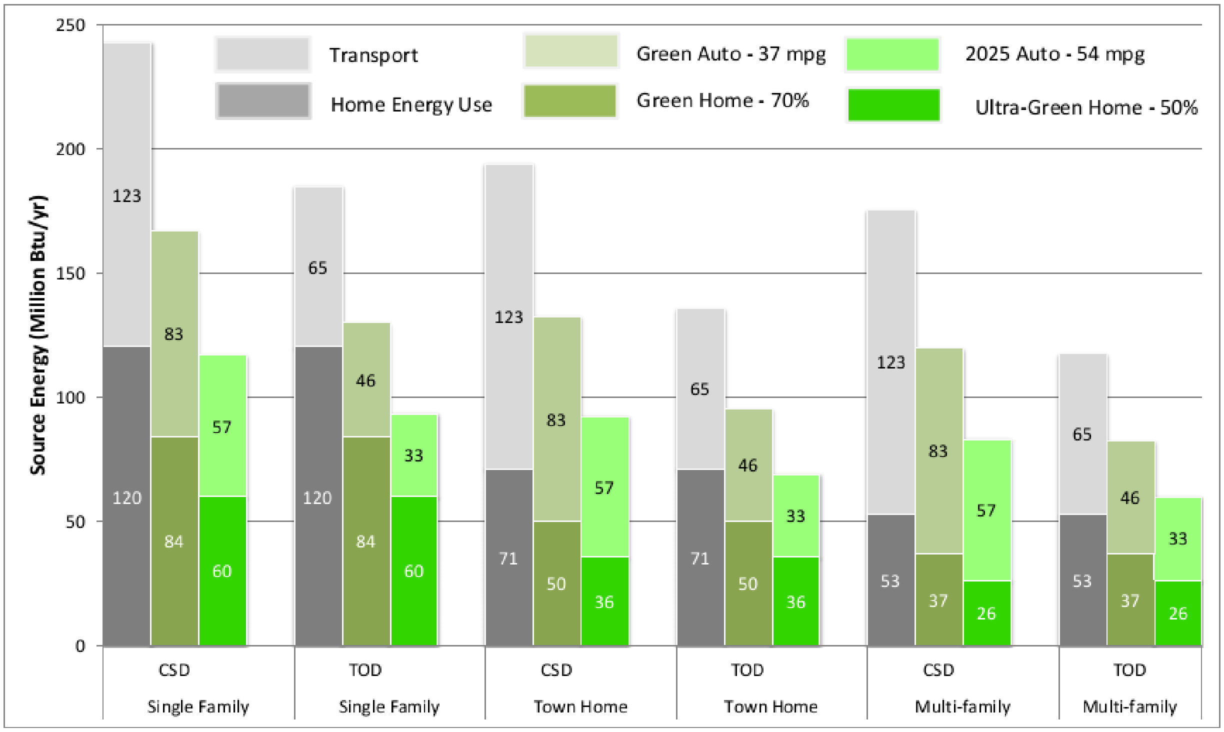


*Figure 15: Energy Use in Buildings and Automobiles by Type of Residence (TOD = Transit Oriented Development; CSD = Conventional Suburban Development)*

On one hand, creating denser neighborhoods with shared energy resources may make ZNE goals more feasible due to the lower energy use per above.

However, higher density also means that it may be more challenging for individual buildings to reach ZNE with onsite renewables. This is especially important in cities with taller buildings. The percent of commercial floor area able to reach zero net energy decreases exponentially with the increase in the number of floors (Torcellini 2006). This is because daylighting and solar potential decreases while plugs loads increase relative to heating and cooling needs (Brown 2012). Thus it may be preferable to look at alternate ZNE definitions such as ZNE Equivalent or ZNE Capable discussed in Section 6.6.2 which provide the same energy efficiency gains as other ZNE definitions without the rigid requirements for onsite renewables.

Denser neighborhoods can also allow people to travel less. Studies have shown reduced transportation energy in denser neighborhoods when compared with suburban (less dense) neighborhoods. Researchers such as Goldstein have argued that ZNE should include transportation energy while others have argued that ZNE should allow tradeoffs between onsite renewables and savings in transportation energy.

When looking at ZNE buildings, defining building boundaries is still under debate. For example, should denser neighborhoods be credited for decreased user transportation? And how can we handle the introduction of electric vehicles (EVs) to the grid? On one hand, if charged at home, EVs can significantly add to the building load. On the other hand, EVs also have the potential to provide energy storage as distributed generation increases (Brown 2012). A detailed analysis of the impact of transportation on ZNE buildings is out of the scope of this study, but warrants further examination.

Separate from issues of density and urban/suburban growth is the issue of layout and design of subdivisions when developments do happen in more suburban/rural areas where more land is available per building. The energy use of buildings and the potential output from a PV system are affected by the orientation of the building and the orientation of roof/windows. A 2013 CASE study looked into several communities that have been recently constructed from the lens of lot and roof orientation[1]. Communities that were designed to be solar communities and those that paid more attention to orientation issues show a better chance of achieving the maximum PV output – community-wide - as seen in Figure 16.

As the report says: "This has significant implications for various state policies, but is particularly relevant to the California Homebuyer Solar Option and Solar Offset Program (SB1, 2006), which requires production homebuilders to offer solar as an option to all homebuyers. Installing solar systems on typical production home developments without consideration for solar oriented development in earlier planning phases will likely result in a 5% to 10% reduction in overall PV output. There is even larger variation between individual homeowner system performance."

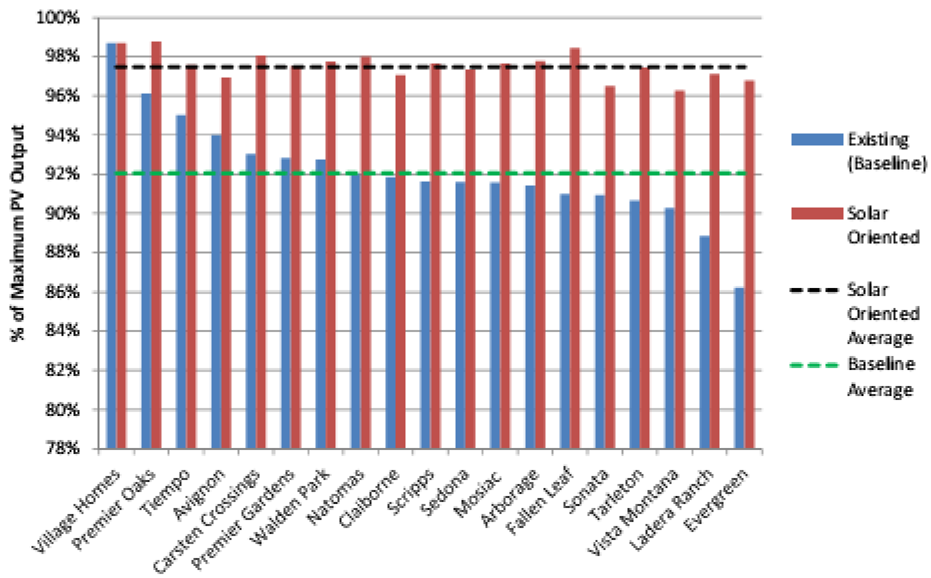


*Figure 16: Impact of lot orientation on solar output*

## *Challenges*

The primary challenge with including land use planning as a pathway to ZNE is that this area of policy-making is a completely separate set of efforts from the energy efficiency/renewable efforts in the state. Further, land use planning is for the most part a local jurisdiction issue when it comes to making specific land use determinations.

The other significant challenge is that land use planning brings into focus the third leg of California's energy use – automotive gasoline usage – that by itself is a complex set of issues that go beyond the state boundaries and into national issues. This study does not look into the locational efficiency related issues, however further studies are needed to better understand

1 http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/2013_CASE_R_Solar_Ready_Solar_Oriented_Developments_Sept_2011.pdf

the correlation between dense neighborhoods and ZNE. While the concept is indeed intriguing and good arguments have been made for why a joint approach for building and transportation energy should be looked into, there are several practical challenges to making this a reality. There have been studies (including the Holtzclaw study referenced above) that have outlined the broader trends but the challenge is to convert these higher-level analyses into actionable strategies that work at a project-by-project level. At its best, we will encourage more sustainable communities, but if not done well, the tradeoffs between energy/PV/transportation could water down the ZNE concept and result in greater energy use than a pure ZNE framework based on building energy use alone.

A more incremental step – if not necessarily easier – would be to target orientation of subdivisions and lots for energy efficiency and PV production. The 2013 CASE efforts have made initial recommendations in this regard, but more work is needed to bring in stakeholders and decision-makers from the land use planning field to make the CASE recommendations a reality.

### 6.5.9 Renewables

If energy efficiency is one side of the ZNE equation, renewables are the other side of the equation. Once cost-effective energy efficiency is achieved renewables either on-site or within a development are essential to achieve ZNE performance on an annual basis unless ZNE Equivalent or ZNE Capable definitions are adopted.

While there are several renewable options available to make a building ZNE, currently the most popular is solar photovoltaic (PV) and in particular rooftop solar PV. As outlined in more detail in Section 6.8 there are a number of renewable policies that affect ZNE including:

- Rules and policies around net export of electricity to the grid from distributed generation
- Utility rate structures and their impact on customer and TDV cost-effectiveness of solar
- Promoting community scale solutions where appropriate
- Offsetting natural gas usage with on-site renewable electricity sources, or other renewable energy
- Strengthening the grid infrastructure to handle both the large amount of distributed renewable energy necessary for ZNE and for the large flow of electricity back to the distribution network during certain times

## 6.6 ZNE Policy Framework

### 6.6.1 Regulatory Authority and Responsibility

One of the primary misconceptions in the market is that the state has ZNE mandates. As explained in section 6.1 this is not accurate. Currently, there is no mandate – regulatory or legislative – that requires the achievement of ZNE goals outlined in the Strategic Plan and the IEPR.

The closest we could come to a mandate for ZNE buildings in the future is through the Title 24 process which is under the CEC's regulatory authority. But as discussed in section 6.5.1, the CEC can only exercise this regulatory power IF the measures needed to achieve ZNE goals are cost-effective, have market traction and have proven to be effective. Further, Title 24 may not regulate all of the building energy use components due to federal pre-emption and jurisdictional issues.

The CPUC through energy efficiency and distributed generation programmatic activity can provide incentives (monetary, training, education, design support) as a way to encourage the market actors to adopt ZNE goals. However, it is our understanding that the CPUC by themselves cannot mandate ZNE.

The only true authority that can mandate the state to meet some form of a ZNE goal is the California Legislature, which has powers under the state constitution to make laws and mandates. At least one attempt has been made to mandate ZNE goals but it has not been successful. Assemblyperson Saldana proposed a legislative mandate for 2020 ZNE goals, but ultimately was turned down by the Senate Housing and Transportation committee. (AB 2112, 2008)

### 6.6.2 ZNE Definitions and Metrics

The study team coordinated with the CPUC, CEC, PAG and other interested market actors on the operational definition and methods of evaluating what constitutes ZNE. We do not intend to replace the current CPUC efforts to define ZNE. Instead, we have provided our inputs and perspectives on the impacts of the ZNE definition for the IOUs, CEC and CPUC to consider when making decisions regarding the final definition of ZNE.

It is important to note that previous 'definitions' often conflate two separate but related ideas – a definition that defines the goal and metrics that are used to measure or quantify or translate the goals in practice. This report focuses on the metrics for quantifying ZNE goals.

Previously, at the national level, ZNE metrics and definitions fell into four main categories:

- Site Energy
- Source Energy
- Cost
- Emissions

The details of these metrics, their advantages and their limitations have been previously documented (Goldstein 2010, Torcellini 2006, McHugh 2012, Brown 2012) and are briefly summarized in the sections below and outlined in Figure 17 (reproduced from Torcellini 2006).

| Defintion | Pluses | Minuses | Other Issues |
|---|---|---|---|
| **ZNE Site** | • Easy to implement.<br>• Verifiable through on-site measurements.<br>• Conservative approach to achieving ZNE.<br>• No externalities affect performance, can track success over time.<br>• Easy for the building community to understand and communicate.<br>• Encourages energy-efficient building designs. | • Requires more PV export to offset natural gas.<br>• Does not consider all utility costs (can have a low load factor).<br>• Not able to equate fuel types.<br>• Does not account for nonenergy differences between fuel types (supply availability, pollution). | |
| **ZNE Source** | • Able to equate energy value of fuel types used at the site.<br>• Better model for impact on national energy system.<br>• Easier ZEB to reach. | • Does not account for nonenergy differences between fuel types (supply availability, pollution).<br>• Source calculations too broad (do not account for regional or daily variations in electricity generation heat rates).<br>• Source energy use accounting and fuel switching can have a larger impact than efficiency technologies.<br>• Does not consider all energy costs (can have a low load factor). | • Need to develop site-to-source conversion factors, which require significant amounts of information to define. |
| **ZNE Cost** | • Easy to implement and measure.<br>• Market forces result in a good balance between fuel types.<br>• Allows for demand-responsive control.<br>• Verifiable from utility bills. | • May not reflect impact to national grid for demand, as extra PV generation can be more valuable for reducing demand with on-site storage than exporting to the grid.<br>• Requires net-metering agreements such that exported electricity can offset energy and nonenergy charges.<br>• Highly volatile energy rates make for difficult tracking over time. | • Offsetting monthly service and infrastructure charges require going beyond ZNE.<br>• Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates. |
| **ZNE Emissions** | • Better model for green power.<br>• Accounts for nonenergy differences between fuel types (pollution, greenhouse gases).<br>• Easier ZNE to reach. | | • Need appropriate emission factors. |

*Figure 17: Summary of ZNE Site, ZNE Source, ZNE Cost, and ZNE Emissions definitions. (Reproduced from Torcellini 2006.)*

In recent years, several other key terms have emerged when considering ZNE definitions, such as ZNE TDV, all-electric and zero electric. Figure 18 provides an overview of various infrastructural, cost and usage issues considered by these various terms.

| ZNE Definitions\Issues Considered | ZNE Site (Electric+Gas) | ZNE Site (All-Electric) | ZNE Site (Electric-Only) | ZNE Source | ZNE Code (TDV) | ZNE Capable | ZNE Equivalent | ZNE Energy Cost | ZNE Emissions |
|---|---|---|---|---|---|---|---|---|---|
| **All Cost-Effective Energy Efficiency** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Fuel Source Covered** | | | | | | | | | |
| *Electricity Consumption onsite* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Natural Gas Consumption onsite* | Yes | | | Yes | Yes | Yes | Yes | Yes | Yes |
| **Renewables Covered** | | | | | | | | | |
| *Onsite Renewables for Electricity Generation* | Yes | Yes | Yes | Yes | Yes | | | Yes | Yes |
| *Onsite Renewables for Natural Gas Offset* | Yes | | | Yes | Yes | | | Yes | Yes |
| *Offsite Renewables for Electricity Generation* | | | | | Potential | | Yes | | |
| *Offsite Renewables for Natural Gas Offset* | | | | | Potential | | Yes | | |
| **Tradeoffs** | | | | | | | | | |
| *Renewable Offsets/Credits for Electricity* | | | | | Potential | | Yes | | |
| *Renewable Offsets/Credits for Biogas* | | | | | Potential | | Yes | | |
| *Tradeoff renewables with Locational Efficiency* | | | | | Potential | | Yes | | |
| *Tradeoff renewables with Vehicular Miles Travelled* | | | | | Potential | | Yes | | |
| **Impact on Customer Utility Bill** | | | | | | | | | |
| *Zero Utility Bills* | | | | | | | | Yes | |
| *Zero Electricity Energy Use Charge (Based on Usage)* | Yes | Yes | Yes | | | | | Yes | |
| *Zero Natural Gas Energy Use Charge (Based on Usage)* | Yes | | | | | | | Yes | |
| **Electricity Grid Impacts** | | | | | | | | | |
| *Value of Reduced Emissions from Power Plants* | | | | | Yes | | | | Yes |
| *Value or Reduced Need for New Power Plants* | | | | | Yes | | | | |
| *Costs and Resources Needed for Grid Flexibility/Upgrade Costs* | | | | | | | | | |

*Figure 18: Issues considered by various ZNE definitions*

## *Current Metrics and Definitions in Regulatory Proceedings*

According to the California Energy Efficiency Strategic Plan January 2011 Update:

*"A ZNE home employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid. The CPUC has defined "Zero Net Energy" at the level of a single "project" seeking development entitlements and building code permits in order to enable a wider range of technologies to be considered and deployed, including district heating and cooling systems and/or small-scale renewable energy projects that serve more than one home or business".*

The 2011 Integrated Energy Policy Report (IEPR) developed by the California Energy Commission (CEC) outlines the following recommendation for ZNE definition:

*"The Energy Commission and CPUC should work jointly on developing a definition of ZNE that incorporates the societal value of energy (consistent with the time dependent energy valuation approach used for California's Building Energy Efficiency Standards)".*

The document further explains the societal value as envisioned by the CEC as:

*"While the ZNE idea is straightforward, translating the policy into standards, guidelines, and incentive structures requires collaboration between agencies and stakeholders. To maximize the alignment of ZNE with California energy system reliability and policy goals, the Energy Commission recommends the use of metrics that account for the societal value of energy, including the critical impact of avoiding peak demand and the value of avoided carbon emissions, and other energy system costs. These components are well-addressed in the time dependent valuation of energy concept used by the Energy Commission for its efficiency standards and the CPUC for its valuation of efficiency program savings."*

These are very important changes being proposed to the original ZNE definition in the Strategic Plan, and they have far reaching consequences in terms of how ZNE applies to new construction in urban versus rural areas, as well as development in green-fields versus urban infill development.

A number of key ZNE questions still remain unresolved even after this revised proposed definition and goal. Of all the fuels that can be used onsite, electricity offers the best option for most residential and commercial customer to achieve 'net zero' since they can add electricity back to the grid using readily available renewable generation technology on-site or at other locations. With all other fuels, with a few exceptions, one is essentially looking at minimizing consumption onsite, while inserting an equivalent amount of electrical energy back into the grid. Thus the energy use intensity (EUI) becomes a critical driver for ZNE. Another aspect that needs some additional attention is whether the TDV metric as it is currently defined by the CEC will address all of the concerns with operationalizing the ZNE definition.

## *"Traditional" Metrics*

### *ZNE Site Energy*

A ZNE Site building produces as much onsite renewable energy as it uses annually. This assumes that the building is connected to the grid and that extra energy can be bought and sold as needed.

One advantage of ZNE Site is that it is simple to quantify and to understand. However, ZNE Site does not differentiate between fuel types, so units of gas and electricity are interchangeable. This may lead to suboptimal technology choices when considering the larger grid mix and thermodynamic quality of the energy. For example, under a ZNE Site definition, electric heating would appear more favorable than gas heating. Overall, stakeholders have not come to a consensus about how to offset gas use on buildings. Currently, the three main options are: all electric buildings (ZNE Site all-electric), offsetting gas use with excess PV production (ZNE Site electric+gas), and ignoring gas use (ZNE Site electric-only) (Brown 2012).

With ZNE Site all-electric, the building only uses electricity as fuel for all energy end uses and achieves ZNE by offsetting electricity consumption with renewables. A ZNE Site all-electric building is also a ZNE Site building, except that the building must additionally have all-electric end uses.

A ZNE Site electric-only building only considers the electricity use of the building for the purposes of offsetting onsite energy use with renewables. So, if gas or other fuels are used onsite, these are not accounted for and thus ignored for ZNE purposes. A ZNE Site electric-only building may not be the same as a ZNE Site building or a ZNE Site all-electric building and will likely have a different energy mix and costs.

For ZNE Site electric+gas, gas use is offset in addition to electric use with PV production. The PV installation in this instance provides adequate energy to offset the energy content in both electric and gas uses and thus needs to be sized larger than the other two ZNE Site definitions. A significant implication of the site electric+gas definition is that it would require larger PV systems for a given building type than any other definition, including ZNE Source and TDV based definitions discussed later in this section of the report. For further discussion of this point see Section 6.8.1.

Given the high, but declining, first cost of PV systems the need for a larger PV system increases the challenge to make ZNE a cost effective proposition to building owners under the site definition. For further discussion of this point see Section 6.7.

## *ZNE Source Energy*

A ZNE Source building produces at least as much energy as it consumes annually, accounted for at the source of energy production. In contrast to a site energy based definition, source (or primary) energy ZNE definitions aim to account for the total amount of nonrenewable energy that is used to power a building. Here, fuel types are differentiated by the amount of energy used to generate, transmit, and distribute that energy to the building.

This model can be challenging because there is a need to develop source energy conversion factors for various fuel types and locations to account for generation, transmission, and distribution losses. As a rule of thumb, a source energy conversion factor of 3 is usually used for electricity.

Various studies have developed more detailed source energy conversion factors (Deru 2006, Torcellini 2006, AGA 2009). For the US, the source energy conversion factor is 3.13 for electricity and 1.09 for natural gas (AGA 2009).

However, national averages do not account for regional grid mix variability. When broken down by state, the source energy conversion factor for electricity in California is 2.45, significantly lower than the national value (AGA 2009).

These state breakdowns do not differentiate by time of use, which can have a significant effect on the source energy used. TDVs do account for this, in addition to regional differences. The ZNE TDV definition described below builds upon the ZNE Source concept.

When (and if) these source energy conversion factors are determined, the actual calculation is completed with simple multipliers. But, these factors should be updated regularly to reflect the current grid mix.

In contrast to the site definition, the source energy conversion factors can work to the building's advantage, resulting in a smaller PV system. If the local site to source conversion factor for electricity is 3, then the building needs to produce about 1/3 of the PV electricity that it would have to offset onsite electricity use under a site definition. Therefore, a smaller PV system can be used to reach a ZNE Source goal as compared to a ZNE Site goal.

One advantage to a source energy definition is that is has been adopted by other rating systems in North America and Europe. However, due to locational differences in grid mixes, source energy conversion factors will vary. So, achieving ZNE Source will also vary by location and may change over time (McHugh 2012).

## *ZNE Cost*

With a ZNE Cost building, the amount the utility pays the building owner (or ratepayer) is greater than or equal to the amount the building owner pays to the utility. While a zero net bill for energy generation may be appealing to consumers, zero net cost may not result in decreased energy use, costs to maintain the grid, or GHG emissions. Consequently, this definition may not serve other state goals, such as Assembly Bill 32. Further, unless the building were entirely disconnected from the electricity grid (by utilizing energy storage technologies in combination renewable generation for example), it would probably be difficult to achieve zero bills since the electric utility would still need to recover its fixed costs. Whether it is actually possible to achieve a "Zero Net Energy Cost" building while still being connected to the grid for back-up power will depend on a region's retail rates and other policies.

## ZNE Emissions

A ZNE Emissions building produces as much emissions free energy as it consumes from emissions producing sources, which accounts for fuel type differences. As with ZNE Source, detailed conversions are required to accurately reflect the emissions associated with source energy use. In the U.S., EPA reporting of power plant emissions can be used to identify regional differences in average electricity generation emission rates. In the US, the average $CO_2$ emissions rate is 1,329.4 lb/MWh, while in California, it is only 540.1 lb/MWh. Similar values have also been calculated for $NO_x$, $SO_2$, $CH_4$, $N_2O$, and Hg (AGA 2009). As with the source energy conversion factors, these regional values do not typically differentiate by the time of use. It is possible to develop marginal, as well as average, emissions factors for regions which vary by time of use, but the methods for developing these factors are not currently standardized or widely adopted (see Section 6.9).

With a ZNE Emissions building, the required PV system can vary significantly by region, and will depend on how emissions are calculated. For example, the amount of PV needed would be much smaller in an area that uses hydro-electric or nuclear power, as compared to an area that relies more heavily on coal-fired electricity generation. If gas is used onsite, gas offsets will also need to be accounted for, as discussed above under the ZNE Site section.

## ZNE Time Dependent Valuation (TDV)

In the previous metrics, the time of use of energy is not explicitly considered. Time dependent valuation (TDV) is one approach to address this issue. With TDV, the value of electricity differs depending on time of use (hourly, daily or seasonally) and the value of natural gas differs depending on season. TDV is based on the cost for utilities to provide energy at different times (CEC 2011). TDV also accounts for differences in efficiency and emissions by considering the time of use. “TDV is essentially a long term forecast of the value of energy based upon the costs of providing energy to the end-user; this includes energy commodity costs, transmission and distribution costs… Because electricity cannot be stored easily and peak demand dictates the sizing, and thus the cost, of electrical distribution, electrical costs vary by a factor of 20 to 1 (2,000%), whereas the long term costs of natural gas fluctuates within a given year by a relatively modest 30%” (McHugh 2012). For a more detailed description of TDV, please see Time Dependent Valuation (TDV): a “modified participant cost test” under Section 6.7.3.

TDV differentiates the value of generation more than other definitions, but it is not currently designed to reflect a high penetration of distributed PV on California’s grid and may need to be updated over time to account for this. For more on this point, please refer to Section 0.

One way of understanding the TDV-based definition of a ZNE building is the following: if a homeowner were to pay an hourly “real-time” retail rate based on the building’s location and a state-wide average retail electricity and gas rate, and the homeowner was also paid for her total PV generation according to these same hourly electricity rates, then a ZNE home in this model would have a net zero energy bill over the course of the year. Of course, homeowners do not pay hourly real-time electricity rates, nor are homeowners compensated for their solar PV output based on an hourly real-time rate. However, the time-dependent valuation (TDV) definition of ZNE does capture the differences in the time and locational value of energy to the grid, which the site-energy definition does not do.

TDV can be a very valuable tool because it can encourage peak reductions and reflects overall grid reliability and performance issues. However, it is more complicated to calculate, more challenging to explain and is specific to California. Although TDV may be more complicated to explain, there should be some familiarity with the metric in California's building design community since it is already being used by the CEC in Title 24 and the California Whole-House Home Energy Rating System (HERS).

## *Emerging Metrics Better Suited for State Policy*

On-site renewable generation, such as rooftop PV, has several environmentally beneficial attributes. For example, self-generation, by utilizing existing rooftop space or small patches of already disturbed land, can have a lower environmental impact than large central station renewable generation, which may be developed in sensitive ecosystems and requires larger, contiguous land footprints. Likewise, self-generation can avoid the visual and environmental impacts of developing new long-line transmission to interconnect large renewable generation facilities. By promoting the ZNE goal, state policymakers clearly see benefits to encouraging local, renewable self-generation, beyond the benefits achieved from utility-scale renewable generation.

However, there are drawbacks associated with rooftop PV as well. Not all building rooftops are ideally suited for solar PV, due to the rooftop design such as the pitch or construction material, and due to limits on total and un-shaded rooftop space. Shading from trees and other foliage can be a good way to reduce a building's summertime cooling energy use and can increase property values, but may not be compatible with optimal solar PV performance. Other uses for rooftop space, such as skylights for natural day-lighting or rooftop gardens, can also compete with PV for limited space.

In high-density developments, the ratio of solar-appropriate rooftop space to total building energy demand is much lower than for low-rise and suburban developments, making it more difficult for high-density developments to achieve ZNE status with onsite renewables. This is despite the fact that high-density residential and nonresidential developments can be extremely energy efficient and have a relatively low carbon footprint. By considering only the energy use of the building, rather than the broader context in which the building is located, the ZNE definition may create unintended incentives towards lower-density development.

There are therefore several emerging ZNE metrics that are of interest and may be better suited to the intent of the ZNE goals:

### *ZNE Capable*

A ZNE Capable building is one that is designed, modeled, and constructed with an energy performance that is comparable to a ZNE Site building, but does not yet have onsite renewables, or doesn't have sufficient on-site renewable generation to meet a ZNE Site definition. It should be noted that a ZNE Capable building can potentially also meet the requirements of a ZNE Equivalent building, discussed in the next section.

### *ZNE Equivalent*

Another closely related definitional piece to consider is the idea of ZNE Equivalent buildings. The concepts of equivalency address valid concerns of those working in urban environments or other sites with limited potential for solar and other renewables. We reviewed ongoing work in this area to start to understand related issues such as the impact of renewables and their location, compliance, and urban density requirements. While not all buildings will be able to reach ZNE under any of the common definitions, there should be a metric that allows for an equivalent offset.

For example, this may be through the installation of offsite renewables. While TDV can be used to value the offsite production, policy choices would need to be made regarding whether there should be locational limits to these offsets, to account for differences in grid impacts of distributed versus centralized renewable generation, for example.

In addition to offsite renewables, another option to reach ZNE Equivalent would be to provide credits for higher density developments, reduced transportation or reduced embodied energy of buildings (McHugh 2012).

Higher density developments would include urban infill projects, brownfield development and planned communities with compact growth policies.

Determining the embodied energy of a building is a very complicated process, but would include factors such as the energy embodied in building materials and water use. It should be noted that under any definition of embodied energy, as buildings continue to become more efficient, lowering the operational energy use, the ratio of embodied energy to operational energy will increase

Embodied energy may also account for differences between building location due to transportation needs. Transportation energy could be quantified through vehicle miles traveled.

Calculating the embodied energy of a building is still in the early stages of research and would require significant work to quantify. In general, no matter which metrics are used to determine equivalency, more research would be needed to determine how these offsets or credits would work.

### 6.6.3 Energy Use Intensity (EUI) for ZNE Buildings

The study scope calls for reviewing EUI performance targets for various building types and climate zones. This was based on the results of existing, best practices studies and savings estimates. In doing so, we identified gaps in the existing data that could be filled by the Technical Feasibility study.

As a point of reference, there are several regional and national studies that have undertaken similar efforts to identify energy use targets for ZNE buildings. The German Passivhaus model has a heating and cooling demand of 15 kWh/m2/yr of conditioned floor area, and total appliance, hot water heating and space heating/cooling of 120 kWh/m2/yr, for Northern Europe where the program was developed, though they vary based on climate zone. In Europe as a whole, there is a 'nearly zero' carbon component to the EU nZNE goal, so the EU is considering the standard to be around 3 kgCO2/m2yr3. In the USA, the Massachusetts Task Force working on ZNE has proposed the use of performance metrics in terms of kBTU per square foot for commercial buildings with the absolute target varying by building type.

To review EUIs, the team first identified appropriate criteria for stratifying the EUI targets – building type, climate zone, and market sector – and then identified methods to group these criteria in order to develop meaningful stratification that can be broadly applied without having to stratify into many small segments.

For nonresidential buildings, our analysis used the recent report for ZNE conducted by the New Buildings Institute[1] that identifies 35 kBtu/sf/yr as the average EUI for buildings that are either ZNE or ZNE Capable (have low enough energy use but may not have PV). We compared this ZNE Capable target against the current stock of efficient buildings in the state with LEED new construction (NC) certifications. The purpose of this analysis was to identify the gap between current nonresidential high efficiency designs versus designs needed for ZNE or ZNE Capable performance.

For residential buildings, no such benchmark number exists. However, our market interviews and literature review points to a consistent goal of 50-60% energy savings compared to the 2008 Title 24 standards as a metric. We compared the resulting EUI and whole building energy use numbers against the existing stock of residential buildings. To do so, we used the Residential Appliance Saturation Survey (RASS) data from 2009 and findings from McHugh 2012.

## *Nonresidential Building EUI Analysis*

### *Existing Building EUI Data*

There are two primary sources of existing building energy performance data available to the team: the U.S. Energy Information Agency's Commercial Building Energy Consumption Survey (CBECS), and California's Commercial End-Use Survey (CEUS)[2]. Both of these studies select a sample of buildings from which to obtain energy consumption and building characteristic data, and then extrapolate energy consumption out to the state or national level. Energy consumption is typically reported as energy use intensities (EUIs), which is calculated by dividing total energy use by building area per year (kBTU/ft$^2$/year).[3]

Note that care needs to be taken when interpreting and applying the reported EUI data. Specifically, there are differences between whether EUI statistics are calculated on a per-building basis, versus an area-weighted basis—i.e., there is a significant difference between the "total number of buildings" with an EUI below a threshold versus the "total floorspace" below that threshold. Also, there is a difference between EUI statistics of the sample versus the entire population. Many end-use surveys use a variation of a "stratified random sample," where a statistically significant sample is selected for each minimum "strata group" (e.g., sample equal number of buildings for each climate zone/building type grouping), and different weighting factors are used to extrapolate this back to the entire population.

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[1] New Buildings Institute. "Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings." March 2012. http://www.newbuildings.org/sites/default/files/GettingtoZeroReport_0.pdf

[2] The team also investigated a number of other sources for additional EUI data, but for various reasons useful data wasn't able to be obtained. Energy Star Portfolio Manager contains historical energy performance data for a wide range of buildings; strict confidentiality requirements precluded access to this data. The University of California (UC), California State University (CSU), and Investor-Owned Utility (IOU) Energy Efficiency Partnership maintains databases on campus efficiency projects, which initially appeared to be a promising source of performance information but data was insufficient to provide consistent EUI calculations. LEED EB data was also explored but confidentiality requirements and other issues precluded its use.

[3] Note that some of the studies use slightly different definitions for EUI. This study consistently presents EUI data based on this definition.

### CBECS Data

The U.S. Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS) is the DOE's primary commercial building energy end use study. CBECS obtains detailed energy consumption and building characteristic data for a sample of commercial buildings throughout the U.S. 2003 is the latest available study data[1].

Average Population EUIs

CBECS data is available in both processed form showing average population EUIs and other energy statistics[2], and the underlying raw sample data[3]. This section presents population averages. The most relevant population subset for which data is available is for CBECS climate zone 4 (<2000 CDD, <4000 HDD), which encompasses California Climate Zones 2-12 and 13.

The average building EUI for CBECS climate zone 4 is 78.6 kBTU/ft$^2$, while the average EUI for buildings in climate zone 4 in the Pacific Census Division is 63.5 kBTU/ft$^2$, so the data in the following graphs will be higher than what is expected in California. Nevertheless, this data provides some insight and is of value to explore.

Figure 19 shows population-average EUI broken out by principal building activity. The graph also shows the percent of building floor area to total floor area for each category, read from the right axis. This data is from CBECS Table C10A, "Consumption and Gross Energy Intensity by Climate Zone for All Buildings, 2003"[4].

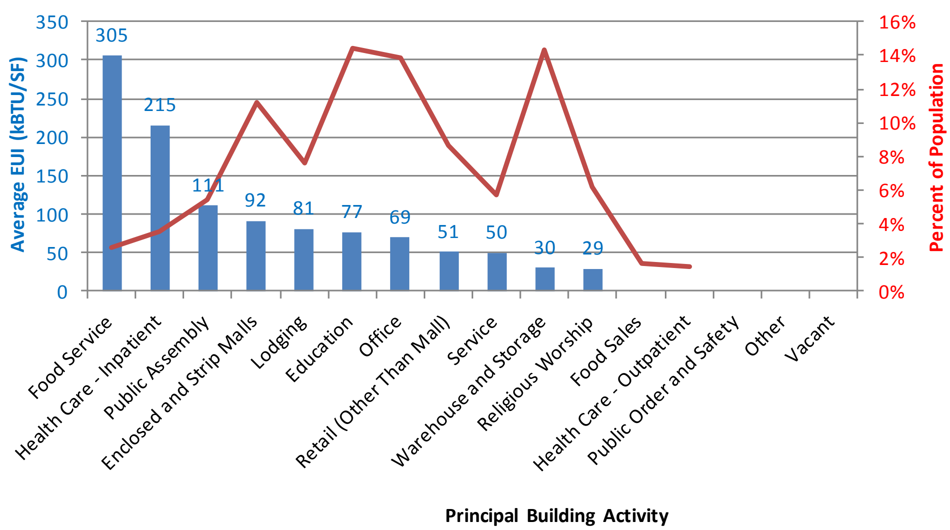


*Figure 19: Population average EUIs by building activity for CBECS Climate Zone 4*

(note: blank values represent insufficient data for meaningful statistics)

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[1] Note that the last (2007) survey was recently cancelled due to survey problems, and a new survey is currently being developed.

[2] http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html

[3] http://www.eia.gov/emeu/cbecs/cbecs2003/public_use_2003/cbecs_pudata2003.html

[4] http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set9/2003html/c10.html

Figure 19 shows that while offices and warehouses may not be the highest energy users in terms of average EUI they are the largest portion of the building population and thus important on the aggregate. Warehouses are also one of the lowest EUI buildings in the CBECS dataset. Conversely, food service and health care are a small portion of the population but have very high energy use intensities.

**California Commercial End-Use Survey (CEUS) Data**

The California Commercial End-Use Survey (CEUS) is a comprehensive study of commercial sector energy use, primarily designed to support the state's energy demand forecasting activities.

There are two ways to look at the CEUS data. The original CEC report and Itron website with CEUS data[1] presents the data on an area-weighted basis, providing average EUI data for total building square footage[2]. This is useful for estimating total energy use and energy end uses at the state-level or other breakdown. It does not, however, present data about the total number of buildings in each category.

Lawrence Berkeley National Lab (LBL)'s Energy IQ program[3] has taken the CEUS data and presents the data on a per-building basis. The intent of this is to facilitate building owners to compare their building to other buildings, and provides insight into the range of building performance by building type and other factors.

Both sets of data are useful, but caution should be used in interpreting the data. There is a significant difference between the average EUI of the population verses the average EUI of a typical building.

CEUS EUI Averages by Square-Footage

The original CEUS results are presented on a building area-weighted basis. This is useful for estimating total population energy use by building type or end use. For each utility service area, floor stocks, fuel shares, electric and natural gas consumption, energy-use indices (EUIs), energy intensities, and 16-day hourly end-use load profiles were estimated for twelve common commercial building type categories. The following figure shows the population average EUIs on an area-weighted basis for all building types. This data is statewide averages taken from the Itron CEUS website[4].

[1] http://capabilities.itron.com/ceusweb/

[2] i.e., individual "sample" building EUIs have been multiplied by the appropriate weighting factors to get the total square feet/energy usage represented by each sample.

[3] Lawrence Berkeley National Lab. "Energy IQ: Action-Oriented Energy Benchmarking". http://energyiq.lbl.gov/

[4] http://capabilities.itron.com/ceusweb/

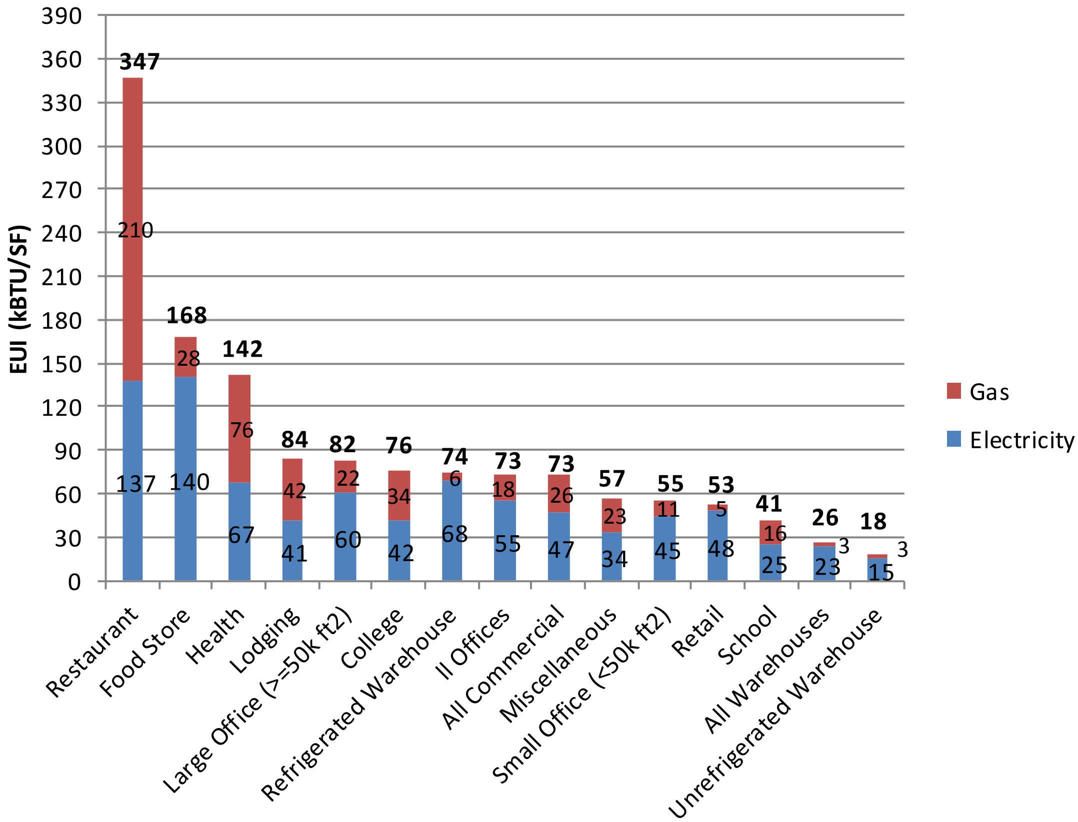


*Figure 20: Population average EUIs (area-weighted) by building type (CEUS)*

CEUS EUI Averages by Building Count

LBL's Energy IQ tool[1] presents the CEUS data on a per-building basis. The Energy IQ benchmarking tool was run to get EUI benchmark data for different building types at the state level. The following figure shows average EUI by building size. Note that for most building types, smaller buildings have significantly lower EUIs than larger buildings.

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[1] Lawrence Berkeley National Lab. "Energy IQ: Action-Oriented Energy Benchmarking". http://energyiq.lbl.gov/

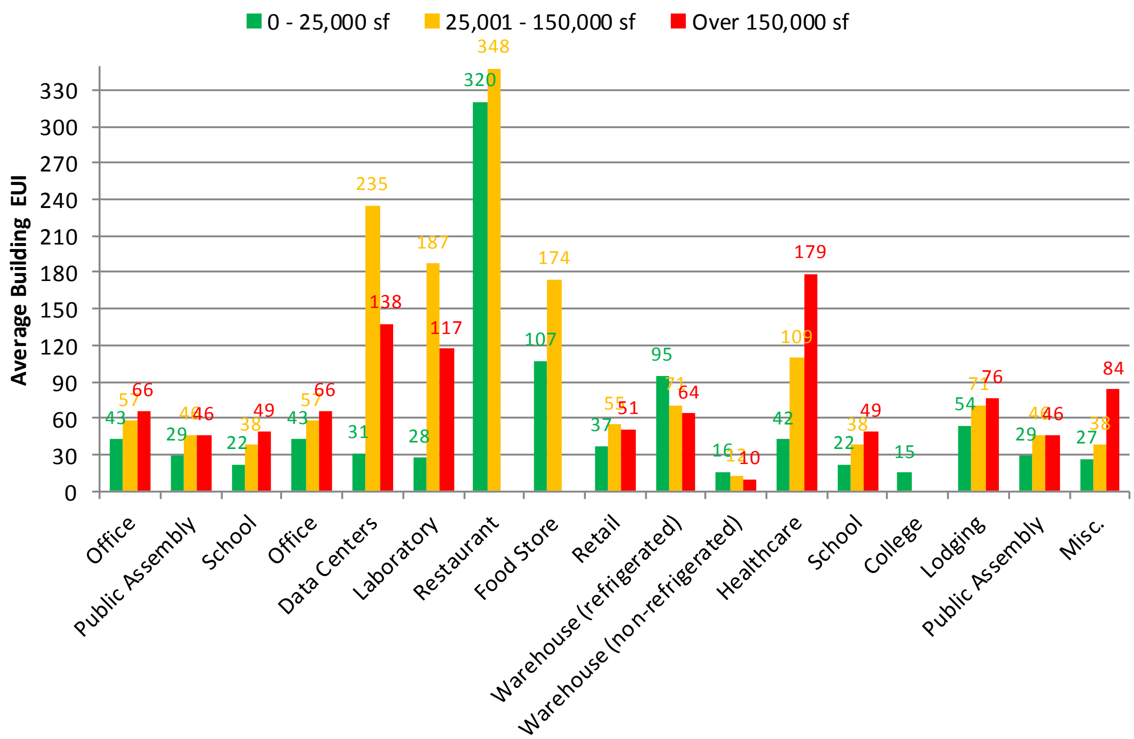


*Figure 21: Average EUI by building size (CEUS data from the LBL Energy IQ Benchmarking Tool)*

## New Construction EUI

The team worked with U.S. Green Building Council (USGBC) to obtain access to modeled energy performance data for LEED for New Construction (LEED NC) certified projects in California. Specifically, the data contained in Energy and Atmosphere credit 1 (EAc1), "Optimize Energy Performance" submittals were obtained for projects utilizing the whole building energy simulation option and analyzed.

Note that unless explicitly stated otherwise all energy use indices (EUIs) presented here are based on conditioned area and measured in kBTU/SF/year. Energy data is based on modeled data and does not represent actual building energy consumption. An effort was made to identify buildings that were both LEED NC and either LEED EB rated or participated in the USGBC's Building Performance Partnership Program.

The buildings were categorized into 21 specific building use types. The following figure shows the distribution of building use types. Offices were the largest category of buildings, followed by higher-education buildings, multi-family buildings, industrial buildings (this use category includes buildings with large process loads, such as data centers), public assembly buildings and K-12 facilities. Other uses are represented in smaller numbers. Note that EUI data for building types with only a single building are not shown.

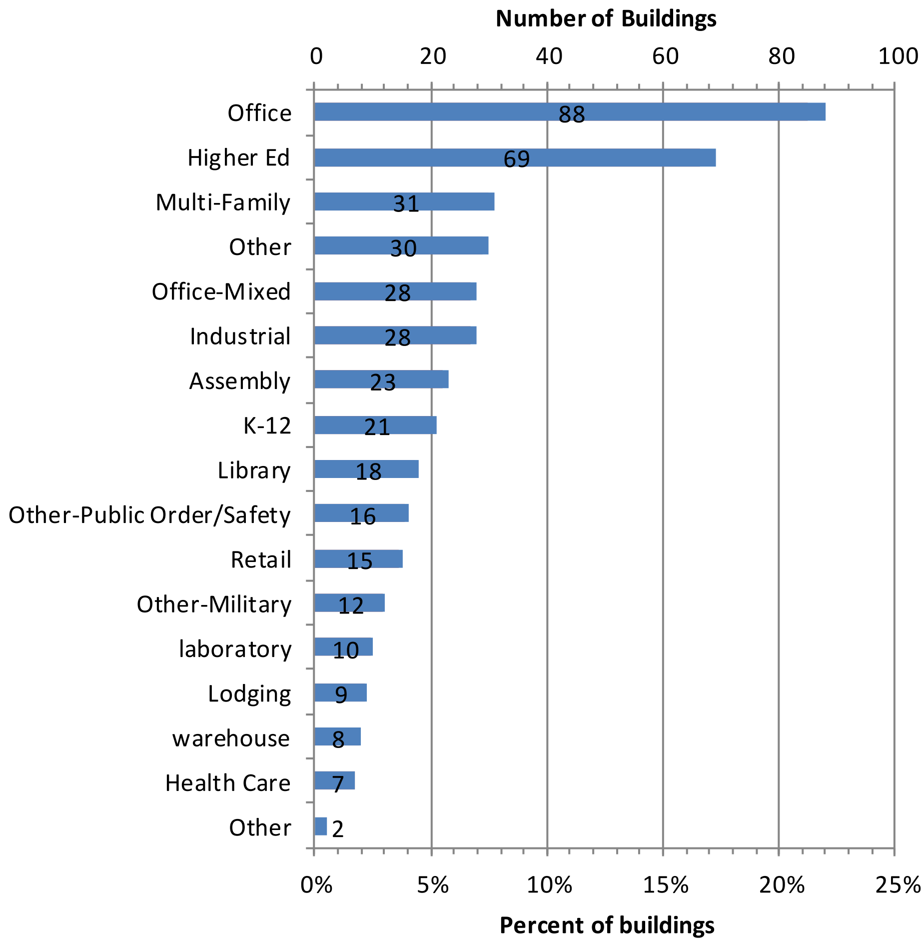


*Figure 22: California LEED NC buildings by primary use type*

The following figure plots building energy end use indices (EUIs) for each building use type. Individual EUIs are sorted from highest to lowest for each building use type (i.e., a histogram). While it is a little busy, this graph provides a quick summary of building energy performance by building type, shows how many buildings are in each category, and the range of distribution of EUIs. The yellow line represents 30 kBTU/SF, which is the highest EUI reported in the New Buildings Institute's Zero Energy Building list[1], and represents the approximate energy performance level for "ZNE Capable" buildings (although 25-30 kBTU/SF is a more likely target goal for ZNE Capable buildings. LEED NC buildings below the yellow line represent buildings that are currently performing at the ZNE building efficiency level. While there are not a lot of buildings with an EUI below 30 kBTU/SF, there are currently buildings being built to this level. As a reminder, the EUIs cited in this section are all modeled EUIs.

[1] New Buildings Institute. "Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings." March 2012. http://www.newbuildings.org/sites/default/files/GettingtoZeroReport_0.pdf

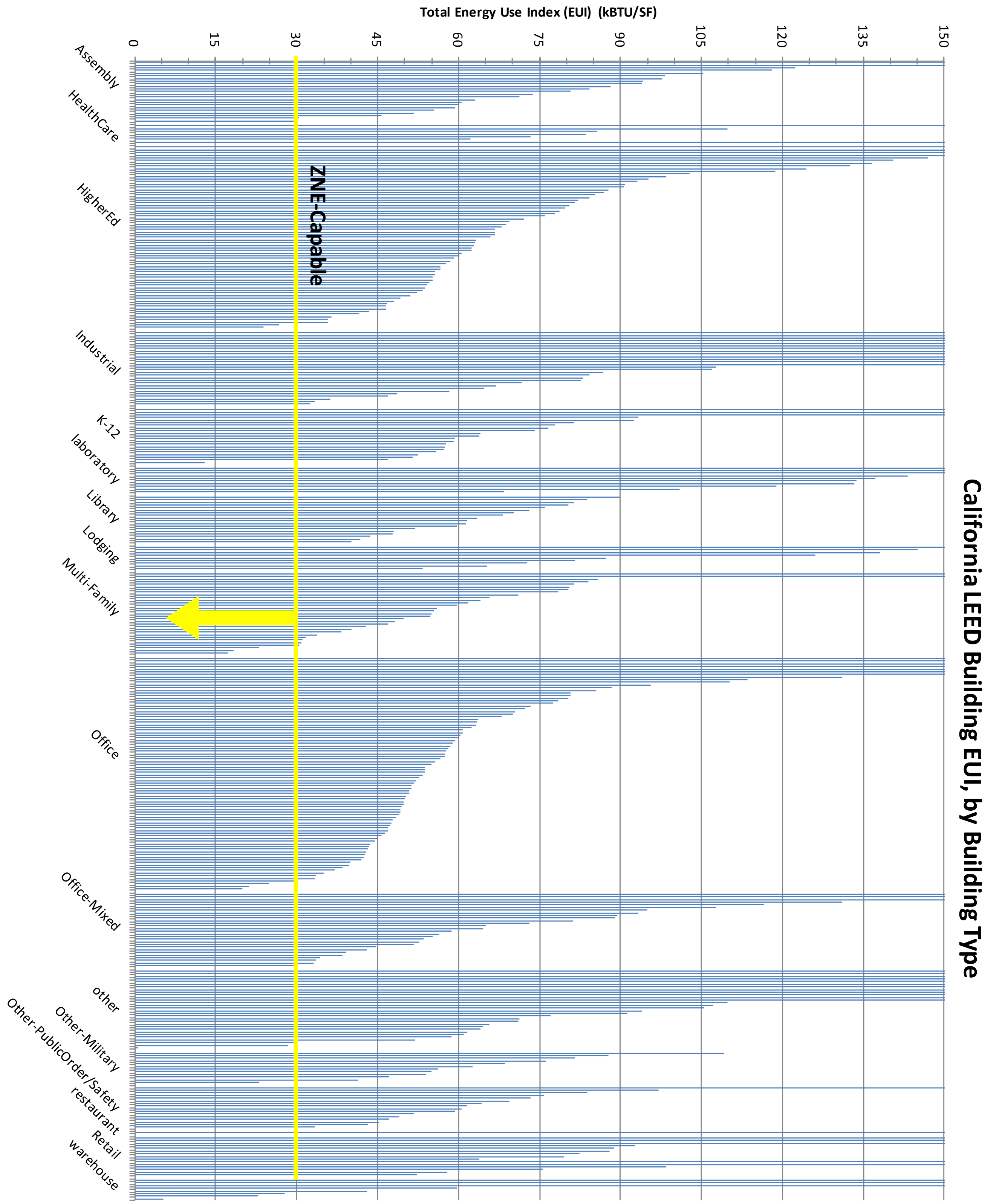


*Figure 23: Histogram of LEED NC Building EUI distribution by building type*

There are a total of 34 buildings with EUI's at or below 30 kBTU/SF/year that are performing at "ZNE Capable" levels.

Refer to Appendix G for further details on the methodology used to derive these values.

## *Residential Energy Use Variability*

To date, there are no clear EUI targets for residential ZNE buildings. There is significant variability in residential energy use and targets will necessarily need to vary by climate zone and buildings size. Below is a brief overview of existing EUI and UEC information. A more detailed explanation is included in Appendix H. Based on our review, it is clear that further research is needed to define residential EUI targets. The results of the Technical Feasibility study should be useful in this process.

### *Whole Building Energy Use*

To explore the variability in residential energy use, we reviewed existing literature and analyzed data from the 2009 RASS. Previous studies have estimated the statewide kWh and kW PV targets at varying levels of energy reduction compared to energy use of 'current new buildings' as defined in RASS (building constructed 2001-2008) (McHugh 2012).

Next we compared the 66% better than 'current' predictions for ZNE against the spread of energy use in existing building stock data from RASS. Figure 26 shows the overall distribution of whole building electric energy use for existing households, as well as the estimated household UEC in PG&E and SDG&E territories[1].

Point estimates such as the 66% average reduction are useful to roughly understand how much of the building stock is currently reaching those targets. However, they do not differentiate by building type and climate zone, where there can be significant diversity. Further research is needed to identify climate zone specific targets.

Currently, RASS data is used to develop the HERS rating index which is an asset rating. Using the statewide or climate zone averages from RASS is appropriate in developing asset ratings. However, ZNE is a performance metric and the variability in energy use due to home size and other factors should be taken into account when developing EUI targets.

[1] Our study received anonmyzed data on residential building energy consumption data from PG&E and Sempra (SDG&E and SCG). This dataset scrubbed any building identifiable data such that we can run statistical analysis on the dataset.

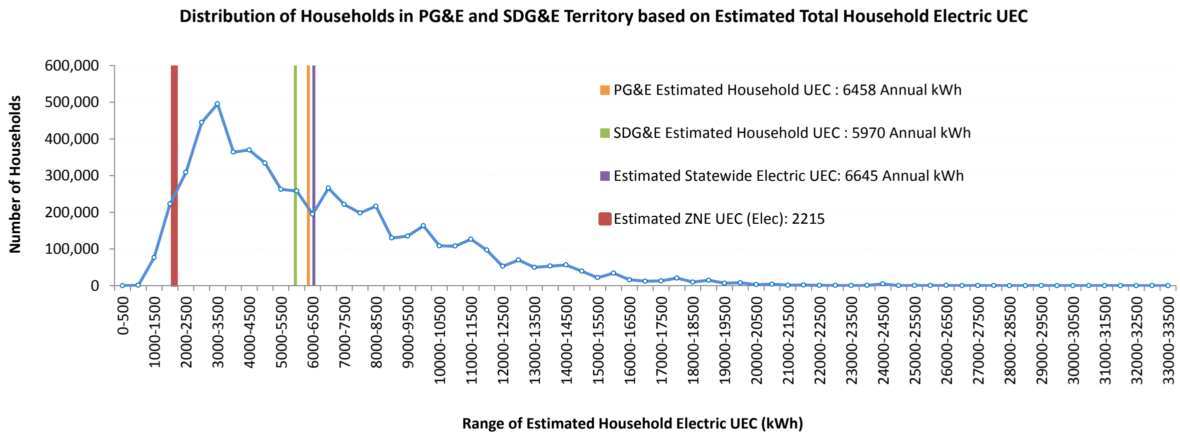


*Figure 24: Distribution of Households in PG&E and SDG&E Territory based on Estimated Total Household Electric UEC*

Figure 24 shows the electric UEC values for the range of homes in the RASS database served by PG&E and SDG&E. There is wide variation in UEC values but a sizable number of buildings use more energy than the average UEC for each utility or the statewide average UEC – while many use significantly less. Comparing UECs from RASS to the proposed UEC (McHugh 2012) for the 66% savings case points to the fact that a significant percentage of buildings have UECs well in excess of the target.

## *Title 24 Regulated Loads*

It is important to note the differences in Title 24 regulated uses as opposed to whole building energy use, since Title 24 currently only covers 46% of the loads, as seen in Figure 10: Percent Residential Energy Use Covered by Title 24.

Below, we analyzed the energy use of residential buildings through two code cycles. Figure 28, Figure 30 and Figure 28 show three sets of values – energy use for a building meeting the 2008 Title 24 standards, energy use for a building meeting the 2013 Title 24 standards and a third hypothetical data point for a building 66% better (lower EUI) than 2008 Title 24. Figure 28 shows this analysis in terms of TDV, while Figure 30 shows gas and electric EUI in kBTU/sf and Figure 26 show the electric-only EUI in kWh/sf.

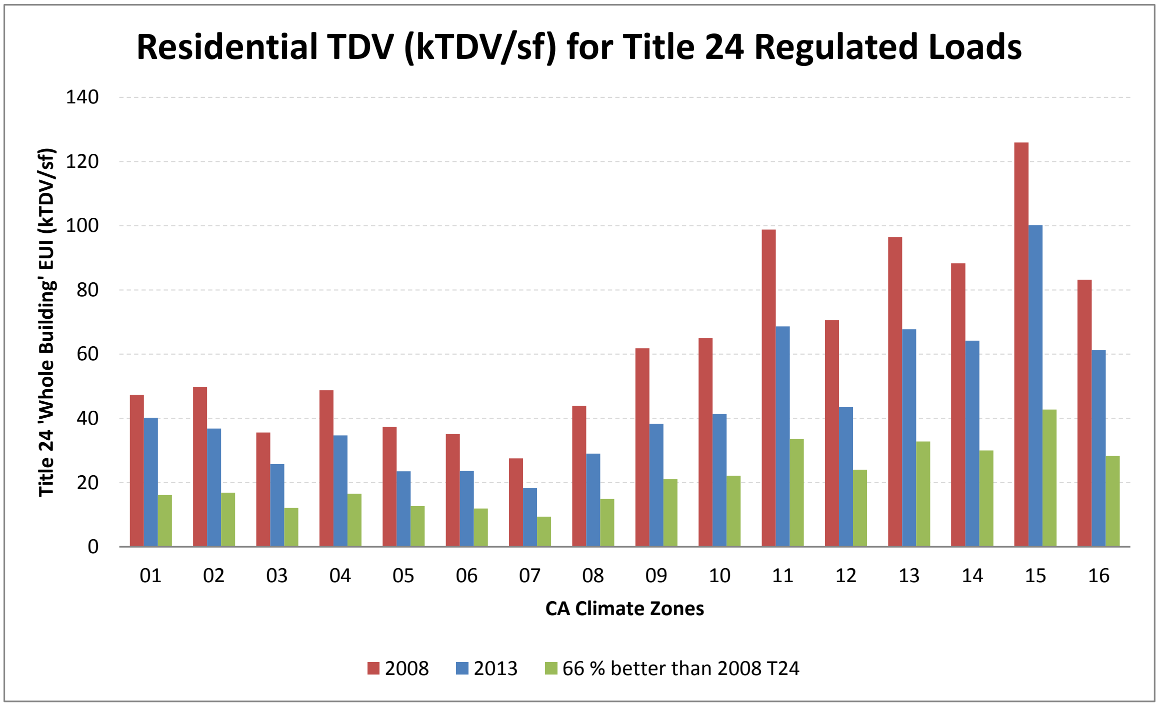


*Figure 25: Residential TDV for Title 24 regulated loads.*

Typically, when considering Title 24 regulated loads, we look at energy use in terms of TDV. From this lens, average EUIs at 66% better than 2008 Title 24 range from about 15-45 kBTU/sf. This represents a substantial savings as compared to 2008. From this perspective, climate zone 15, a cooling dominated climate zone, is the 'worst' performer and thus a target for codes and standards peak savings.

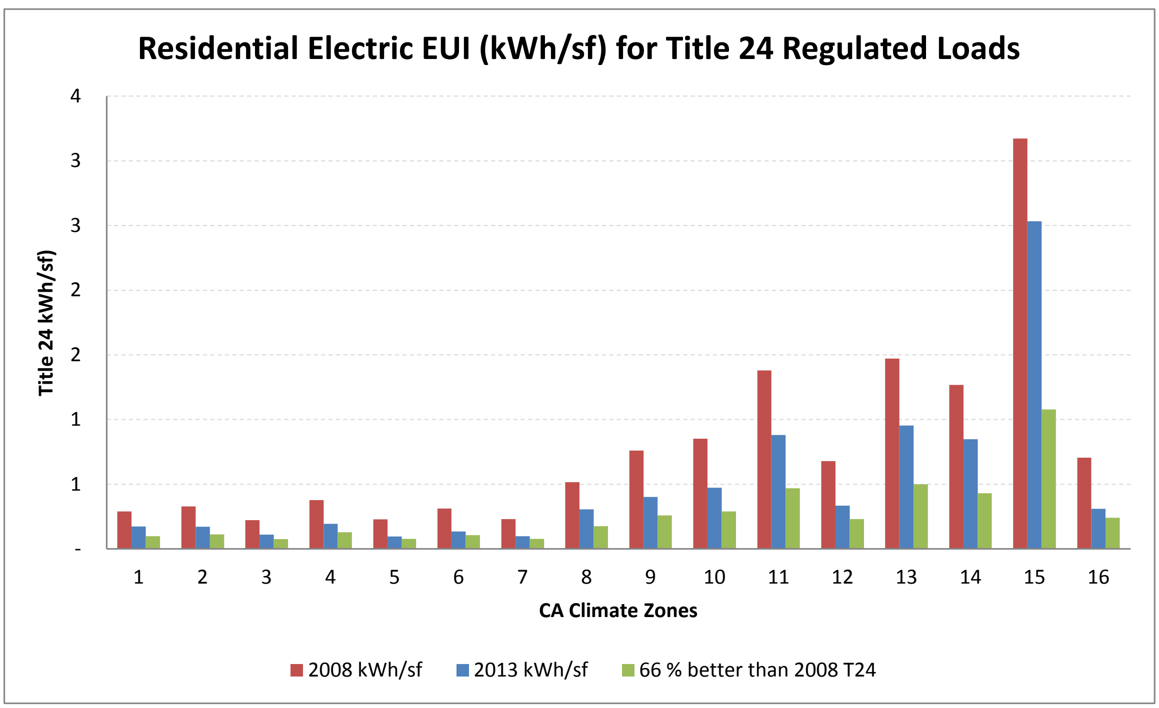


*Figure 26: Residential electric EUI for Title 24 regulated loads.*

Figure 29 shows the electrical use in the same set of buildings. This is closely correlated to the TDV analysis and again, climate 15 is the 'worst' performer.

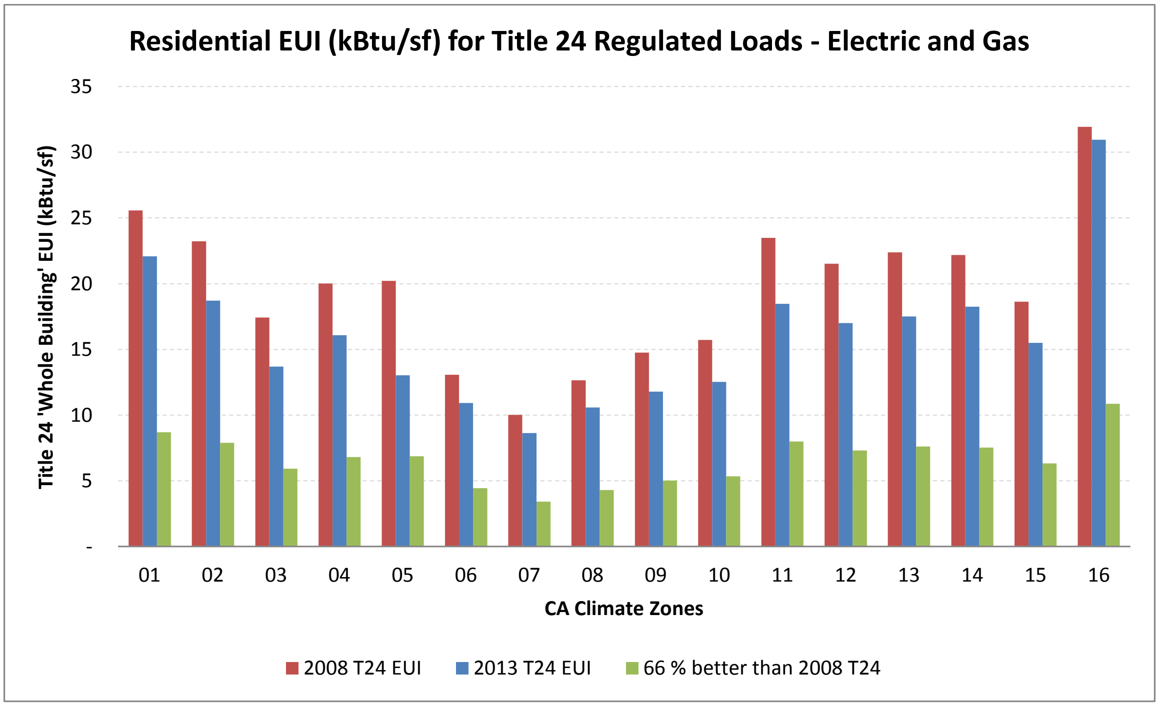


*Figure 27: Residential EUI for Title 24 regulated loads.*

However, if we consider site energy (looking at both electricity and gas use in total kBTU/sf) rather than TDV, the distribution looks significantly different. Here, climate zone 16, a heating dominated climate zone, has the highest EUI. From this perspective, codes and standards should also be targeting heating loads to lower the overall EUI. This also points to the need for setting EUI targets separately by climate zone.

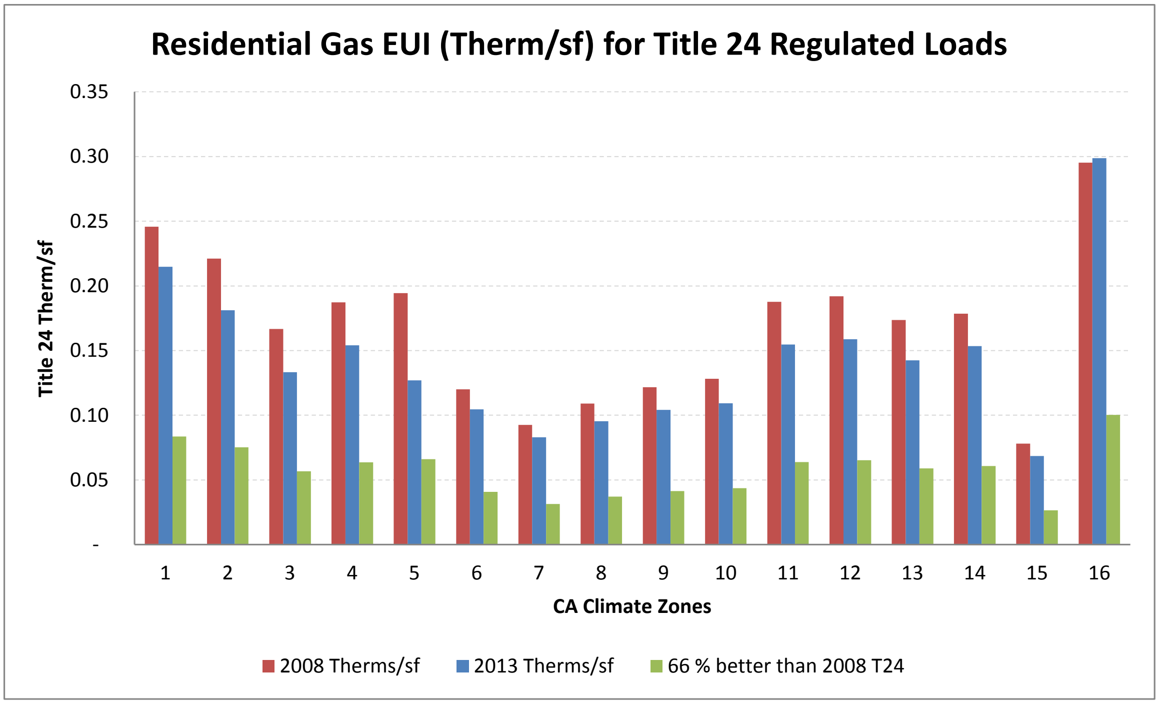


*Figure 28: Residential gas EUI for Title 24 regulated loads.*

Figure 31 shows the gas use for Title 24 regulated loads. These results closely follow the overall EUI seen in Figure 30 as opposed to the shape of the TDV results.

## *Unregulated Loads and the limitations of RASS Data*

As noted above, unregulated loads represent over half the energy use in residential buildings. However, there is a lack of good information on unregulated loads in terms of EUI or UEC.

One of the primary purposes of looking at RASS was to identify the differences in plug load energy use in various dwellings. However, data analyzed by HMG reveals that RASS is limited in its ability to provide data on plug load energy usage due to the way data was collected and sorted into categories. For example, the RASS survey provides bins of house size, rather than the actual square footage, so the data cannot be converted to EUI.

In addition, plug loads and lighting UECs were ‘estimated,’ not measured. These are calculated based on:

- Square footage of the livable spaces in the dwelling
- Age of dwelling
- # of residents
- Household Income

Further research should be completed to carefully look at the plug and appliance energy use assumptions in RASS to ensure that the numbers are not an artifact of calculations but supported through field measurements.

## 6.7 Cost Effectiveness Framework for ZNE

This section discusses the ways that cost-effectiveness of energy efficiency and distributed generation programs are evaluated in California, as well as key considerations influencing the cost-effectiveness of ZNE buildings. They key findings of this section are summarized below. Study recommendations associated with these findings can be found in section 7:

- The cost-effectiveness of zero-net energy buildings has not been rigorously evaluated to-date, but is expected to be a challenge for achieving ZNE. Rooftop solar PV in particular might not pass the CPUC or CEC's cost-effectiveness screens by 2020, unless evaluated as part of a broader portfolio of cost-effective energy efficiency. Developing policies to help achieve further cost reductions of distributed renewable technologies, as well as energy efficiency, in California will be a critical element towards achieving ZNE.
- The CEC, CPUC and private sector (market) all apply different standards to evaluate the cost-effectiveness of ZNE buildings. While it is not necessary or useful to apply a single cost-effectiveness metric to ZNE buildings, it is necessary to understand what drives building design decisions when considering the different cost-effectiveness perspectives.
- The costs associated with electricity distribution and other network upgrades that may be required as a result of high penetrations of ZNE buildings are not currently well quantified. More research is needed to understand the potential future costs of high penetration ZNE buildings at which point such costs could be incorporated into cost-effectiveness evaluations for ZNE.
- California policymakers have encouraged "market transformation" of the rooftop solar PV market through the use of incentives: the California Solar Initiative, the New Solar Homes Partnership and net energy metering rules. As a result of the market transformation goal, these programs have not been constrained by cost-effectiveness tests. A similar market transformation approach could be applied to the development of ZNE buildings, by developing policies to continue to bring down the cost of renewable distributed generation as well as energy efficiency.
- There is significant uncertainty looking forward to 2020 and beyond regarding key policies and regulations which will influence the cost-effectiveness of ZNE going forward. Specifically, the state's retail rate structures and net energy metering rules are currently helping to make solar PV cost-effective to some utility customers with high monthly electricity consumption, and not to other customers with lower monthly electricity use. Furthermore, if ZNE buildings become more widespread, net energy metering (NEM) rules will create a challenge for the current electric utility business model. The NEM policy does not provide a mechanism for the utility to recover its fixed costs associated with serving most ZNE customers on energy-only rates without shifting those costs to non-participating customers. Both the investor-owned utility retail rate structures and the net energy metering rules are currently under review at the CPUC and may change before 2020, with unknown consequences for the cost-effectiveness of ZNE to customers.
- A least-cost approach towards ZNE design would optimize how much energy efficiency versus renewable self-generation is appropriate for each building. However, the least-cost approach may result in less energy efficiency and more renewable self-generation

than policy makers would prefer. Policymakers will need to decide whether or not a minimum level of energy efficiency should be required in new construction ZNE buildings.

- Larger-scale solar PV is generally cheaper than smaller-sized systems on a per unit basis due to economies of scale. However, there are relatively few policies in place that encourage the development of "community" solar or larger, shared renewable energy generation.
- A building that is a net exporter of electricity to the grid falls under the "net surplus power" rules of net energy metering, such that the building owner is compensated for their surplus power at a market price for power, rather than the wholesale retail rate. This means that building owners have little economic incentive to offset their natural gas use with on-site electricity generation. Rather than encouraging all-electric buildings or on-site electricity production to offset a building's natural gas usage to achieve ZNE, other options, such as the use of biogas offsets or an electric-only ZNE definition, may be better alternatives to explore.

### 6.7.1 Why Do We Care About Cost Effectiveness for ZNE Buildings?

Current examples of ZNE buildings have been developed as voluntary, demonstration projects without a standard definition of ZNE. The focus of existing research on ZNE buildings has generally emphasized the technical aspects and feasibility of ZNE building design rather than the costs and benefits of the ZNE buildings to building owners or to society more broadly – although limited cost data are available for specific projects, and additional research is ongoing in this area (US Green Building Council 2012).

To meet California's ambitious ZNE goals by 2020 and 2030, voluntary and demonstration ZNE projects will not be sufficient. It is likely that both energy efficiency incentive programs and building standards will be needed to help drive new construction towards the ZNE goal. This transition from voluntary ZNE building design choices to one guided by state policy goals, energy efficiency incentives, and building codes will necessarily require a better understanding of the costs, benefits and cost-effectiveness of ZNE building choices. This, in turn, will require an agreed upon analysis framework for evaluating ZNE cost-effectiveness.

Good public policy requires a thorough evaluation of the costs and benefits of the use of public funds and of regulatory programs. Cost-effectiveness evaluations, such as those currently employed by the CEC and CPUC, ensure that limited public resources are efficiently allocated and that the benefits of a program or a mandate exceed its costs.

Costs-benefit analyses can be calculated from a variety of perspectives, including from the perspective of building owners, utility ratepayers, utility shareholders, or society more broadly. Each approach can lead to a slightly different cost-effectiveness result. No single cost-effectiveness metric is the "right" one to use in all circumstances, and often it is only by evaluating multiple cost-effectiveness metrics that effective public policies can be designed.

Despite the challenges of monetizing and comparing costs and benefits, cost-benefit analysis remains an invaluable tool for policy making. It provides a transparent and rigorous framework to help inform difficult policy decisions about how to use limited public funds.

California already has regulatory processes in place which could be applied, or adapted, to evaluating the cost-effectiveness of any public ZNE program in the state. Now is an appropriate time to consider how cost-effectiveness analyses will help to inform the state's ZNE strategy. It is also an appropriate time to evaluate what changes to the existing cost-effectiveness frameworks, if any, may be needed to adapt specifically to a whole-building, performance-based ZNE standard.

### 6.7.2 Cost–Effectiveness Screens for ZNE Goals

The general path towards achieving California's ZNE goal begins with voluntary early adoption, R&D and experimental programs, then moves to incentive-based programs, and finally to codes and standards. This path follows a logic driven in large part by economics. For the innovators and early adopters, it may not matter whether a particular energy efficiency measure is cost-effective or has a relatively long pay-back period, but for later-stage adopters, upfront costs become a more important consideration (Rogers 1995, Moore 2002).

Public incentives help to bring down the upfront cost of a measure. In addition, incentives can drive "market transformation" by helping to achieve economies of scale through increased sales. Incentives may also be used to overcome sources of market failure, such as a lack of information or trust in a new product. Cost-effectiveness tests are employed by the California Public Utilities Commission, for example, to ensure that ratepayer-funded energy efficiency incentives save utility ratepayers, as a whole, money. This cost-effectiveness "screen" protects ratepayers and ensures that limited public funds are used efficiently.

Measures that are cost effective to customers without public incentives may be ready for inclusion in a mandatory code or standard. The California Energy Commission, as part of its building standard updates (Title 24) also applies a cost-effectiveness "screen" to ensure that all building code measures are cost-effective for customers.

The cost-effectiveness screens applied by the CPUC and the CEC are key elements in the development of energy efficiency incentive programs and building standards, and will play an important role in shaping the development of a ZNE market in California, as discussed in more detail below.

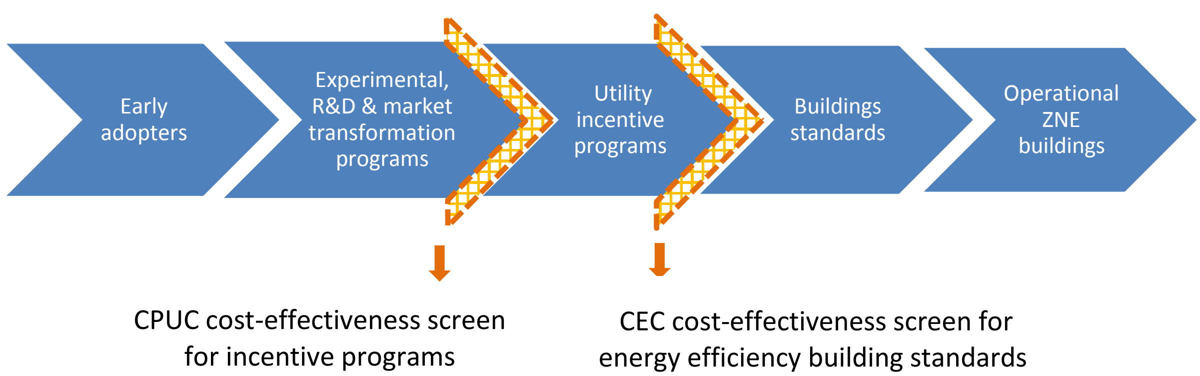


*Figure 29: Cost-Effectiveness Screens to ZNE Goals*

### 6.7.3 California's Current Cost Effectiveness Framework

#### *California Public Utilities Commission Cost Effectiveness Tests*

The California Public Utilities Commission (CPUC) uses rate-payer funded "public benefit" money to fund energy efficiency incentives. The cost-effectiveness analysis of EE incentives at the CPUC is guided by the Standard Practice Manual (SPM). The SPM was adopted by the CPUC in the 1980s, and was most recently updated in 2001. The SPM describes a standardized method to calculate various tests of cost-effectiveness. Officially, only the entire energy efficiency portfolio at the CPUC must pass a cost effectiveness screen. However, in practice, many CPUC energy efficiency programs must also show greater benefits than costs, based on both the Total Resource Cost (TRC) and the Program Administrator Cost (PAC) tests. The SPM also includes details of how to calculate the Participant Cost Test (PCT), the Ratepayer Impact Measure (RIM) test, and the Societal Cost Test.

#### *Total Resource Cost (TRC) Test*

The TRC test evaluates whether a program is cost-effective to the utility and to all its customers as a whole. Costs and benefits are evaluated regardless of who pays the costs and who sees the benefits (excluding certain externalities). If benefits are greater than costs (leading to a TRC ratio above 1) then the test indicates that utility ratepayers as a whole will benefit from the EE measure through lower utility bills. Using the TRC test, the cost of a program is evaluated using the full incremental measure cost, plus any program administration expenses. Ratepayer-funded incentives are excluded from the TRC test, since these incentives simply represent transfers between utility ratepayers.

In California, the benefits of an energy efficiency program under the TRC are evaluated on an hourly- and location-specific basis, and reflect the avoided costs of energy efficiency to the electric utility, including a higher value for peak-demand period savings compared to off-peak savings. The TRC test also includes a market value for avoided greenhouse gas emissions.

The key determinants of whether a ZNE building will pass the TRC include whether the building is evaluated on a holistic basis, or on a measure-by-measure basis, as well as assumptions about natural gas prices, the discount rate, measure lifetime, and of course, the incremental cost of all of the measures, including self-generation, that are needed in a building to achieve ZNE status.

#### *Utility Cost Test or Program Administrator Cost (PAC) Test*

The Utility Cost Test, also known as the PAC test, evaluates whether an energy efficiency program is cost-effective to the EE program administrator or the utility. Under the PAC test, program costs are defined to only include those costs paid by the utility, such as the incentive payment and administrative costs, rather than the full incremental measure cost as is used in the TRC test. Incremental measure costs paid for by the customer are not included. Like the TRC, in California, the benefits in the PAC test are calculated on an hourly- and location-specific basis.

While the TRC test is useful for the CPUC in deciding whether an EE program is broadly beneficial to all utility ratepayers, the PAC test helps to determine the appropriate level of incentive for a program administrator to offer, such that the program will be cost-effective to the utility as well. The key factors determining whether a measure passes the PAC test are the level of incentive offered and the administrative costs of running the program.

### *Participant Cost Test (PCT)*

The PCT measures the cost-effectiveness of an energy efficiency measure to the customers who actually adopt it. Under the PCT, costs are defined as the incremental measure cost paid by the customer, after any incentives have been factored in. The benefits of an energy efficiency measure from the perspective of the participant are the avoided utility bills that the customer no longer pays as a result of the EE measure. In the PCT, the utility rate structure becomes an important element of calculating the benefits of a program. If a measure passes the PCT then the measure is more likely to see uptake in the market. If incentive levels are set too low, the measure will not be cost-effective to customers, may not pass the PCT, and may see low adoption rates as a result. However, if incentive levels are set too high, customer adoption rates may be very robust but ratepayer incentive money may be wasted, by incentivizing adoptions which would have happened anyway.

In its EE program design, the CPUC seeks to strike the right balance between encouraging energy efficiency measures and programs that pass the TRC, the PAC *and* the PCT cost effectiveness tests.

### *Ratepayer Impact Measure (RIM)*

The RIM test measures the impact of an energy efficiency program on utility rates. In general, when energy efficiency programs are effective they reduce a utility's retail sales and reduce total utility costs, leading to lower average customer bills. However, by reducing sales, an energy efficiency program will generally necessitate an increase in retail rates to make up for the utility's lost revenue. Even though average utility bills go down, utility rates tend to go up. For this reason, most EE measures do not pass the RIM test. The RIM test is rarely used in California since it reveals little about the net benefits of an energy efficiency program, but rather focuses on the distributional impacts of an EE program to non-participants.

### *Societal Cost Test*

The Societal Cost Test is similar to the TRC but includes a wider range of costs and benefits than the TRC. In addition, the Societal Cost Test generally includes a lower discount rate than the TRC, reflecting a societal willingness to tolerate longer payback periods on investments than an electric utility or utility ratepayers. The societal cost test also includes an estimate of the societal benefits associated with avoiding environmental externalities which are not otherwise priced into the market. This is in contrast to the TRC, which generally includes the current and expected market value of avoiding pollution and carbon dioxide emissions, such as the market prices associated with a cap and trade program.

The societal cost test is not currently used by either the CPUC or the CEC in evaluating the cost-effectiveness of energy efficiency programs. The CEC's 2011 Integrated Energy Policy Report (IEPR) states that, "*The Energy Commission and CPUC should work jointly on developing a definition of ZNE that incorporates the societal value of energy (consistent with the time dependent energy valuation approach used for California's Building Energy Efficiency Standards).*" Based on interviews and conversations with policy-makers at the CEC, we clarified that the definition of the "societal value of energy" in the context of the IEPR was *not* intended to reflect the Standard Practice Manual definition of the Societal Cost Test. Rather, the intent of the IEPR language was to encourage a common framework for evaluating ZNE cost-effectiveness between the CPUC and the CEC which includes the time-varying value of energy savings. In other words, the IEPR language is simply encouraging a ZNE cost-effectiveness framework that is similar to the approach that the CEC already uses when evaluating proposed energy efficiency standards in the Title 24 Building Energy Efficiency Standard proceedings. The CEC's approach towards evaluating cost-effectiveness, known as Time Dependent Valuation, is discussed in the next section.

## California Energy Commission Cost Effectiveness Test

### Time Dependent Valuation (TDV): a "Modified Participant Cost Test"

The California Energy Commission (CEC) evaluates the cost effectiveness of energy efficiency building standard measures based on criteria established in the Warren-Alquist State Energy Resources Conservation and Development Act of 1974. The Act is generally interpreted to require that building energy efficiency standards must be cost-effective to the participant (i.e. the average building owner).

For the CEC's Title 24 building standards, the benefits of energy efficiency are calculated using a method known as "Time Dependent Valuation" (TDV), which, similar to the TRC, values energy efficiency savings on an hourly- and location-specific basis. However, unlike the TRC, a societal discount rate is applied in the TDV approach. In addition to quantifying the benefits associated with avoided energy, capacity and emissions costs which are also all included in the TRC test, the TDV approach also includes as a benefit any remaining fixed cost components of the utility revenue requirement that are reflected in the participant's avoided electricity retail rate.

As an example of how the TDV metric produces an "avoided cost" or value of energy efficiency or distributed generation, the lifecycle (or levelized) value of distributed generation using the TDV metric is shown in Figure 30 below. Each of the components of the TDV metric is each shown in the "waterfall" chart. The example shown in the figure is the lifecycle value of a rooftop PV system installed in 2014 in climate zone 16. The total lifecycle value of savings comes to just over $0.25/kWh (in 2014 dollars). Energy savings represents the largest source of value using the TDV metric, while the second largest source of value comes from the "retail rate adder", which represents the portion of the average statewide retail rate that is not otherwise captured by the other components of the TDV (i.e. the fixed utility costs that are reflected in rates).[1]

[1] For more information about how the TDV metric is calculated, see the TDV methodology report on the CEC's website, available here: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/

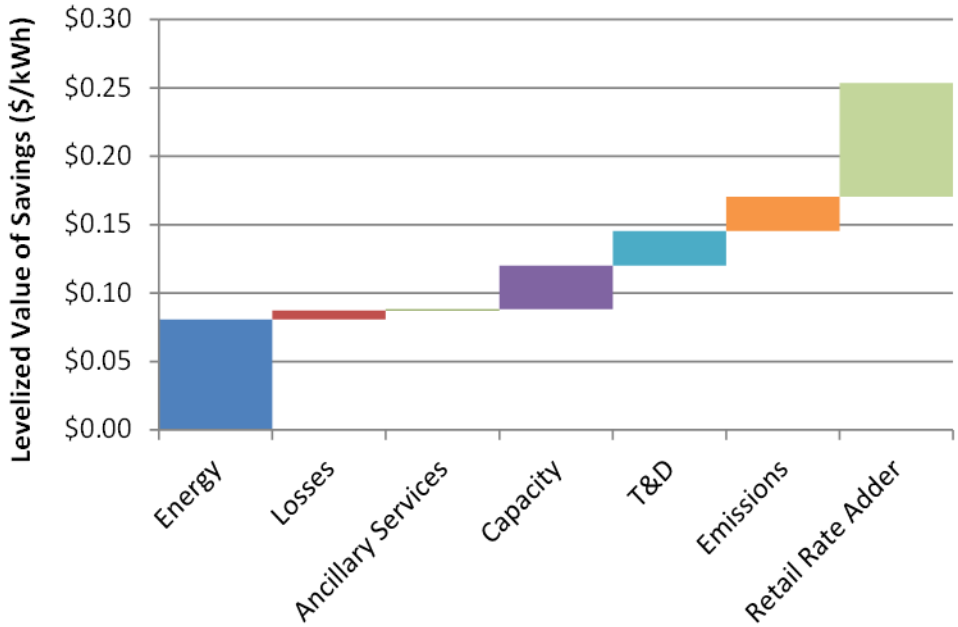


*Figure 30: Levelized (lifecycle) value of rooftop PV generation using the TDV metric (example shown is for a rooftop PV system in climate zone 16, installed in 2014, values are shown in nominal $2014).*

The avoided customer bill component of the TDV benefit calculation is the main feature that distinguishes the TDV cost test from the TRC and a societal cost test. In the TRC and in a societal cost test, a customer's avoided electricity bill would not be counted as a benefit, since any fixed utility costs that one customer avoids through energy efficiency must be covered by someone else, representing a transfer of costs among utility ratepayers. In contrast, in the participant cost test, a customer's avoided bill is one of the main benefits of an energy efficiency measure, along with incentive payments. In this way, the TDV approach used by the CEC calculates, in essence, whether an energy efficiency measure is cost-effective to the average homeowner in California. Put differently, the TDV reflects a "modified" participant cost test (PCT), because the PCT is modified to reflect the time-varying value of energy and a societal discount rate rather than a customer's individual discount rate.

Like the TRC and the societal cost test, key drivers of the TDV cost test are assumptions about future natural gas prices, the choice of the discount rate and measure lifetime. An additional driver of the TDV results includes an assumption about the future direction of retail rates. There are several key differences between the TDV approach used at the CEC and the TRC approach used by the CPUC, including the choice of the discount rate, measure lifetime, and the geographic specificity applied in each.

The TDV cost-effectiveness screen is used as one element in determining whether a proposed measure will be adopted into the CEC's Title 24 building code. Through Codes and Standards Enhancement (CASE) studies, the CEC evaluates proposed measures on the basis of whether the measure is cost effective, as well as whether the measure is sufficiently commercialized, how the proposed standard will interact with other existing codes such as fire codes, what any additional modeling and compliance burden would be for building designers, and whether the measure is generally accepted within the building community, before deciding whether to adopt the proposed measure in the Title 24 building standard.

#### *Costs of ZNE Grid Impacts*

For all new residential construction to be ZNE by 2020, and all new commercial construction to be ZNE by 2030 (whether a TDV-based, site-energy or source-energy ZNE definition is applied), will require a dramatic increase in the amount of distributed solar PV installed across the state. Accommodating these higher penetrations of distributed generation in California would require changes to current interconnection policies, and may have broader implications for the transmission system. More research is needed on how to accommodate high penetration PV, and manage reliability and power quality, at reasonable cost.

In cost-effectiveness tests, only current and known costs are included, so the grid impact costs due to higher penetrations of PV and ZNE are not reflected in today's cost tests. There is currently a lack of good data regarding these costs, and what levels of DG and ZNE penetration will trigger these costs. More research into this area is needed as discussed in Section 5.6.

### 6.7.4 The Cost of ZNE: Uncertainties & Options for Bringing Down the Cost

This section describes several of the factors influencing the cost of ZNE buildings, and highlights some of the uncertainties regarding the cost of achieving ZNE in 2020 and beyond, to building owners, the electric utilities, and the state. This information informs the policy recommendations in Section 7.2 regarding the kinds of incentives, standards and other program design choices that would encourage ZNE adoption in California.

#### *Achieving ZNE Will Require a Market Transformation Effort*

The California "million solar roofs" program provides one example for how ZNE buildings could be promoted in California as a market transformation effort, rather than as a traditional energy efficiency program.

Codified into law by Senate Bill 1 (SB 1, Murray, 2006), the "million solar roofs" initiative is an effort by the state of California to create a self-sustaining market for rooftop solar PV by transforming the market. As a legislative mandate under SB 1, these solar programs are not subject to the same cost-effectiveness criteria as the CPUC's or the CEC's energy efficiency programs and standards.

The SB 1 legislation notes that while solar is not currently (as of 2006) a viable option for many buildings, that *"it is the goal of the state…to establish a self-sufficient solar industry in which solar energy systems are a viable mainstream option for both homes and businesses in 10 years"* (Murray 2006). The state's solar program thus seeks to transform the solar market by increasing solar adoption rates and helping to drive down costs through "learning by doing" and by achieving economies of scale.

The initiative has two main components: 1) the California Solar Initiative (CSI) program, and 2) the New Solar Homes Partnership (NSHP). The CSI program is an IOU ratepayer-funded incentive program to encourage development of rooftop solar PV and solar hot water heaters on existing homes, existing or new commercial, agricultural, government and non-profit buildings in IOU service territories. The CSI program is administered by the CPUC.

The CSI program's cost-effectiveness is evaluated by the CPUC using the TRC, the PAC and the PCT but is not required to pass these cost tests. Under 2007 and 2008 market conditions, for example, the CSI program did not pass the TRC (Energy and Environmental Economics 2011). However, the program has continued to move forward as a result of the legislature's mandate and the market transformation goal for solar PV that by 2016, solar energy systems become a viable mainstream option.

The NSHP is administered by the CEC and provides financial incentives for rooftop solar on new construction buildings across the state. Like the CSI program, the NSHP incentives are not required to pass a cost-effectiveness screen.

It is possible that different elements of a ZNE building design and construction could be held to different standards of cost-effectiveness. For example, the CEC could continue to increase the stringency of the state's building energy efficiency standards, moving towards a standard that includes all cost-effective energy efficiency using the CEC's TDV approach. However, even all cost-effective energy efficiency building codes may not get a building all the way to an operational definition of zero-net energy (especially if a non-TDV based definition of ZNE is used). The remaining gap between energy consumption and energy production could be filled with additional incentives for energy efficiency and self-generation, which may or may not pass a cost-effectiveness screen, and which could be justified based on market transformation goals, similar to the way that rooftop solar PV incentives have been promoting based on the market transformation goal.

### *"Whole-building" vs. Measure Level Cost-effectiveness*

One of the more unique characteristics of a ZNE Site goal is that it represents a performance goal rather than a prescriptive standard. A ZNE building can theoretically be achieved with any number of combinations of energy efficiency, building operational choices, and self-generation. A ZNE building might employ passive solar heating and cooling or might take a more conventional approach to its HVAC system and achieve energy savings in other ways, such as through reduced plug loads and higher levels of self-generation. Unlike a prescriptive standard, or an incentive program directed at a single measure, the ZNE goal presents an opportunity to consider a building's performance on a holistic basis, and to provide for greater flexibility in building design and operation.

However, the challenges of accounting for interactive effects between measures become complex when comparing entirely different building designs and operational patterns as a result of a whole-building standard such as the ZNE goal. Measure-level cost effectiveness assessments are unlikely to be appropriate for new construction ZNE buildings, or for deep retrofits to achieve ZNE. Rather, a portfolio-level, or "whole building" approach may be needed to evaluate ZNE cost-effectiveness.

The National Renewable Energy Laboratory (NREL) has developed a building energy optimization tool, BEopt, which allows building designers to evaluate least-cost efficiency and solar PV packages at various levels of whole-house energy savings, including zero-net energy residential buildings. Under a project funded by the California Solar Initiative RD&D program, and with support from PG&E, the BEopt tool is currently being modified to include the California Standard Practice Manual (SPM) cost-effectiveness tests, avoided costs, and a more sophisticated treatment of solar and whole-house based energy efficiency incentives. Future plans include connecting the BEopt tool to the California Simulation Engine (CSE), which is the future simulation tool for showing Title 24 residential compliance with a TDV-based evaluation of cost effectiveness. With these improvements, California will have a capable building design tool to evaluate cost-effectiveness of residential buildings that can calculate a range of ZNE metrics for specific buildings, and could provide input on development of CPUC or CEC Title 24 proceedings on cost-effectiveness for ZNE.

## *Cost-effectiveness and Self-generation versus Energy Efficiency*

One of the choices facing ZNE building designers is the question of how much self-generation to include in a ZNE building versus energy efficiency. At the extreme, it is possible that a building with no incremental energy efficiency could attain ZNE status if enough solar PV were placed on the rooftop. This would likely not be the most cost-effective way to achieve ZNE, but conceptually it could be done.

More realistically, if the building designer's goal was to achieve ZNE status at the least cost, the designer would compare the lifecycle cost of each energy efficiency measure, or package of measures, to the lifecycle cost of self-generation (most likely solar PV). At the point where the all-in additional energy efficiency measures become more costly than the all-in cost of solar PV, the designer would switch from implementing EE to planning for additional self-generation to meet the ZNE goal. This inflection point, between the cost of EE and the cost of self-generation will be different for every building, depending on its type and location, and will vary over time, as the cost of energy efficiency and solar PV changes under evolving market conditions.

Figure 31 shows an illustrative example of this potential trade-off between implementing all possible energy efficiency measures before turning to self-generation to meet the ZNE goal, versus implementing all energy efficiency that is lower cost than the self-generation option to meet the ZNE goal.

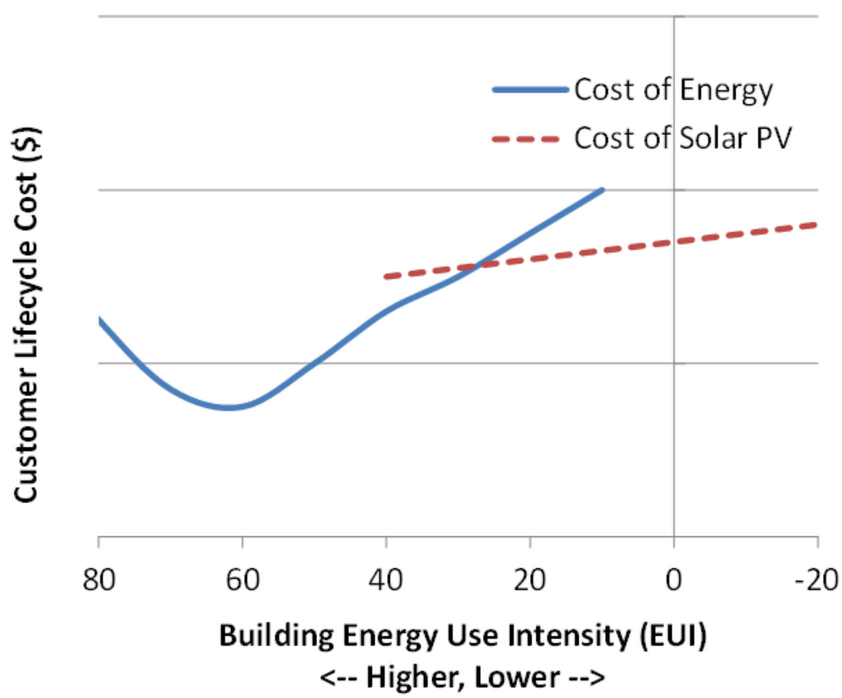


*Figure 31: Illustrative "J-Curve" of the customer cost of energy due to increasing levels of energy efficiency compared to the cost of self-generation from rooftop solar PV.*

The cost of solar PV has dropped dramatically over the past several years, and most forecasts project continued cost reductions going forward (Black & Veatch 2012). These trends make it possible that solar PV costs may be lower than the cost of an increasingly large number of energy efficiency measures going forward. Of course, the cost of energy efficiency measures for

ZNE buildings may come down as well over time; these cost trends are currently less well understood.

In practice, many building designers and owners do not explicitly evaluate the lifecycle cost comparison shown in Figure 31 because of differences in how energy efficiency and solar PV are paid for and financed. For example, the upfront capital cost of energy efficiency measures in a new home are generally factored into the home sale price; effectively financing them through the home-buyer's mortgage. In this case, the home builder must carry the cost of the energy efficiency measures until the home is sold. In contrast, the cost of solar PV is increasingly being financed through third-party installers and is paid for in monthly installments, rather than as an upfront cost. In this case, the home builder may not put in any upfront costs for the solar PV and the PV may not affect the listed price of the home. In both cases, there are lifecycle costs and benefits to the energy efficiency and the solar PV, but few building designers or homeowners are likely to compare the lifecycle costs of each explicitly, which adds to the complexity of finding "least-cost" solutions to achieve ZNE.

Policymakers have several options to address this choice between EE and self-generation in a ZNE building. The first option would be to allow a building designer or occupant to have complete flexibility and choice between EE and self-generation when complying with the ZNE goal. While providing maximum flexibility, this approach also runs the risk of some "back-sliding" on energy efficiency achievements relative to current best practice, by potentially allowing building designers to replace currently required efficiency measures with self-generation.

Alternatively, policymakers may decide that encouraging some minimum level of energy efficiency in ZNE buildings is a priority, even if it is more expensive than self-generation at some point. This choice might be made on the basis of the energy efficiency Strategic Plan, which calls for achieving all cost-effective energy efficiency. Or, the claim could be made that deep energy efficiency improvements are a necessary pre-condition to meeting the state's long-term climate change goals, so there is a public interest in encouraging energy efficiency. An argument could also be made that some energy efficiency upgrades to a building are inherently more permanent and long-lived than self-generation, which can be removed relatively easily from a building site. So, if the goal of ZNE buildings is to encourage a long-term transformation in the state's energy consumption, policymakers may therefore conclude that some minimum level of energy efficiency should be a part of ZNE buildings.

Policymakers could pursue at least two approaches towards encouraging EE as part of a ZNE building. One option would be to provide increased incentives for higher levels of EE savings within a ZNE building. This option would maintain a building designer's flexibility to choose how much EE and self-generation to select, but would provide a financial incentive to choose more EE. Another option, which is not necessarily mutually exclusive with the first, would be to set a minimum level of EE achievements for all buildings. This could be accomplished by requiring all new and deep retrofit buildings to meet current Title 24 EE standards regardless of how much self-generation is included in the building design.

### *The Importance of Achieving Continued Reductions in Solar PV Costs*

A key determinant of the cost-effectiveness of ZNE buildings is tied to the cost of rooftop solar PV, since rooftop solar PV is currently the most common and lowest-cost form of self-generation for most buildings. In this section, we do not try to forecast whether solar PV is likely to be cost-effective for ZNE buildings by 2020 or 2030. Rather, we discuss the factors that will influence solar PV costs, highlight the uncertainties around future costs of solar, and emphasize the importance of continuing to achieve cost reductions of solar PV over time as a key element of achieving the ZNE goals.

The capital cost of solar PV has come down rapidly over the past ten years. In addition, the presence of state incentives and federal tax credits for solar further reduce the customer cost of PV, at least in the near-term. Likewise, solar panel performance has improved, as have the efficiency of solar PV inverters. How solar PV costs will continue to develop through 2020 and 2030 remains a major source of uncertainty around the future cost-effectiveness of ZNE for many buildings.

Figure 32 below illustrates some potential ranges for the future cost of solar. The figure shows how much the lifecycle cost of rooftop solar energy (levelized cost of energy, LCOE) to a typical homeowner in 2020 could come down as the capital cost of solar PV falls. In the figure, the investment tax credit (ITC) is assumed to be 10% in 2020, consistent with current federal policy which has the ITC falling from 30% today to 10% after 2016. The figure also assumes that by 2020 *no* state incentives will be available for solar PV in 2020 (i.e. no incentives are assumed from the California Solar Initiative or the New Solar Homes Partnership, consistent with current state policies).

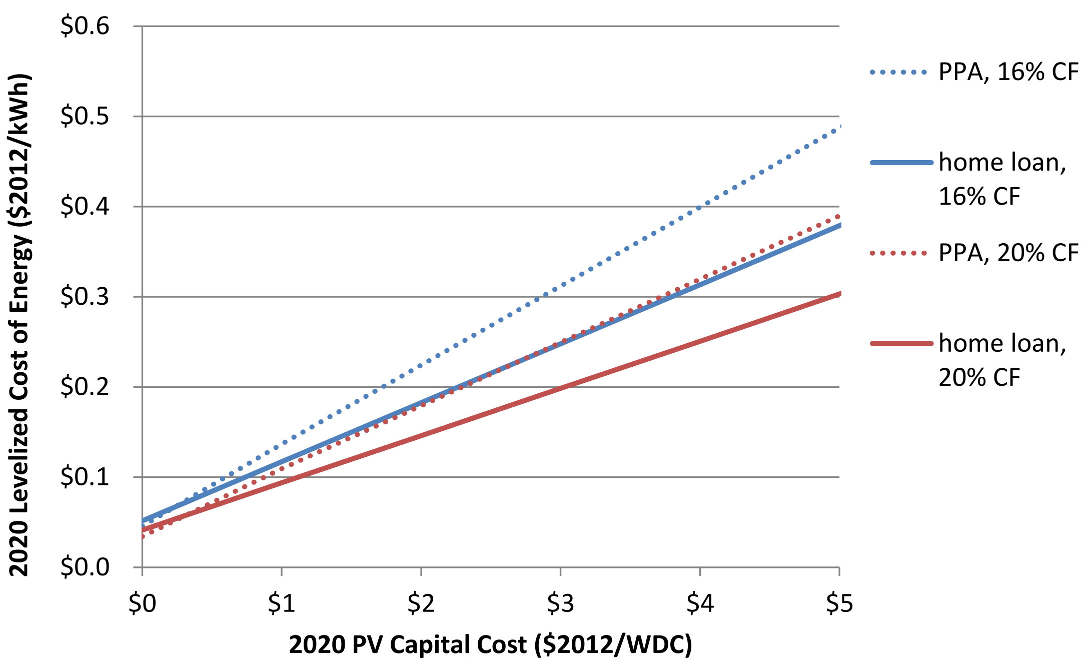


*Figure 32: Estimated 2020 levelized cost of energy (LCOE) of solar PV to a homeowner, under four different scenarios, compared to installed capital cost of solar PV (assumes 10% investment tax credit, per current policy after 2016, and no state incentives for solar PV in 2020).*

*Key: PPA = power purchase agreement, CF = solar PV capacity factor.*

The figure above also shows how solar energy costs vary with different capacity factor (CF) assumptions (ranging from a 16 – 20% capacity factor - which is fairly typical for California rooftop systems across different regions of the state), and under two different project financing approaches: a third party financed power purchase agreement (PPA) and a home loan. The home loan could represent either a home mortgage, such as might be the case for a new construction home with solar already installed on the rooftop, or a home equity line of credit, which might be the case for an existing building that is retrofit with solar. For the purposes of this figure, the differences in the cost of borrowing, and the impacts of a fixed interest rate versus a variable rate, between a home mortgage and home equity line of credit are assumed to be far greater than the uncertainty regarding the future cost of borrowing in 2020. It should be noted that the future cost of financing a solar PV system in 2020 under any structure is highly uncertain not least because interest rates are likely to change over the next eight years.

Under the assumptions used in Figure 35, it can be seen that if installed rooftop solar PV costs come down to approximately $4 per watt-DC by 2020 (in 2012 dollars), then the all-in cost of solar energy to a homeowner will likely be in the range of 25 to 40 cents per kWh (in 2012 dollars), depending on what kind of financing is used by the homeowner and what capacity factor the solar project achieves. Alternatively, if the all-in installed capital cost of solar falls to a $1/watt-DC by 2020, then the levelized cost of solar energy would be in the range of $0.10/kWh. This wide range of potential solar energy costs in 2020 highlights the uncertainty over the future cost of achieving ZNE, and emphasizes the importance of the solar industry continuing to achieve cost reductions.

As a point of comparison, in the third quarter of 2012, the California Solar Initiative reported that installed residential rooftop solar PV, for systems under 10 kW in size, currently cost between $5.69 and $5.95/watt-dc (depending on whether 3rd party installer costs are included in the average). It should also be noted current levelized solar energy costs are not comparable to the LCOE numbers in Figure 32 because the current investment tax credit is at 30% and the California Solar Initiative state incentives are still in effect. As a result, many current solar projects today actually result in a lower cost of energy to the customer than might be expected in 2020 if current subsidies expire and continued cost reductions are not achieved in that timeframe.

In Germany, where government policies have been aggressively promoting distributed rooftop PV, the installed cost of solar PV is about 45% lower than United States average, indicating that with the right set of policies and incentives, the installed cost of PV in the U.S., and California, could potentially be reduced. A September 2012 Scoping Analysis from Lawrence Berkeley National Laboratory investigated some of the reasons for the lower solar capital costs in Germany compared to the U.S. and found that the differences were primarily due to “soft” balance-of-system costs, such as installation, labor, permitting, customer acquisition as well as differences in the level of profit realized on projects (Seel, Barbose, Wiser, 2012). This finding indicates that there is potential for reducing the balance-of-system costs of solar in California particularly. Policies to help bring down the solar PV balance-of-system costs would be helpful to furthering the state’s ZNE goals.

### *Community Solar and PV System Project Size*

Rooftop PV projects are also generally smaller in size than distributed ground-mounted PV systems and tend to have a slightly higher unit cost than larger projects (see Figure 33). There could be a variety of reasons for this difference, but it is likely that the “soft” balance-of-system costs are higher on a per unit basis for the smaller projects.

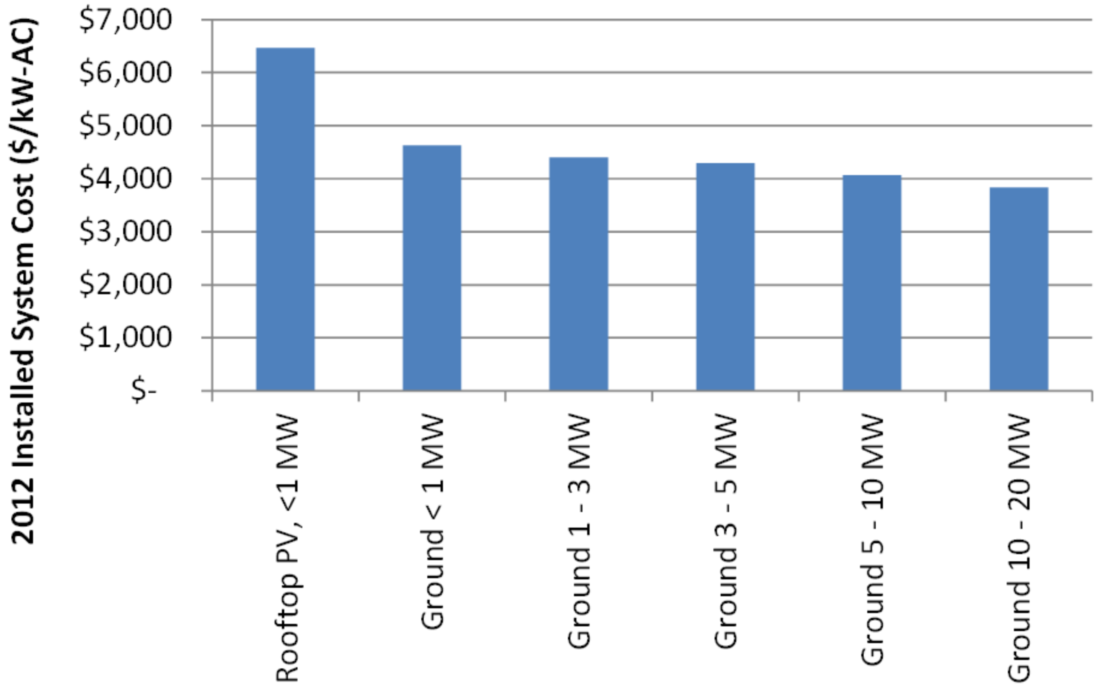


*Figure 33: Comparison of current solar PV installed system costs (2010 $/kW)*

*Source: Rooftop PV prices from California Solar Statistics, CSI database, Q3 2012 available at: http://www.californiasolarstatistics.ca.gov/reports/quarterly_cost_per_watt/ all other data from Energy & Environmental Economics, Inc. "Technical Potential for Local Distributed Photovoltaics in California: Preliminary Assessment," March 2012.*

Although the larger ground-mounted systems have a lower capital cost per kW than the rooftop solar PV systems, there are other challenges associated with using these larger PV projects to meet ZNE goals as part of a "ZNE Community" or "ZNE Equivalency" definition. For example, while many rooftop PV projects currently qualify for Net Energy Metering benefits and a state incentive under the CSI or NSHP program, the larger ground-mounted projects generally do not qualify for these benefits. As a result, even though larger PV projects may be lower cost than smaller systems prior to the receipt of state solar incentives, the smaller systems become lower cost after incentives are factored in.

In addition, since the larger PV systems produce more energy than would be needed by a typical building to achieve ZNE (especially single family residential buildings), it would make sense to consider applying the output of a single, large PV system to a "community" of ZNE buildings. However, California does not currently have in place many policies to support larger, distributed generation projects being used to offset the energy use of multiple, independent buildings within a "ZNE community."

The passage of SB 594 (Wolk 2012) may begin to change this situation for some customers, most likely agricultural, commercial, industrial, institutional, and government customers (rather than residential customers). The new law allows customers to aggregate the load of multiple meters located on or adjacent to the property where a renewable generation facility (up to 1 MW in size) is located, and apply NEM to the aggregated load, with a few stipulations. The customer must solely own all of the properties where the meters are located.

## Retail Rates and the Participant Cost Test

The cost-effectiveness of ZNE buildings, from the perspective of the building owner/occupant is determined by the Participant Cost Test (PCT). The benefits of energy efficiency, and self-generation, from the perspective of the participant, are determined by the customer's avoided cost of energy, i.e. the avoided electricity or natural gas retail rate.

In California, electricity customers face a variety of different retail rates, depending on what utility and climate zone they live in, what optional rates they have elected to participate in, such as a time-of-use (TOU) rate, and whether they are on a "CARE" rate for low-income customers, or an "all-electric" rate for customers that use electric heat rather than gas heat.

Currently, most residential customers in California see some form of "inclining block" rate, or "tiered rate."[1] This means that as a building's energy consumption increases throughout the month, the marginal price that the customer pays for electricity increases as well. For certain large residential customers, the marginal electricity price can be above $0.20 to $0.30/kWh. These relatively high marginal electricity rates mean that both energy efficiency and self-generation (under the state's net energy metering rules) are more likely to be cost-effective for residential customers with electricity consumption in the upper tiers, under the Participant Cost Test, than they would have been under a flatter rate structure. Likewise, for customers with electricity consumption levels that put them in the lower tiers, conservation and self-generation may be less cost-effective.

Figure 34 illustrates typical tired residential retail rates for five electric utilities in California (note: does not include CARE rates and retail rate details by zone, season, etc. are not shown).

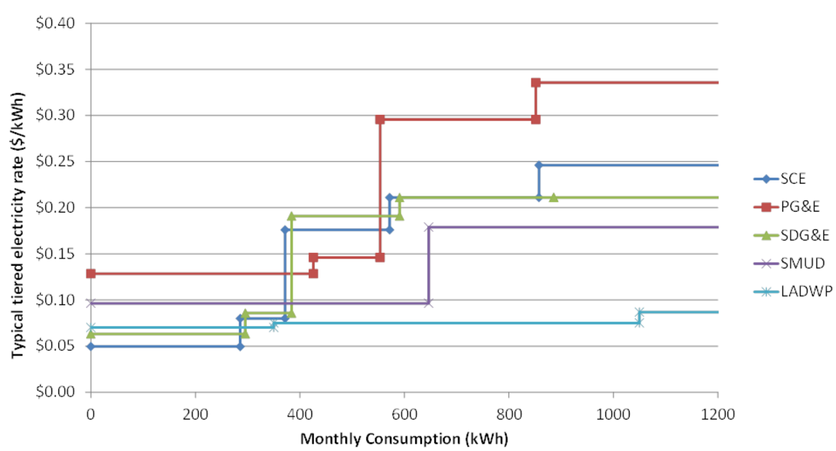


*Figure 34: Typical tiered residential retail rates in California increase with higher monthly electricity consumption (non-CARE typical 2012 rates)*

Retail rates are regularly updated, approximately every three years, by utilities to reflect changing costs and rate design strategies (with the approval of the CPUC or a municipal board of directors in the case of municipal utilities). This uncertainty over future rate structures makes it

[1] As of 2011, approximately 35% of residential investor-owned utility customers that participate in the net-energy metering (NEM) program were on a time-of-use rate, with the remainder of IOU NEM customers on non-TOU rates (based on E3 analysis of customer account data for an evaluation of the California Solar Initiative).

challenging to say with any certainty whether a ZNE building will be cost-effective to participants in 2020 or 2030.

Going forward, the CPUC may end up transitioning away from tiered retail rates as the default choice for residential customers and move towards the use of time variant rates as early as 2013, as permitted by California Senate Bill 695 (2009). The CPUC is exploring rate design options, including the transition to time varying rates and dynamic pricing (through the regulatory docket R. 12-06-013). If carried forward, changes to the existing retail rate structure may end up reducing the high marginal prices that large residential customers currently see, thereby reducing the participant cost effectiveness of some energy efficiency and self-generation options for consumers currently in the upper tiers. The changing dynamics of rate structures are hard to predict, but will have a large impact on the cost-effectiveness of ZNE buildings from the participant cost perspective.

## *Customer Compensation for Distributed Renewable Generation*

Retail rates structures are a major determinant of whether a rooftop solar PV system is cost-effective for a customer (under the PCT) due to the state's current net energy metering (NEM) rules. NEM represents California's current policy mechanism for paying owners of behind-the-meter distributed generation for their power that is exported to the grid.

The current NEM rules allow customers with rooftop solar PV to run their meter "backwards" when their solar system is generating more power than the building is consuming, effectively crediting customers with rooftop solar PV for their solar generation at the full retail rate that they otherwise would pay.

Under residential tiered rate structures, solar PV is most cost-effective when it is sized to avoid only the highest (most expensive) tiered rates, rather than a customer's full electricity consumption, some of which is billed at the lower tiered rates. Likewise, for customers that already have a low energy consumption baseline, such as apartment-dwellers or occupants of very energy efficient buildings, the marginal electricity rate is already relatively low under tiered rates, making solar PV less cost effective to these customers (See Figure 34above).

As of December 2012, 43 states in the U.S. have implemented some form of net energy metering policy, most of which are limited by a maximum capacity size for individual systems, and limited by a maximum statewide or utility-wide installation capacity (see www.dsireusa.org). In California, the NEM program is limited to the point at which the total rated generating capacity of NEM customers exceeds five percent of a utility's aggregate customer peak demand. In Decision 12-05-036 (May 24, 2012), the CPUC clarified "aggregate customer peak demand" to mean the sum of individual customers' peak demand, i.e. their non-coincident peak demands, thus effectively expanding the cap on NEM compared to how utilities had previously been interpreting the definition.

The total amount of solar PV that is allowed to operate under NEM is still limited by the CPUC's decision. However, the exact method for how to calculate the amount of solar PV capacity that will be allowed under the current NEM rules, based on the CPUC's 2012 Decision, is still being discussed. As a result there are currently few reliable estimates available for what year the NEM cap is likely to be reached. In addition, the CPUC has announced that on January 1, 2015, there will be temporary suspension of the NEM program for new customers pending a further Commission study and Rulemaking on NEM.

The purpose of the new NEM study is to develop, "a better understanding of who benefits, and who bears the economic burden, if any, of the NEM program" (CPUC, D.12-05-036 ). This study is to be followed by a new rulemaking proceeding on NEM. In D.12-05-036, the Commission notes that, "In the [next] policy-setting phase, we intend to explore the costs of NEM, and alternative mechanisms for compensating customer-sited renewable generation. The updated NEM study will inform our consideration of the most cost-effective path forward to achieve the state's renewable energy distributed generation goals."

An example of an alternative approach to NEM that is used more commonly in Europe for compensating owners of distributed renewable generation for their net power production is a fixed payment per kWh of energy produced, known as a feed-in-tariff. Other policy options exist as well, which will be explored in the upcoming NEM study commissioned by the CPUC.

In short, CPUC is actively exploring the costs and benefits of NEM, and possible alternatives to NEM, and may issue substantive changes to the policy as early as 2014 or 2015. This means that by 2020, when the state's residential ZNE goals are defined, homeowners may be operating under a different policy regime, which could significantly alter the cost of rooftop PV for these customers. This is an issue that will need to be closely followed by policymakers seeking to encourage ZNE buildings.

### *ZNE Buildings' Challenge to the Current Utility Business Model*

The shift to zero net energy buildings and homes would represent a significant challenge to the current utility business model. Currently, many costs of customer service are collected in utility rates using a per kWh delivered basis even if costs are fixed such as poles, wires, service drops, meters, etc. Therefore, this shift to ZNE buildings would likely require a fundamental change in the way that California's utilities recover the costs of providing electric services, particularly from customer classes that are billed predominately based on energy use charges, as well as providing appropriate compensation for NEM generation based on its value to the grid. For instance, in the residential customer class, almost all of the fixed cost of service of California's investor owned utilities (IOU) is recovered through energy related charges and very little is recovered through non-energy related charges, also known as customer charges[1].

For ZNE customers operating under current net energy metering (NEM) rules and existing rates, energy charges on their bills could be significantly reduced, zero, or net negative, which may not allow the electric utility to recover the cost to serve these customers from the customers. Instead, the costs will need to be recovered from other non-ZNE customers. Electric utilities are concerned by the prospect that since these fixed utility costs still exist and must be recovered, the cost to serve ZNE customers will then be shifted from ZNE customers to non-participating customers. In particular, both State law and Commission policy prevent the IOUs from increasing customer charges to customers in the first two tiers in the residential rate structures to recover revenue for grid related costs[2] which may lead to significant increases in costs to some customers.

Additionally, a zero or negative bill incurred by a ZNE customer, or a NEM customer more generally (on predominately energy rates), inaccurately signals that the utility cost to serve this

[1] Non-residential classes have rate designs that more closely align to their marginal cost drivers and include higher customer charges and peak-demand related charges.

[2] See PU Code 739.9 and CPUC Decision D.11-05-047.

customer is zero. The following two examples illustrate this point: first, customers in ZNE buildings are generally still connected to the electric grid (as opposed to being fully "off-grid"), and receive the benefits of having the capability to export to or consume energy from the grid as needed. ZNE customers also enjoy the benefits of receiving reliable energy services along with other utility customers. Specifically, the poles, wires, transforming equipment, and generation capacity benefit ZNE customers at a cost. Electric utilities are concerned that mechanisms should be in place to recover those costs without shifting these costs to non-ZNE customers. Second, there is a value difference between the time of day when a ZNE customer is either a net consumer or provider of power. It is possible for a ZNE customer to export higher valued energy to the grid compared to the power they consume, which would result in a system-wide benefit for the energy provided. However, the inverse of this situation is also possible. In short, the costs to the electric utility to serve ZNE customers are most likely not zero, and may not be time-dependent.

If ZNE buildings become wide-spread in California, policymakers will needs to consider more sustainable solutions to reallocating the costs of service and customer charges for ZNE customers to better follow cost causation and marginal cost principles that have been established by the Commission. Some of these issues, as they pertain to the impacts of Net Energy Metering, are currently being evaluated at the CPUC through the NEM proceeding, as discussed in the section above.

### *Offsetting Natural Gas Consumption to Achieve ZNE Goals*

An important element of the solar PV NEM rules is the "net surplus" rule. Under this rule, solar generation is credited at the full retail rate when total solar PV generation over the course of the year is less than or equal to a building's total electricity consumption over the course of the year. If solar PV generation is higher than electricity consumption over the year, then the net surplus solar PV is credited to the customer at a calculated market rate (calculated using an avoided cost derived from an hourly day-ahead electricity market price), which is currently approximately $0.04/kWh (CPUC 2011b). This means that there is a significant financial incentive to a customer to avoid over-sizing their solar PV relative to their building's annual electricity demand.

The rules around net surplus power of solar PV (as set under AB 920) have important implications for ZNE building design. If a building includes natural gas end uses, and seeks to achieve ZNE status by offsetting the natural gas energy use with solar PV generation, then the building will need to over-size the solar PV system relative to the building's electric loads. The resulting "net surplus" solar PV generation can be used to offset the building's natural gas use, but the cost-effectiveness of the larger solar PV array will be greatly diminished under the current NEM rules.

Over the course of the year, a ZNE building that offsets its natural gas use with net surplus solar generation will export significantly more electricity to the grid than the building consumes, and will receive relatively little value for the net surplus power.

As long as a building is all electric, and uses no natural gas (or other non-renewable fuels) for space heating, water heating, cooking, clothes drying, etc., then it is possible to use solar PV to offset the building's complete energy demand without running into the net surplus rules. However, all-electric buildings may not be practical for many commercial applications. Likewise, all-electric residential buildings may be less attractive to those home buyers who prefer gas stoves, gas water heat or gas clothes dryers.

In addition, on-site use of natural gas is generally more efficient than combusting natural gas to produce electricity and then transporting the electricity across the transmission and distribution system, with associated line losses, in order to deliver electric power to a building. For this reason, California energy efficiency policies have long encouraged natural gas end-uses over electric end-uses in buildings where feasible.

Over the long-term, as California's electricity generation mix moves towards higher penetrations of renewable energy, resulting in less greenhouse gas emissions from electricity generation, the state may want to encourage more electric end-uses over natural gas to save greenhouse gas emissions (see Section 5.7 on greenhouse gas emissions). However, the AB 920 net surplus rules for solar PV, and a policy push for ZNE buildings, should not be a driver for electric end-uses over on-site natural gas use.

Alternative options to sizing the solar PV system in a ZNE building to offset both electricity and natural gas energy use would be to apply an "electric only" definition of ZNE which ignored a building's natural gas use, or allow a building owner to purchase biogas credits to offset the building's natural gas consumption. Currently, it is not feasible to deliver biogas to most California customers, but biogas offsets, not necessarily delivered biogas, could provide a way for a building to achieve ZNE in a more cost-effective way than offsetting natural gas use with on-site solar PV generation. The use of biogas offsets for natural gas use does not appear to be a part of the current understanding of ZNE buildings, however, policymakers may want to investigate this option as a potential way to lower the cost of achieving ZNE equivalency.

### *Costs of ZNE Grid Impacts*

For all new residential construction to be ZNE by 2020, and all new commercial construction to be ZNE by 2030 (whether a TDV-based, site-energy or source-energy ZNE definition is applied), will require a dramatic increase in the amount of distributed solar PV installed across the state. Accommodating these higher penetrations of distributed generation in California would require changes to current interconnection policies, and may have broader implications for the transmission system. More research is needed on how to accommodate high penetration PV, and manage reliability and power quality, at reasonable cost.

In cost-effectiveness tests, only current and known costs are included, so the grid impact costs due to higher penetrations of PV and ZNE are not reflected in today's cost tests. There is currently a lack of good data regarding these costs, and what levels of DG and ZNE penetration will trigger these costs. More research into this area is needed, as discussed in 6.8.

## 6.8 Grid Implications of ZNE Goals

ZNE buildings as outlined in the Strategic Plan and the IEPR (where onsite or distributed renewables is an inherent component of ZNE) introduce a number of grid integration challenges that are not posed by buildings that are simply energy efficient. ZNE buildings require renewable self-generation in addition to energy efficiency in order to offset the building's energy usage not affected by energy efficiency. Under current market circumstances, this self-generation is typically provided by rooftop PV systems. Because PV systems can only operate during daylight hours, PV systems sized to offset a building's total energy usage are necessarily larger than the average electricity demand of the building. In the absence of energy storage this leads to some hours when ZNE buildings are net exporters of electricity and other hours when the building still relies on the grid for all of its electricity demand.

This fundamental shift from buildings and communities acting as electrical loads to being both producers and consumers of electrical power at different times of day has important cost and distribution engineering implications. To illustrate these points, in this section we approximate the amount of residential rooftop PV capacity that would be required to meet the 2020 residential ZNE goals under a site-energy, source-energy and TDV-based definition of ZNE. We draw from the literature to discuss technical and regulatory challenges of integrating this amount of PV on to the electricity grid. We also identify critical opportunities for reducing the barriers to achieving the ZNE goals from a grid integration perspective.

The key findings of this section include:

- Meeting the 2020 residential ZNE goal with rooftop PVs will likely require higher rooftop PV adoption rates when compared with California's current policy goals of achieving 1,000 MW of residential rooftop PV, and 2,000 MW of non-residential rooftop PV, by 2017 under the "million solar roofs" initiative. (In addition, see Section 5.5 for a discussion of the current policy limits on net energy metering for distributed generation).
- It is estimated that meeting the residential ZNE goal will require annual new PV installations of between 330 MW and 1,400 MW in 2020 and each year thereafter, depending on the definition of ZNE and assumptions regarding economic growth in 2020.

- Meeting the state's commercial building ZNE goals in 2030 will require additional renewable distributed capacity, well above the amount of solar needed to meet the residential ZNE goals. The amount of renewable distributed energy needed to meet the commercial ZNE goals has not been quantified in this report due to data, cost and policy uncertainties in 2030 and beyond, but this would be a useful question to evaluate in future ZNE research.
- Many of the technical distribution grid impacts of high penetrations of solar PV (voltage rise and stability, fault detection, and unintentional islanding) are currently addressed through California's Rule 21 Interconnection Standards. These standards are in the process of being updated at the CPUC.
- The costs associated with electricity distribution and other network upgrades that may be required as a result of high penetrations of ZNE buildings are not currently well quantified.
- The international experience with high penetration rooftop PVs suggests that policy changes to California's interconnection standards could help enable higher penetrations of rooftop PVs, but these distribution upgrades may also lead to higher interconnection costs.
- Increased PV penetration from ZNE, when accompanied by additional distributed PV development spurred by California's Renewable Auction mechanism and feed-in tariff, may at some point lead to less efficient utilization of the transmission infrastructure or require additional transmission network upgrades, the costs of which have not yet been identified.
- More research should be devoted to: quantifying the expected interconnection costs and transmission network impacts as distributed PV penetrations increase, exploring appropriate ways to allocate these costs, and testing the ability of smart inverters to regulate voltage, curtail renewables, and support reliability and safety in California's ZNE communities.

### 6.8.1 How Much Solar PV is Needed to Meet California's ZNE goals?

A simple analysis was performed to approximate the amount of PV capacity that would be required to meet California's 2020 residential ZNE goal, under the site energy-based, source energy-based and 2013 TDV-based definitions of ZNE. The analysis assumed that beginning in 2020 all residential new construction is ZNE. Note that the amount of renewable distributed energy needed to meet the commercial ZNE goals in 2030 has not been quantified in this report due to data, cost and policy uncertainties in 2030 and beyond, but this would be a useful question to evaluate in future ZNE research.

For each California climate zone and residential building type (single family, multifamily low-rise, and multifamily high rise), the total annual energy usage associated with new residential buildings in 2020 is approximated using simulated energy usage data for representative "exemplar" high-efficiency homes based on data from Arup's Technical Feasibility Study (Arup 2012) (See Table 1). The 2020 forecast for new residential construction by building type and climate zone comes from data developed for the CEC's 2013 Title 24 code update, and square footage data for new residential buildings by building type comes from data for the Western US from the US Census Bureau (US Census Bureau 2012). Solar output profiles for each climate zone are used to estimate the capacity of PV required for each building type to reach ZNE in each climate zone. These results are added together to produce a state-wide estimate of residential ZNE PV capacity needs in 2020. A more detailed description of the methodology and the input assumptions can be found in Appendix D.

*Table 1. New construction residential EUI's used in PV sizing analysis based on data from "exemplar" residential buildings simulated by Arup for the Technical Feasibility Study (2012)*

| Climate zones | Representative climate zone | EUI (kBtu/sqft-yr) | |
|---|---|---|---|
| | | Single Family | Multifamily |
| 1, 2, 3, 5 | 3 | 17.3 | 19.0 |
| 6, 7, 8, 9, 10 | 10 | 13.4 | 18.3 |
| 4, 11, 12, 13 | 12 | 17.5 | 19.0 |
| 14, 15 | 15 | 13.0 | 19.4 |
| 16 | 16 | 19.7 | 21.1 |

The results of the 2020 residential ZNE PV capacity analysis are shown in Figure 37. Our analysis found that the PV capacities required to meet the 2020 new residential ZNE construction goal depend strongly on both the definition of ZNE and the assumption regarding new residential construction starts in 2020. Despite the uncertainties, it seems clear that meeting the 2020 residential ZNE target with PVs will require a dramatic increase in residential solar development above the levels incentivized by past and current policies. Meeting the residential ZNE goal in 2020 would require installing more PV in a single year than California has installed on residential buildings to date under the CSI and NSHP programs.

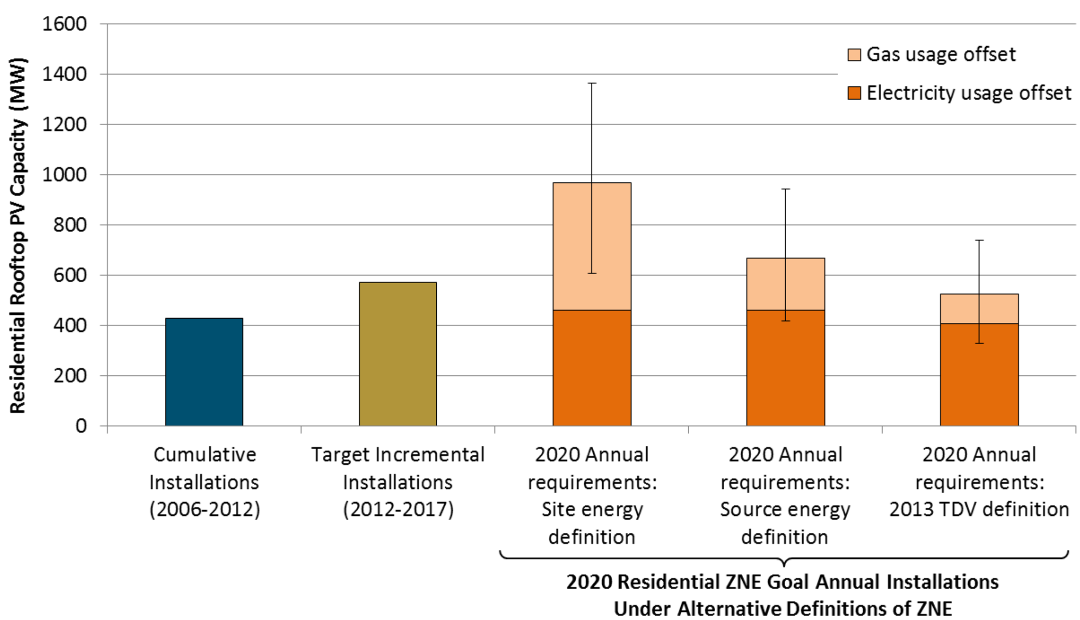


*Figure 35.Cumulative historical residential PV installations associated with the California Solar Initiative (CSI) and New Solar Homes Partnership (NSHP) (2006 – 2012) (CEC, CPUC 2012); the additional residential PV installations required to meet a statewide target of 3,000 MW of rooftop PV's in California (assuming that 33% of these are built on residential rooftops) (2012 – 2017); and the annual PV installations needed for all new residential construction to achieve ZNE in 2020 under the site energy, source energy, and TDV-based definitions of ZNE.*

Note: The error bars on the 2020 numbers represent uncertainty around new residential construction starts in 2020. The error bars were calculated by taking the 10th and 90th percentiles of the difference in new construction starts each year from a linear fit to the historical trend.

The site energy-based definition of ZNE would require approximately 970MW of PV installed in 2020, based on a residential construction forecast of 150,000 new units, with an estimated range between 610MW and 1,400MW of solar PV in 2020 depending on the new residential construction starts. The 2013 TDV-based definition would require almost half as much PV as the site-energy definition: 530MW of PV installed in 2020, with an estimated range of 330MW to 740MW depending on the new residential construction starts. The source energy definition would require a level of new PV capacity between those determined with the site energy and TDV-based definitions.

For context, these 2020 PV install numbers are shown in Figure 35 next to two benchmarks: the total cumulative residential PV installations under the California Solar Initiative (CSI) and the New Solar Homes Partnership (NSHP) from 2006 through 2012; and the additional rooftop PV installations required between 2012 and 2017 to meet the residential share (33%) of the statewide “million solar roofs” goal of 3,000 MW by 2017.[1]

Also shown in Figure 35 is a breakdown of the PV capacities needed to offset new residential electricity usage versus gas usage in buildings, under all three definitions of ZNE. Under the site energy definition, the breakdown between gas and electricity PV offsets simply represents the proportion of total site energy demand that is associated with electricity and gas consumption in residential new construction. The source energy definition accounts for the primary energy that does not need to be consumed at power plants due to the energy produced on-site at the ZNE building (by the PV system). By accounting for the avoided source energy due to on-site PV generation, less PV is required to offset a building’s onsite natural gas use compared to the site energy definition of ZNE.

Under the TDV-based definition of ZNE, the same total amount of energy is being consumed by residential buildings, but not all of this energy use is being offset by PV. This is because the energy is valued differently under TDV. In the 2013 TDV factors, the value of natural gas is generally much lower than for electricity. Furthermore, because the value of PV output is assessed using the electricity TDVs (i.e. the avoided cost of electricity), it requires relatively little PV generation to offset natural gas use under the TDV-based definition.

One important caveat to note with regards to the TDV-based definition of ZNE applied here, is that the analysis is based on the 2013 TDVs, reflecting recent forecasts of electricity and natural gas market conditions. The TDV values are usually updated at 3-year intervals based on the CEC’s Title 24 code cycle. As a result, by 2020, the value of the TDVs and the amount of solar required to meet a 2020, rather than a 2013, TDV-based definition of ZNE could change significantly. For example, as higher penetrations of solar PV in California are achieved this will shift the statewide system peak to later in the evening hours, thereby reducing the value of

[1] The residential share of 33% was derived from the residential vs. commercial goals of the CSI program (CEC, CPUC 2012).

solar PV generation under the TDV definition (see the section on system level effects and Figure 40).

An additional analysis was performed to illustrate how much incremental PV capacity might be needed from 2020 through 2030 to meet the residential ZNE goal. We assume that the number of new residential housing starts remains at 150,000 units (single family and multi-family combined) each year between 2020 and 2030, and that the EUIs for residential new construction remain constant over this period. The resulting estimate of PV installations needed for residential ZNE homes are shown in Figure 36.

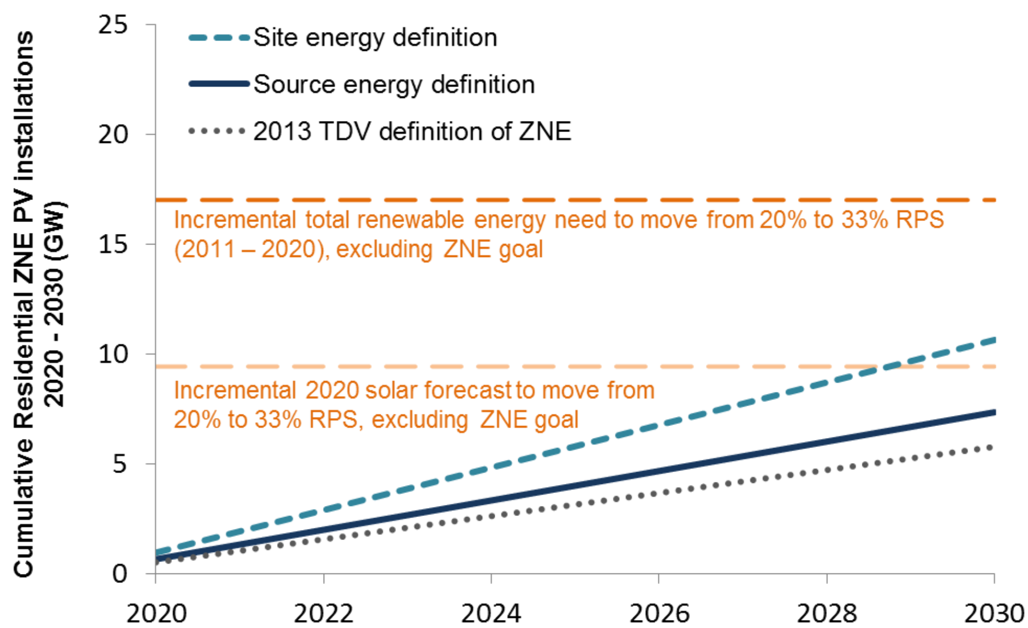


*Figure 36. Rooftop PV capacity required to meet residential ZNE goals from 2020 to 2030. For context, the additional renewable capacities projected to be required in order to get California from its current 20% RPS to a 33% RPS target are shown by the dotted orange.*

Depending on the definition of ZNE, the PV capacities required to meet only the residential ZNE goal from 2020 to 2030 could be between approximately 5,000 MW and 11,000 MW. This level of development is comparable to the total incremental installations of solar power (including ground-mounted PV and CSP) expected to be installed between 2011 and 2020 in order to meet the state's 33% renewable portfolio standard (RPS). Achieving the ZNE goals would therefore represent a major addition to the current renewable development goals of California. The scale of the PV penetration required to meet the ZNE goals also has implications for the potential grid impacts of ZNE buildings. These impacts are discussed in the next section.

### 6.8.2 Grid Operational and Physical Impacts

The impacts of ZNE building construction on the electricity grid can be decomposed into system-level and local effects. System-level effects refer to any changes that are required to be made to the transmission infrastructure or the operation of the grid (commitment and dispatch of generators or reserve requirements), in order to maintain reliability of electricity supply to the entire system (i.e. the CAISO operating area). The system-level effects of meeting the ZNE goals may be significant if, for example, ZNE homes with PV systems, in aggregate, change the daily statewide electricity demand patterns. By contrast, local effects refer to any changes in the engineering or operation of the local distribution systems on to which each ZNE home or ZNE community is interconnected.[1]

The electricity system as a whole benefits from the aggregation of a large number of diverse loads and generators. It therefore takes sweeping changes to affect system-level operation. Distribution systems, on the other hand, serve small areas with more correlated load (and in the case of ZNE communities, generation) profiles. Significant changes to the load or generation profiles of a community, due to ZNE development for example, might require substantial upgrades to the distribution infrastructure while having negligible system-level impacts.

#### *Local Distribution Effects*

As is discussed in this section, high penetration PV on ZNE buildings introduces more challenges at the local distribution level than at the system-wide level. However, because each distribution circuit is unique, the ability of the distribution system as a whole to accommodate large-scale rooftop PV is not straightforward to quantify. For this reason, we will discuss the general technical concerns and regulatory challenges around integrating large-scale distributed generation on distribution circuits and provide an example community-wide analysis demonstrating these challenges, rather than attempt to quantify the system-wide costs or technical limitations of PV integration.

#### Technical Challenges

Current distribution circuits are typically designed for one-way flows, from transmission lines down to residential, commercial, and industrial loads.[2] This one-way paradigm has dictated the design of power lines, power electronics, system controls, reliability contingencies, and safety protocols. When power is instead generated at the load end of the line, by several rooftop PV systems for example, distribution system upgrades may be required to prevent the distribution line from operating outside of its normal operating conditions, affecting power quality and even human safety. The experience with rooftop PV systems thus far has suggested that single houses with photovoltaic systems do not give rise to these issues because the maximum PV

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[1] There is not always a clear distinction between transmission and distribution systems, but lines are typically categorized as either transmission or distribution according to their voltage. For example, PG&E considers any lines above 60kV to be transmission lines for interconnection rule determination.

[2] This is true for radial topologies, which dominate the distribution system, however some customers are connected to networked distribution circuits, called secondary distribution networks. These networks, which can experience two-way flows, are discussed in the following section.

power output is small relative to the rest of the load in the community. Of more concern to power engineers are new housing developments in which a large fraction of the homes have PV systems or are ZNE or existing communities in which a large portion of homes are retrofitted to achieve ZNE. For these systems, prior analyses have identified three primary technical challenges for integrating large-scale distributed generation:

- **Voltage regulation**

  In conventional distribution systems, high PV output and low load may result in higher voltages along distribution lines than the systems have been designed to accommodate. Currently, capacitor banks or transformer tap changers are used to maintain voltages within the acceptable range. These technologies can be costly upfront, may require additional operational expenses, and are limited in their real-time flexibility to handle large voltage fluctuations due to rapid changes in the solar resource. Demonstration projects have suggested that advanced PV inverters can contribute to maintaining stable voltages, (Coddington et al. 2012, Liu and Bebic 2008) but these smart inverters, as a relatively new technology, are currently barred from regulating voltage by current interconnection standards (CPUC 2012a). In the future, increased acceptance of these controls by utilities and regulators may lead to more flexible interconnection standards allowing voltage regulation.

- **Unintentional islanding**

  In communities that boast high-penetration distributed PV, there is also a risk that the community will at some point experience "unintentional islanding," or an electrical disconnection from the rest of the system, while the PV continues to generate. This situation poses technical challenges to the electrical system. When a community is islanded, it may be difficult to re-synchronize with the rest of the grid. It may also pose safety risks because line workers may not know that a distribution circuit is still live when an outage has occurred upstream. While this is an important technical concern, unintentional islanding can be avoided by integrating the appropriate controls in distributed generation systems and/or ZNE homes or communities, such as automatic tripping devices and Minimum Import Relays. With these controls, experience with high penetration PV systems so far suggests that unintentional islanding is a rare phenomenon (Coddington et al. 2012).

- **Fault detection**

  Maintaining system reliability on the grid requires the use of protections to isolate the impacts of local failures like faults. In current systems, these protections typically rely on the detection of the very large currents that arise in the area of a fault. PV inverters, which rely on solid state electronics, produce different levels of this fault current than conventional (synchronous and asynchronous) systems. This can be beneficial in distribution circuits that are bordering on too much fault current.

  Some fault protections were also designed on the assumption that reverse flow (power flow from the load back toward the transmission system) should only occur when a fault occurs upstream. Reverse flows due to PV systems may lead to false positive fault detection and isolation on these systems, potentially resulting in a local power outage. On these circuits, power electronics are sometimes installed to ensure that the local demand never falls below a minimum threshold (Mike Coddington et al. 2009), making a ZNE community operationally impossible under such a control system.

Because PV systems can change the way that distribution systems behave under fault conditions, each individual distribution circuit with a large number of PV interconnections needs to be carefully engineered to ensure proper fault protection given the characteristics of the load, distributed generation sources, and existing protections.

## Regulatory Challenges

The electric power industry is overwhelmingly focused on system reliability and safety, with good reason. As such, regulations have been put in place to ensure that each point on the grid remains within a range of acceptable operating conditions. As has been discussed, the local effects of distributed generation are specific to each distribution circuit. Regulators have therefore adopted generation interconnection screens strict enough to ensure that all fast-tracked interconnections will maintain proper operations on the distribution circuits. In California, Electric Rule No. 21 dictates the interconnection rules for distributed generators (CPUC 2012a). Rule 21 lists a set of required protective functions that ensure that voltages and frequencies remain within acceptable ranges and that distributed generators do not pose safety risks to line workers. The components of Rule 21 that are crucial to the development of ZNE buildings are listed below.

- **Maximum capacity screen**

  Rule 21 requires additional review of (and potentially protective controls for) distribution systems on which the distributed generator capacity exceeds 15% of the peak load of a line section. Recent revisions of Rule 21 include a supplemental review that allows fast-tracked interconnection for distributed generators that fail the 15% screen but have a capacity less than the minimum daytime load on the line to which they are connected (California Public Utilities Commission 2012a), given that other screens are also passed). This supplemental review ensures that the line does not experience reverse flows. A simple analysis of 500 residential and commercial feeders in Southwestern US city indicated that the minimum daytime load is on average about 30% of the peak load (Coddington et al. 2012). Although there is limited data for evaluating the effects of the capacity screen in the supplemental review, this statistic suggests that the updated screen may approximately double the maximum capacity of PV projects with fast-tracked interconnection. If a distributed generator fails this additional screen, then additional review is required. This process may increase the cost of interconnection on existing systems if several ZNE building retrofits occur on a single circuit. Upgrades of existing circuits can cost between thousands and hundreds of thousands of dollars, depending on the equipment being upgraded and the length of the line (Coddington et al. 2012). For new ZNE subdivisions, however, distribution equipment can be selected up front that mitigates interconnection issues for low to moderate penetrations of rooftop PVs.

- **Voltage regulation**

  Rule 21 requires that distributed generators do not cause other customers on the distribution line to experience voltages outside of an acceptable range. Since distributed generation tends to increase voltages at the point of interconnection, large systems may require voltage regulating equipment to maintain voltages within acceptable levels, which can increase the cost of distributed generation interconnection. Smart PV inverters are also capable of regulating voltage using reactive power flows, but Rule 21 currently prevents distributed generators from using this relatively new technology. The CPUC has suggested that the second phase of Rule 21 updates may address "potential modifications to technical operating standards, limited to smart inverter functionalities and generation output metering" (CPUC 2012b). It is currently unknown whether these modifications will include provisions for the use of voltage regulation functionality.

- **Automatic tripping**

  Rule 21 requires that distributed generation systems disconnect in the case of a fault on the distribution line. This regulation ensures safety for line workers responding to power outages, but prevents grid-connected PV systems on ZNE buildings from meeting the onsite demand during power outages on the grid. This is an important consideration if a major selling point of a ZNE home is the perception that it is more resilient in the face of a power outage. Under current rules, if an outage occurs on a distribution network with ZNE homes, the solar PV self-generation will trip off for safety reasons. Backup power for outages must be connected to the home through a switch so that the home runs either on electricity from the grid or the back-up generator, but is never connected to both at the same time.

In addition to Rule 21, utilities' policies regarding net metering may inhibit commercial ZNE building development on non-radial distribution systems (known as secondary distribution networks). In California, distributed generators up to 1MW in capacity qualify to participate in net metering, provided that they are not connected to a secondary system (CPUC 2011a). Secondary distribution networks, which have a networked (or meshed) rather than a radial topology, are commonly used to bolster reliability at large commercial or industrial facilities or downtown urban areas. The exclusion of distributed generators on secondary distribution networks from net metering programs may present additional challenges to meeting commercial ZNE goals. There has been limited testing of net metering schemes with two-way flows on networked systems, but successful implementation has thus far been demonstrated only on systems in which the PV power output rarely exceeds the building's load (Coddington et al. 2009). Additional demonstration projects that test two-way flows between the grid and secondary networks are required before recommendations can be made for implementing ZNE buildings on secondary networks. These types of projects necessarily fail the current Rule 21 interconnection screens, requiring extensive analysis prior to interconnection and installation of additional protections to prevent reverse flows.

### *At a glance: Grid interconnection of a ZNE-ready community*

To put these grid issues into context, consider a hypothetical new development of ZNE-ready homes. Throughout this example, for the purposes of illustration, we apply the site-energy definition of ZNE. The development, in California's Central Valley was designed with high levels of building energy efficiency, and each homeowner is allowed to decide if and when to install solar PV on his or her building's rooftop. Suppose that a new substation and distribution system is being built to provide electricity to the development. Engineers have modeled the ZNE-ready homes and have concluded that the average home's peak electricity demand is just over 2kW in the summer, and that to offset the annual electricity (not including gas) usage, the average home requires 2.8kW of rooftop PV panels. One typical summer day of electricity usage, PV output, and the resulting net electricity demand from the grid for a typical ZNE home with rooftop PV in this community is shown below.

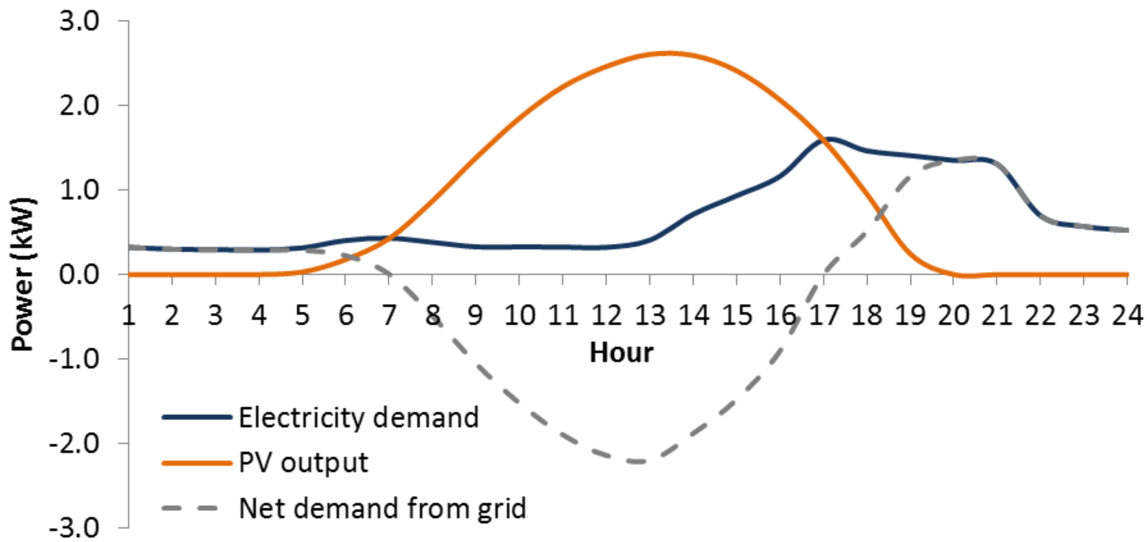


*Figure 37. Example electricity demand from grid, PV power output for a system sized to offset annual electricity only use (not natural gas), and resulting net load profile for a ZNE home (site energy definition) on a summer day.*

It is approximated that the 500-home community's peak demand will be about 850kW, assuming a diversity factor of 0.8 (this accounts for the fact that not every home has its peak electricity demand at the same time). The substation is therefore conservatively designed to accommodate maximum power flows of 1000kW, without accounting for the potential effects of adding solar PV to rooftops in the community on substation performance requirements. Now suppose that the community seeks to offset its electricity usage with rooftop PV systems.

*Current regulatory challenges*

According to Rule 21, if the PV capacity exceeds 15% of the peak demand then it fails the primary interconnection screen and an interconnection review may be required. For this community, that means that only 150 kW/2.8 kW = 53 of the 500 homes can achieve ZNE while meeting the Rule 21 primary interconnection screens. Some additional homes may meet the recently-adopted secondary minimum daytime load-based capacity screen, but this number is expected to be on the order of about 50 additional homes (depending on the specific load patterns of the community), rather than the additional 450 required to meet an operational ZNE goal for the entire community. PV may be installed on the remaining homes if the requisite interconnection study determines that the circuit is robust enough to accommodate the additional distributed generation. However, such high penetrations of PVs would likely require additional distribution system upgrades, which are currently paid for by the developer, in addition to the cost of the interconnection review.

*Looking forward*

Now suppose that 100% of the homes could interconnect PV systems offsetting their electricity usage. This could be accomplished through a combination of distribution system upgrades and/or regulatory changes allowing for voltage regulation with smart inverters, for example. In this scenario, the maximum power flow and approximate number of hours in which power flows in each direction (from the grid to the ZNE community and from the ZNE community to the grid) are listed for a system in which PV's offset all of the community's annual electricity demand in Tables 2. In this type of system, the peak flows would be negative, i.e. represent exports to the grid and dominated by the PV capacity, rather than the electricity demand.[1] For this specific system, a PV penetration level consistent with a ZNE community results in a peak flow of -1200kW (exported to the grid), compared to +850kW (imported from the grid). Despite the zero net electricity demands of the community, the peak flows experienced by the substation actually increase relative to the 1000kW substation that was needed prior to the addition of solar PV to reach ZNE. The substation for the ZNE community with solar PV will also require upgraded power electronics to accommodate both reverse flows and larger peak flows.

*Table 2. Forward and reverse flow statistics for the ZNE community (site energy definition) with rooftop PVs offsetting all of the community's electricity use. The PV installations result in more hours of the year with reverse flows than forward flows and the peak reverse flow is larger than the expected maximum flow due to solely to the community's electricity demand.*

| | Grid to ZNE Community (Forward Flow) | ZNE Community to Grid (Reverse Flow) |
|---|---|---|
| **Approx. Maximum Flow** | 850kW | 1200kW |
| **Approx. % of Hours Each Year, by Flow Direction** | 35% | 65% |

The distribution-level upgrades required for substations serving high penetrations of ZNE buildings will vary widely. However, this example demonstrates some of the distribution-level

[1] Since the entire community experiences approximately the same solar resource on a sunny day, the peak flow is not reduced by the same diversity factor that reduces the community-wide peak electricity demand.

regulatory and technical challenges that could hinder a "ZNE-ready" community from meeting its ZNE operating goals with rooftop PVs.

## Maximum Technical Potential of Rooftop PV

The common thread between the technical and regulatory challenges described in this section is that local effects depend on the characteristics of specific distribution systems. It is therefore difficult to extrapolate local-level considerations to a system-wide quantification of the technical potential of rooftop PV systems. One method of attempting a technical potential analysis is to repeat the analysis performed for our hypothetical ZNE community for every substation in the system and to aggregate across all substations to obtain a state-wide maximum penetration. E3 performed this type of analysis for rooftop PVs (without the effects of efficiency improvements in ZNE buildings) in a prior analysis (Energy and Environmental Economics 2012). Application of the 15% capacity screen yielded a maximum potential of about 7,000 MW of PVs, including ground-mounted systems up to 20 MW. Using a zero reverse flow requirement (i.e. generation may never exceed loads) instead of a 15% capacity threshold increased this figure to 15,000 MW. Recall that our PV sizing analysis determined that the meeting the residential ZNE goals might require between 5,000 MW and 11,000 MW of PVs by 2030, depending on the definition of ZNE.

One important note about this study is that interconnection issues can (and will) arise at penetrations below this study's technical potential thresholds. Consider our hypothetical ZNE community. With sufficient PV capacity to meet the ZNE goal, this community would not pass the Rule 21 screening requirements without triggering an interconnection study, regardless of the statewide level of PV penetration. The technical potential thresholds in this study should therefore be interpreted as the minimum statewide capacity at which any additional PV installations in the state will necessarily fail interconnection screens. In other words, if rooftop PV is deployed in the perfect locations and in the perfect quantities for grid integration, the study's technical potential threshold may be met without interconnection problems, but "real" systems will likely run into interconnection issues long before these thresholds are met.

## International Experience with High Penetration of PV

Although it is unclear exactly what penetration of distributed PVs will begin to cause distribution-level effects in California, some additional insight can be gained from the international experience. In Germany, where both public policy and interconnection rules have been designed to encourage distributed generation, rooftop PV installations have grown rapidly to about 20% of peak demand (BSW-Solar 2012). For comparison, rooftop PV systems in California currently comprise approximately 2% of peak demand. If California were to achieve a rooftop PV penetration comparable to Germany's, this would require about 10GW of rooftop PVs. However, direct comparisons between the regions are complicated by the fact that there are structural differences between the distribution systems in Germany and the United States. Most notably, German distribution systems are higher voltage than in California, which reduces the voltage impacts of distributed generators. We do not suggest that the Germany example can or should be replicated in California; however, the German example illustrates some of the potential policies that may aid increased development of distributed PVs in any system.

A recent report, which was commissioned by the California Energy Commission, compared both the technical and regulatory interconnection issues in Germany and Spain with those in California (KEMA 2011). The key findings of the report that are relevant to ZNE development are summarized below.

- PV growth in Germany has been primarily driven by the country's feed-in tariff, but has also been supported by streamlining of interconnection procedures for distributed generators. For example, Germany requires that distributed generators be allowed to interconnect to the grid and socializes any costs associated with upgrading a circuit or moving the point of interconnection to a more robust point in the distribution system to ensure that the interconnection meets all technical standards. In California, interconnection of distributed PV requires more review and requires project developers to pay for grid upgrades when identified at the time of interconnection. Additional costs associated with line upgrades that may be incurred after the interconnection has been established are shared among utility ratepayers.
- In Germany, the distribution network operates at higher voltages than in California, and the distribution network as a whole is larger. This means that in Germany, the incremental impact to the distribution grid of additional distributed PV generation is less than in California. The technical standards in terms of relative (per unit) voltage deviations and power quality in Germany are generally similar to those in the US. However, the burden of compliance with these standards is shifted away from the owner of the distributed generator to incentivize more installations.
- German interconnection rules allow for two-way flows, as long as voltage limits are not exceeded, and distributed generators are not only allowed to regulate voltage, they are in some cases required to include this functionality. These provisions have allowed more distributed generation on Germany's distribution systems, with little impact on distribution system reliability. California does not currently allow distributed generators to actively regulate voltage at the point of interconnection with technologies such as smart inverters.
- Germany recognizes that continued PV growth may present new operational challenges in the future, which will likely require improved renewable power forecasting and remote curtailment of distributed renewables by the system operator. In anticipation of these issues, the PV interconnection rules for medium-voltage networks already require controls to allow remote curtailment of PVs by the system operator. There is no remote curtailment of distributed generation in the United States.

International experience has also shed light on the extent to which different technical concerns become realities in high penetration PV communities. A recent International Energy Agency (IEA) review of high penetration PV pilot studies around the world found that increasing voltages were the most ubiquitous distribution-level effect (Ehara 2009). The IEA study highlighted the Japanese solution of using PV inverters to curtail output when the PV generation would otherwise cause the voltage to exceed acceptable limits. The study also found that power quality issues resulting from high penetrations of distributed generation were not a significant concern thus far. Furthermore, the study found that while unintentional islanding is extremely rare, the consequences warrant continued efforts to ensure anti-islanding functionality.

The primary lesson learned from the international experience with high penetration rooftop PV is that technical issues with grid integration of rooftop PVs can most likely be mitigated with careful planning and/or the use of existing technologies. However, it does seem clear that accommodating higher penetrations of distributed PV on California's distribution network will entail network upgrade costs. How these future network upgrade costs will be allocated among utility customers going forward is currently under discussion at the CPUC. A recent scoping memo from the CPUC suggests that Phase 2 of the Rule 21 updates may consider alternative cost allocation structures that reduce the burden placed on the first DG developer on a distribution line. Phase 2 may also include “consideration of proposals for ratepayer support of distribution system upgrades triggered by the interconnection of distributed generation” (CPUC 2012b).

## System–level Effects

The system-level effects of net zero energy buildings arise due to the reduction in electricity demand associated with improved energy efficiency and more predominantly, an increase in the available electricity provided by rooftop photovoltaic systems during the day. At very large scales, these factors have the potential to influence statewide electricity demand profiles, potentially requiring additional system flexibility or reserve requirements, even while reducing system peaking requirements. However, at small scales, demand reduction and the variability of photovoltaic power output can be accommodated by the same methods used to accommodate demand fluctuations today.

### Peak Demand

If PV penetrations are large enough, the diurnal shape of PV power availability can change the daily load shape. As is shown in Figure 38, large PV capacities can reduce the peak demand and shift it to later in the day. This reduces the need for peaking capacity, but it also reduces the marginal value of solar power. The E3 PV Technical Potential Study demonstrates that even for very large build-outs of PVs (up to 12,000 MW), the effect on the load shape is to reduce system-wide peak demand by 4,500 MW and to shift the peak hour from roughly 3pm to 6pm (Energy and Environmental Economics 2012).

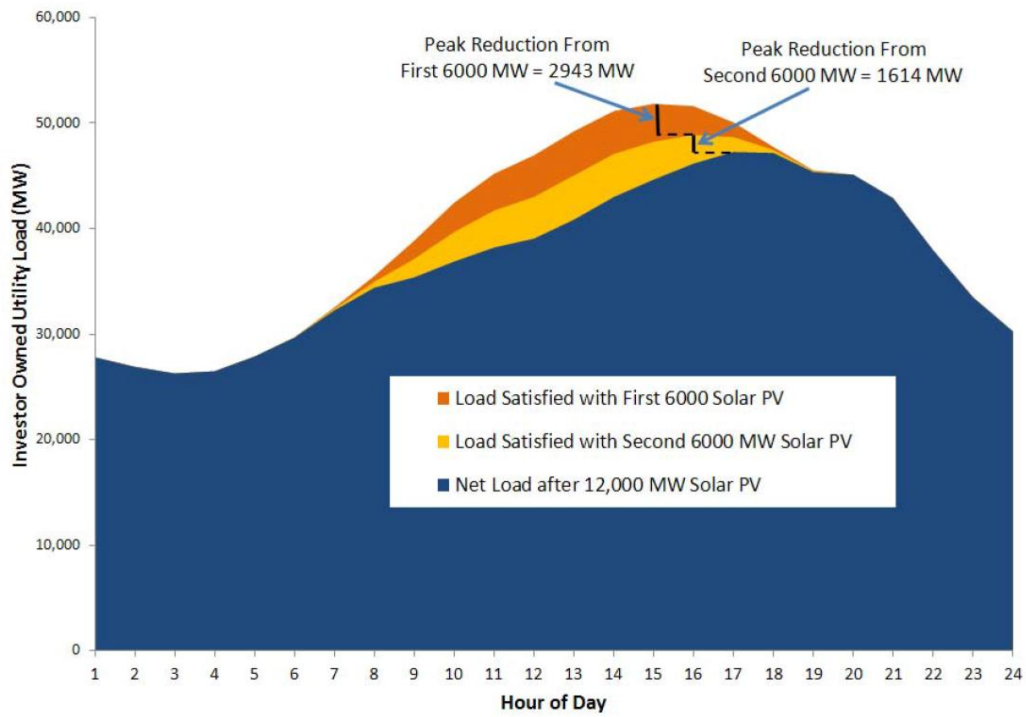


*Figure 38. IOU load shape for a summer day before and after the addition of solar PV from E3 PV Technical Potential Study(Energy and Environmental Economics 2012). The addition of solar PV to the California grid both reduces peak demand and shifts the system peak hour to later in the afternoon/early evening.*

## Need for Flexibility

Utility distribution engineers have expressed the concern that, at time scales under one hour, high penetration PV may have more profound consequences at the system-level, particularly for reserve requirements. At short time scales (subhourly down to seconds), the system must accommodate deviations of the demand from forecasted levels with reserves. The concern is that high penetration rooftop PV could increase the amount of reserves that must be held to accommodate fluctuations in the net load (electricity demand minus PV output). The need for fast ramping flexible resources with higher renewable penetrations is currently being investigated in multiple venues, including the CAISO's 33% RPS analyses, the CPUC's Resource Adequacy (RA) Rulemaking, and the Long-term Procurement (LTPP) proceeding. While it is anticipated that the 33% RPS will require additional reserves for very short term fluctuations in the net load (known as regulation reserves) due to renewables, it is still not known whether the current system is capable of providing the requisite flexibility or whether new flexible capacity must be procured to support further renewable integration.

This topic of flexibility procurement is an important area of research especially with respect to the large centralized wind farms and solar power plants that will carry most of the responsibility for meeting the 33% RPS, but is less relevant to the relatively small and distributed PV systems on ZNE buildings. Portfolios of small PV systems distributed over large geographic areas are much less variable on short (sub-hourly) time scales than large centralized renewable facilities because weather events affect distributed PVs at different times. While a single PV array experiences rapid power output fluctuations as clouds pass overhead, the short-term fluctuations in power output of geographically diverse portfolios of PVs are found to be largely uncorrelated (Mills and Wiser 2010). This effect reduces the regulation reserve requirements of distributed renewables relative to centralized renewables. Further analysis is required to determine how longer ramp events (exceeding one hour) due to distributed PV will impact system operation in California[1]. This type of analysis is particularly difficult because the distributed PV levels associated with the ZNE goals will be incremental to the centralized renewables already anticipated to meet the 33% RPS. The ability of the system to accommodate the longer fluctuations of distributed PV systems will likely depend on how flexibility is (or is not) procured for the 33% RPS.

## Transmission System

It is possible for a large amount of distributed generation on a system to alter transmission system utilization. This situation would eventually require transmission system upgrades where the system was designed to accommodate distribution-level loads that are now met locally. The DG thresholds at which these transmission-level issues become important are not yet known, because they depend on the specific architecture of the grid, the load patterns, and the manner in which distributed generation is built out. However, there is growing concern that the medium-scale distributed generation projects spurred by California's Renewable Auction Mechanism and feed-in tariff may push the limits of the existing transmission infrastructure. If these concerns are realized as PV penetrations increase, then the PV installations associated with meeting the ZNE goal may further increase congestion and/or network upgrade costs. More research is needed to quantify these impacts and their potential costs going forward.

[1] A recent analysis of the effects of building up to 1,042 MW of PVs in Southern Nevada found that increased reserve requirements would increase the operational costs of providing electricity in the region by up to $8 per MWh of PV output (Navigant 2011). The aggregation argument suggests that California's integration costs could be lower than this figure, but a detailed analysis accounting for the solar resources at several locations throughout the state, the accuracy of state-wide solar forecasts, and the state's electricity and ancillary service markets would be required to determine the integration cost for California.

## 6.9 Potential Impact of ZNE on Building Energy Related Emissions

Zero-net energy buildings should consume less energy than a similar "standard" or code-compliant building, resulting in greenhouse gas emissions savings. Likewise, by producing renewable generation on-site, ZNE buildings will offset some or all of their energy use with renewable generation.

In order to demonstrate the impact of a ZNE building on greenhouse gas emissions relative to a similarly designed "standard" building, we perform a simple set of calculations. We compare the energy use and GHG emissions of three nearly identical hypothetical medium-sized commercial office buildings located in the same climate zone in California (climate zone 12). The first building is designed to meet the CEC's adopted 2013 Title 24 energy efficiency building code. The second building is referred to as an "exemplar" building, which is designed to exceed the Title 24 2013 building code using all feasible energy efficiency strategies without altering the building's fundamental form and function.[1] The third building includes the same energy efficiency measures and uses the same amount of energy as the "exemplar" building but also uses solar PV generation to achieve zero-net energy use over the course of the year, based on a site-energy definition of ZNE. (The amount of PV needed to achieve ZNE would differ under a TDV-based or source-energy definition of ZNE, but would not fundamentally alter the takeaways of this high-level comparison).

Each of the three buildings' modeled annual net energy consumption is summarized in the table below. The "exemplar" high efficiency building consumes 41% less total energy than the 2013 Title 24 code compliant building on an annual basis, despite using 7% more natural gas.

The ZNE building consumes zero energy on net over the course of the year, offsetting its combined electricity and natural gas consumption with electricity production from solar PV generation. (Note: For this building, the on-site solar PV generation would not all fit on the building's rooftop and would need to be at least partially located elsewhere, such as in a near-by parking lot. This medium-sized office ZNE building requires approximately a 1.6 MW-dc solar PV system to offset its annual energy use. A solar PV system of this size would cover an area approximately 4-times larger than the building footprint of 38,400 square feet.)

*Table 3. Summary of annual site energy use for three medium-sized office buildings (climate zone 12); buildings are identical other than energy efficiency measures and use of on-site renewable generation*

| **Building Type** | **Total Energy (Million BTU)** | **Annual Electricity (MWh)** | **Annual Natural Gas (therms)** |
|---|---|---|---|
| 1. 2013 Title 24 Code compliant | 14,484 | 4,005 | 8,202 |
| 2. "Exemplar" high EE building | 8,506 | 2,237 | 8,745 |
| *ZNE building on-site solar PV* | *(8,505)* | *(2,493)* | *0* |
| 3. ZNE building (site energy def.) | 0 | -256 | 8,745 |

[1] The "exemplar" building design is based on research being undertaken through the "Technical Feasibility of Zero Net Energy Buildings in California " study being led by ARUP.

The carbon emissions associated with each of these three buildings' electricity use can be calculated using the modeled hourly load profile of each building combined with an estimate of the hourly marginal emissions rate of California's electric grid. For the ZNE building, we net out the hourly solar PV generation from the building's hourly electricity demand. In some hours, when the ZNE building's solar generation exceeds its electricity use, the surplus electricity is assumed to be exported to the grid, displacing fossil generation, and the building is credited with emissions savings. The emissions from each of the buildings' on-site natural gas consumption are calculated using a constant emissions factor based on the carbon content of the fuel.

Figure 39 shows the annual carbon emissions of each of the three hypothetical buildings described above, using an estimate of the marginal emissions rate in 2020 (as described in Appendix E). The "exemplar" high energy efficiency building emits 43% percent less greenhouse gas emissions over the course of the year than the otherwise identical 2013 Title 24 code compliant building. The ZNE building, on net, slightly reduces total greenhouse gas emissions in the state over the course of the year, by offsetting all of its energy use with zero-carbon renewable electricity generation.

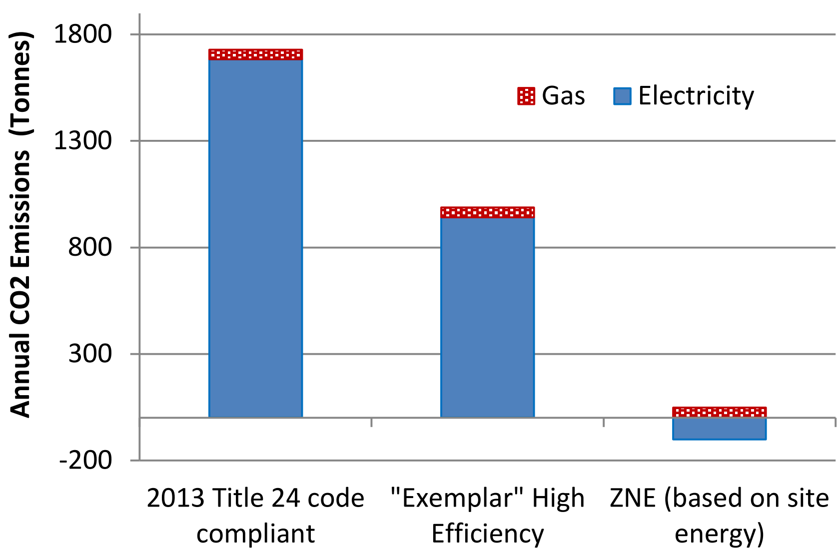


*Figure 39. 2020 estimated annual $CO_2$ emissions of three hypothetical medium-sized commercial office buildings in climate zone 12, calculated using 2020 marginal emissions rates for electricity in California*

# 6.10 Current ZNE and High Performing Building Energy Characteristics

## 6.10.1 Commercial Buildings

In early 2012, NBI and NASEO released a research report summarizing the available case study literature on the technology and design measures used for Commercial ZNE Buildings (NBI Study). The NBI study identified a total of 99 buildings, including 21 documented ZNE buildings and an additional 39 potential ZNE buildings that were either still under construction or could not provide enough data to verify zero-energy performance. Just over half of the ZNE projects were completed between 2008 and 2010. (Note: Buildings completed in 2011 were unverified because they lacked a full year of performance data.) Another 39 zero energy-capable buildings were also identified—highly efficient buildings that could be zero energy based on their energy use intensity (EUI), but didn't take the final step of installing onsite renewable resources. The NBI study focuses on cases in which the zero energy goal is achieved on a single site, even though location, space constraints, and building activity type won't always accommodate this goal.

The current zero energy buildings are located in a variety of U.S. climates, as shown in Figure 1 below. California is well represented, with six buildings. The milder climates regions of CA certainly help make ZNE buildings achievable, however, projects have also been completed in the harsher climates of Minnesota, Wisconsin, and New York.

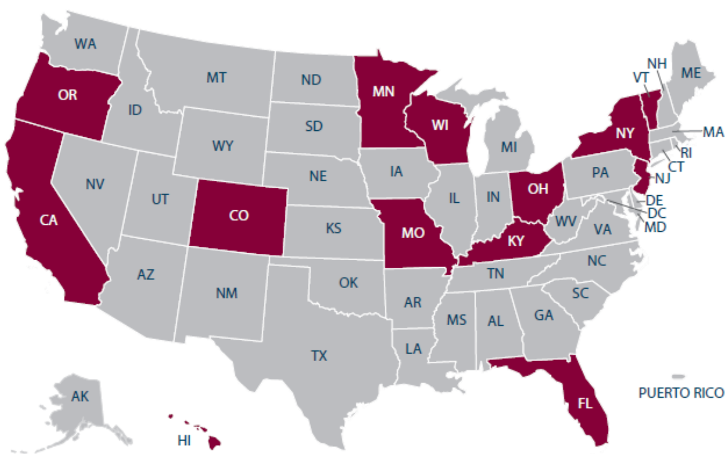


*Figure 40: Location of the 21 zero energy projects*

With exception of two facilities completed in 2010 — Richardsville Elementary in Kentucky and the NREL facility in Colorado — all documented ZNE buildings are less than 15,000 square feet, and half are less than 5,000 square feet. More large building examples will be helpful in expanding the ZNE impact, however, this relatively small building size is representative of the overall existing commercial building stock.

## *ZNE Capable Commercial Buildings*

Expanding the search to zero energy capable buildings increases the data set to 60, including the 21 already described and the 39 ZNE Capable buildings. A fairly generous eligibility cut-off was used in identifying these cases, taking all buildings with total energy use of 35 kBtu/sf or less. Whether or not they are currently using renewables, these buildings have total EUIs low enough that many would have the potential for achieving net zero through onsite renewables. As with the smaller group of current ZNE buildings, activity types in the ZNE Capable cases tend to be in lower-use categories. For comparison purposes, the 2003 national average EUI of all U.S. commercial buildings (CBECS) is 93 kBtu/square foot (sf).

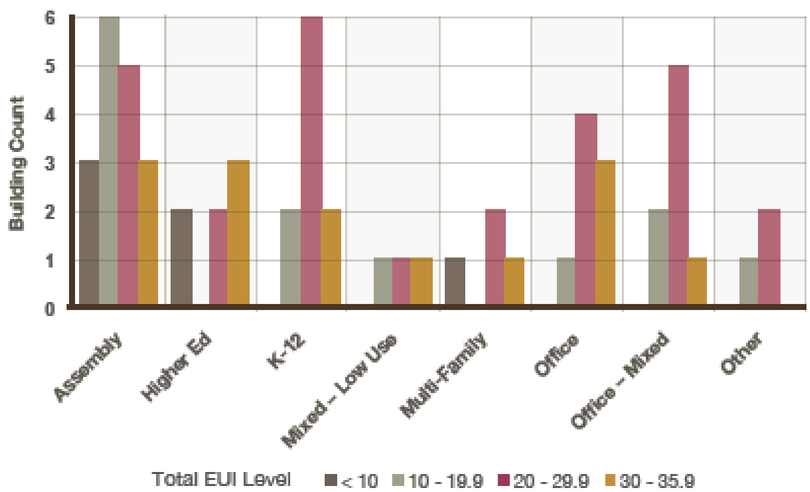


*Figure 41: Net Zero Energy and Net Zero Energy Capable Building EUI data*

This larger set of cases is still weighted toward small and very small buildings, which is representative of the total commercial building stock. However, this group also includes examples in the important mid-to-large office building categories, as shown in Table 4.

*Table 4: Zero energy and zero energy-capable counts by type and size*

| | Size (total square feet) | | | | | | |
|---|---|---|---|---|---|---|---|
| Type | 1k - 5k | 5k - 10k | 10k - 25k | 25k - 50k | 50k - 100k | > 100k | Total |
| Assembly | 6 | 4 | 5 | 2 | | | 17 |
| Higher Ed | 2 | | 4 | 1 | | | 7 |
| K-12 | | 1 | 1 | | 6 | 2 | 10 |
| Mixed-Low Use | 2 | | 1 | | | | 3 |
| Multi-Family | | 2 | 1 | | | 1 | 4 |
| Office | 1 | 2 | 3 | | 1 | 1 | 8 |
| Office-Mixed | 1 | 2 | 3 | 2 | | | 8 |
| Other | 1 | | 1 | | 1 | | 3 |
| Total | 13 | 11 | 19 | 5 | 8 | 4 | 60 |

## *California ZNE Commercial Buildings*

Using the same date set of buildings, the graph below charts 33 California buildings that have achieved ZNE, are intending to achieve ZNE (Emerging), or have an energy efficiency level that would make a ZNE goal for the building possible (ZNE Capable). (Note: There are undoubtedly many more ZNE Capable buildings in California that we do not have data to report on.) While the sample size restrict analysis, some initial interpretations from this limited data are that offices and multifamily are seeing current market interest in ZNE, and that a fair number of schools are ZNE Capable (many of which could probably be ZNE given typical school site and construction that allow for an effective PV installation).

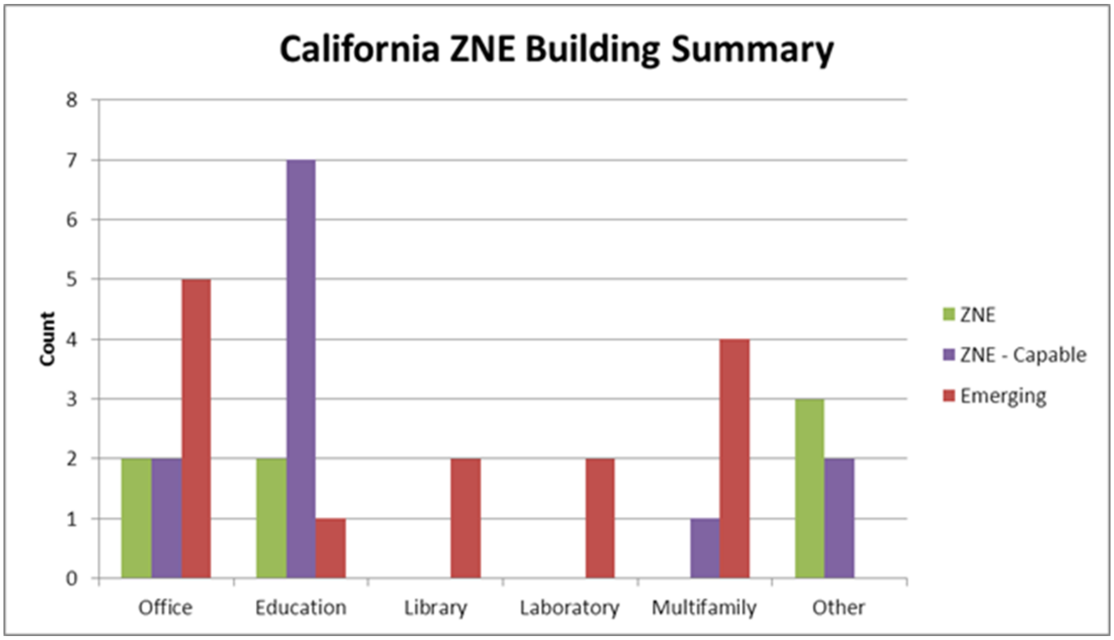


*Figure 42: California ZNE Building Summary*

Table 5 identifies the 21 occupied commercial buildings with either measured net zero energy results (15 cases) or credible modeled[1] expectations for such results (six cases). Those cases without published measured results have been vetted reviewing submissions to the U.S. Department of Energy's (DOE) Zero Energy Buildings Database or other reliable sources.

| Year | Building | Type | Location | Square Feet | Purchased EUI (1) | Total EUI(2) | Data Source |
|---|---|---|---|---|---|---|---|
| 2000 | Oberlin College Lewis Center | Higher ed | Oberlin, OH | 13,600 | 0 | 32.2 | Meas. |
| 2001 | Environmental Tech. Center Sonoma State | Higher ed | Rohnert Park, CA | 2,200 | 0 | 2.3 | Meas. |
| 2002 | Challengers Tennis Club | Recreation | Los Angeles, CA | 3,500 | 0 | 9.1 | Mod. |
| 2002 | Leslie Shao-Ming Sun Field Station | Higher ed | Woodside, CA | 13,200 | 3.8(3) | 9.5(3) | Meas. |
| 2003 | Audubon Center at Debs Park | Interp center | Los Angeles, CA | 5,000 | 0 | 17.1 | Mod. |
| 2003 | Science House | Interp Center | St Paul, MN | 1,530 | 0 | 17.6 | Meas. |
| 2005 | Hawaii Gateway Energy Center | Office; Interp center | Kailua-Kona, HI | 3,600 | 0 | 27.7 | Meas. |
| 2007 | Aldo Leopold Legacy Center | Office; Interp center | Baraboo, WI | 11,900 | 0 | 15.6 | Mod. |
| 2007 | IDeAs Z2 | Office | San Jose, CA | 6,600 | 0 | 24.6 | Mod. |
| 2008 | Camden Friends Meeting House | Assembly | Camden, DE | 3,000 | 0 | na | Meas. |
| 2008 | Environmental Nature Center | Assembly | Newport, CA | 8,535 | 0 | 17.6 | Meas. |
| 2008 | Hudson Valley Clean Energy HQ | Warehouse; Office | Rhinebeck, NY | 4,100 | 0 | 13 | Meas. |
| 2009 | Chrisney Library | Library | Chrisney, IN | 2,400 | 0 | 15.3 | Meas. |
| 2009 | Living Learning Center (at Tyson Research Center) | Higher ed | Eureka, MO | 2,968 | 0 | 24.5 | Meas. |
| 2009 | Omega Center for Sustainable Living | Interp Center | Rhinebeck, NY | 6,246 | 0 | 21 | Meas. |
| 2009 | Pringle Creek Painter's Hall | Assembly | Salem, OR | 3,600 | 0 | 9.5 | Meas. |
| 2009 | Putney Field House | Recreation | Putney, VT | 16,800 | 0 | 9.7 | Meas. |
| 2010 | Energy Lab at Hawaii Preparatory Academy | Education | Kamuela, HI | 5,902 | 0 | 11 | Meas. |
| 2010 | Magnify Credit Union | Office | Lakeland, FL | 4,151 | 3.5 | 45 | Meas. |
| 2010 | Richardsville Elementary | K-12 | Bowling Green, KY | 77,000 | 0 | 18 | Mod. |
| 2010 | NREL Research Support Facility | Office | Golden, CO | 222,000 | 35(4) | 35 | Mod. |

1 Purchased EUI is the building's total EUI less any on-site generation. Energy Use Intensity is reported in kBtu/sf/yr. A few sites report small annual totals of renewable generation in excess of the amount used on-site, which may be exported to exterior or adjoining uses. Those excesses are not quantified here.
2 Total EUI includes both renewable and purchased energy.
3 Leslie Shao-Ming Sun Field Station purchased energy omits propane usage because of metering problems.
4 NREL Research Support Facility is modeled to reach net zero upon installation of 1.6 MW PV system.

*Table 5: Verified Zero Energy Buildings*

### 6.10.2 Residential Buildings

#### *"Pre–ZNE" Efforts*

This section provides a summary of efforts in the last decade toward establishing performance goals, building designs, and research on whole-house integrated design strategies with a goal of achieving significant reduction in energy consumption of residential buildings. ZNE represents one end of a continuum of low-energy projects that focus on whole-house strategies.

#### *SMUD Home of the Future*

The Sacramento Municipal Utility District (SMUD) launched its Home of the Future (HOF) initiative[1] in 2008 that aims to be both a goal as well as a blueprint for how to achieve deep reductions in energy use for residential buildings. The HOF was developed in collaboration with the National Renewable Energy Laboratory (NREL) and the Building Science Corporation (BSC).

Per the HOF website, "*SMUD HOF aims to reduce annual energy use and utility bills by 80% — including zero net electric use — and cuts peak demand by four-fifths compared to homes built to current Title 24 energy standards*". Since the HOF program was initiated in 2008, the 'current' standards here represent the 2005 Title 24 standards. Key features promoted by the SMUD HOF (based on information gathered from the SMUD website in October, 2009) are as follows:

- ***Cost effective, energy-efficient design** by integrating the most cost effective, energy-efficient technologies, including advanced framing, super-insulated walls and ceilings, and ENERGY STAR® appliances and lighting*
- ***On-site renewable energy generation** through solar water heating and solar electricity*
- ***Whole house energy management** that automatically adjusts heating, cooling, lighting, home office, landscape irrigation, and home entertainment systems to maximize energy efficiency and performance*
- ***Increased comfort** by reducing summer solar gains, drafts, and cold walls and windows, and by using the latest in heating and cooling equipment, the Home of the Future increases comfort, regardless of time of day or season.*

The HOF also provides a detailed envelope design scheme based on advanced framing as a best practice for HOF homes. There are several partners working with SMUD on the HOF, and so far one home has been completed. This home – The RJ Walters Home – located in Folsom, CA, has the following energy efficiency features per the HOF website:

- *Advanced framing with rigid insulation in the walls that results in R30 walls*
- *Advanced roofing consisting of an unvented-cathedral sized attic with R-38 insulation and air barrier located at the roof deck, which keeps the air conditioner and ductwork inside the conditioned volume of the building*
- *Double-pane low-e windows with automated window shades for solar control*

[1] http://www.smudshomeofthefuture.org

- *Aqua Chill water cooled evaporative air conditioning system*
- *A solar assisted space heating system for the main house, and a ductless "mini-split" SEER 20, HSPF 10 heat pump for the garage apartment unit*
- *Smart Vent night ventilation system*

## *SMUD SolarSmart Homes*

From the website[1], features of a SolarSmart Home include:

- A state-of-the-art rooftop solar electricity system generates much of the energy you will use. And, when your system makes more electricity than you use, you'll see a credit right on your SMUD bill.
- A radiant barrier in the roof lowers the need for air conditioning by reflecting away heat that would otherwise enter the attic.
- A 90% efficient furnace that converts natural gas into heat for your home.
- A high-efficiency (14 SEER/ 12 EER) air conditioning system that remains efficient even in extreme conditions. You save even on the hottest days.
- Energy-efficient Compact Fluorescent Lighting (CFLs).
- ENERGY STAR® windows that keep your home cooler in the summer and warmer in winter, giving you maximum comfort.
- Third-party certification and SMUD quality assurance inspections to ensure better built homes. You can be confident that the energy efficiency features are properly installed and operating as designed.

## *DOE/Building America Program*

The U.S. Department of Energy's (DOE) Building America (BA) program is an industry-driven building research effort that promotes advanced construction intended to significantly reduce residential building energy use.  Through its research teams and industry partners, BA applies "systems engineering" to residential design and construction focused on a whole-building approach.

Nationwide, BA has been involved in over 41,000 projects to date.  Its mission is to implement advanced systems in "real world" conditions to evaluate constructability, cost-effectiveness, and post-installation performance.  The Building America Program is provided technical, research, resource development, and publication support by the NREL, Oak Ridge National laboratory (ORNL), and the Pacific Northwest National Laboratory (PNNL).  Its website provides significant energy efficiency and quality building resources for homebuilders and homeowners, including fact sheets, best practices guides, case studies, strategic planning, and more.

One BA program component is its strategic goal of enabling marketable, zero net energy homes by 2020. BA asserts that these Zero Energy Homes (ZEH) will need to use 60% to 70% less energy than current conventional practice on a national basis, with the remaining energy needs supplied by renewable energy technologies.

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[1] https://www.smud.org/en/residential/environment/solar-for-your-home/solarsmart-homes/

One of the most prominently featured Building America projects in California is the Borrego Springs project where four homes were built in partnership with Clarum Homes. These four homes shared an identical floor plan, but had different envelope and system specifications. These included advanced framing, high-efficiency evaporative coolers, radiant heating and cooling and night-time ventilation in various combinations.

## *The Passive House Institute, U.S.*

The Passivhaus Institut founded in Darmstadt, Germany, by Dr. Wolfgang Feist in 1996 promotes a whole building approach based on aggressive envelope insulation and air tightness coupled with continuous outdoor ventilation. The Passive House (PH) approach has had significant success in Europe in predicting energy savings based on its prescribed design process, performance testing, and a proprietary energy analysis model. In recent years, the movement has been gaining ground in the U.S., as well, with the Passive House California group focusing specifically on the California market.

According to the Passive House California website, their designs represent "today's highest energy standard, with the promise of reducing the energy consumption of buildings by up to 80% while providing superior comfort and air quality -- all at minimal additional upfront cost. When coupled with renewable energy systems, such as solar, Passive House puts true zero energy buildings within reach."

The Passive House approach sets specific energy use performance targets such as a maximum of 4.75 kBtu/sf/yr for heating or cooling the building and 38 kBtu/sf/yr for all end uses in the building including plug loads and appliances. Passive House also prescribes a very tight envelope that minimizes infiltration and heat losses from the envelope.

## *The California New Solar Home Partnership*

The California Energy Commission's New Solar Homes Partnership (NSHP) is part of a comprehensive statewide solar program, known as the California Solar Initiative. According to the published literature on the NSHP website, "*The NSHP provides financial incentives and other support to home builders, encouraging the construction of new, energy efficient solar homes that save homeowners money on their electric bills and protect the environment.*"

While the NSHP encourages adoption of solar technologies in homes, the CEC acknowledges the importance of energy efficiency as the most cost-effective means to meeting the energy needs for a home. The NSHP rules for new residential buildings that are granted an incentive under the NSHP require buildings to have better energy performance than required by Title 24.

Based on NSHP requirements outlined on the NSHP website (accessed Nov 6, 2009) residential buildings are required to meet one of two tiers of energy efficiency to be eligible for NSHP incentives:

- *Tier I — 15 percent reduction in the residential building's combined space heating, space cooling, and water heating energy compared to the current Title 24 Standards.*
- *Tier II — 35 percent reduction in the residential building's combined space heating, space cooling, and water heating energy and 40 percent reduction in the residential building's air conditioning energy compared to current Title 24 Standards.*

*In addition, for either Tier I or II, each appliance provided by the builder must be ENERGYSTAR® if an ENERGYSTAR designation is applicable for that appliance.*

*The Tier I level is a minimum condition for participation in the NSHP. The Tier II level is intended to differentiate builders who make a greater commitment to energy efficiency, aim for immediate positive cash flow to homeowners—allowing the PV system to be downsized to be more affordable—and encourage builders to move towards zero energy new homes. The Tier II level is consistent with what is being accomplished by California builders participating in the Building America program.*

## *Current ZNE Projects*

There are a number of residential ZNE projects that have been completed or are currently under development. However, this represents less than 1% of the market and there are still very few completed projects that are currently occupied.

### *KB Homes*

KB Homes has started a nationwide effort to introduce ZNE homes in a number of their current market areas. In 2011 and 2012, the first ZeroHouse 2.0 model homes opened in California, Colorado, Florida, Texas, Nevada, and Maryland. These homes range in size from 1,520 to 4,000 square feet and include a variety of efficiency measures, in addition to onsite PV systems by SunPower

### *Cottle Zero Energy Home*

The Cottle Zero Energy Home is a high-end, custom luxury home in San Jose, CA built by One Sky Homes. Completed in 2012, this home has already received a variety of certifications including:

- LEED Platinum
- Passive House
- EPA Indoor Air Plus
- HERS certified Net Zero Energy Home

This house was designed with significant attention to energy efficiency measures, in addition to maintaining indoor air quality, comfort, and water efficiency. It includes both solar PV and hot water systems, as well as a charging station for an electric vehicle that will be included with the house.

### *UC Davis West Village*

UC Davis West Village is currently the largest planned zero net energy community in the United States. This will be a mixed-use community to house students, faculty, and staff. The West Village Project was founded on three principles (westvillage.ucdavis.edu):

- Housing Availability. New housing options will enable faculty and staff to purchase new homes locally, at below market prices, and will expand the choices for students to live near campus.
- Environmental Responsiveness. Sustainable design of the site and the buildings will reduce reliance on cars, limit energy consumption, enable energy production, and contribute to a healthy environment.
- Quality of Place. A network of open spaces, parks, gardens, pathways and courtyards will provide the attributes and character of traditional Davis neighborhoods.

Energy efficiency measures have been designed to reduce energy demand to 50% below current code and renewable sources will be implemented to meet the rest of the energy requirements.

### *SCE Demonstration Homes*

Southern California Edison's (SCE) ZNE Retrofit Demonstration Showcase Home is a ZNE home retrofit project located in San Berdardino, CA. This 1,550 square foot 1962 vintage house has undergone significant renovations including new windows, upgraded electrical panels and additional insulation. These upgrades have been documented online with instructional videos to help inform the public about this process.

SCE recently completed a ZNE, LEED Certified, high performance ABC 2.0 Green Home located at the Orange County Great Park. SCE has developed this home in partnership with Green Home Builder Magazine, the KTGY Group, and Habitat For Humanity for a U.S. Veteran family. Along with the design of the home, SCE has designed a 12 month multi-platform marketing program including printed magazine ads, PR and advertorials, linked digital flipbook magazines, web banners, skyscrapers, and E-marketing. A virtual tour, a comprehensive Web series and publicity campaign, and on site events and programs is available on the project website.

## 6.11 Impacts of Building Operations, Maintenance, and Occupants

The majority of ZNE building programmatic focus has been on the design phase of new buildings. While the design and technological features required to achieve a ZNE building are important and merit significant attention, it is also important to recognize that by the time a building reaches the design phase, many of the key building design features have already been made (or limited) during the planning, permitting and entitlement processes. This is particularly relevant for multi-building projects that often have much more involved planning and entitlement requirements which must be considered. Furthermore, buildings endure for decades and sometimes centuries, and must adapt to ever changing context (people, uses, policy, environment, etc.). It is critical that the entire lifecycle of a ZNE building be addressed. Failure to do so presents a significant barrier to realizing ZNE buildings that actually perform over the long-term. Achieving true ZNE buildings requires that the divide between the design and operational performance be bridged.

Appendix C reports the results of an extensive review of the literature on building occupancy and interactions of people with buildings and systems. While studies of ZNE occupancy per se are rare (as we might expect), insights about the effects of building operations, maintenance and occupancy from prior research focused on conventional buildings can usefully be applied to the ZNE case. These include an appreciation of the wide array of building "users," the potential impacts of occupant behavior and choice on energy consumption levels, and the disconnects between buildings as-designed and buildings as-operated.

Understanding building operations and occupants begins with understanding who the building occupants or users are that affect building energy use.

### 6.11.1 Defining Building “Users”

Building “users” are typically considered as a single group of occupants who work in the building. Most occupant engagement programs focus on this group of occupants. While this is generally true for residential buildings, this is not true for commercial buildings. There are four distinct building “user groups”, each with a unique sphere of influence on building operations and energy use. These four “user groups” include:

- Building Occupants (e.g., those traditionally thought of as the building “users”)
- Building Operators (e.g., facility engineers, facility maintenance staff, etc.)
- Building Decision Makers (e.g., managers, portfolio managers, etc.)
- Building Design Support (e.g., architects, engineers, contractors, etc. hired to support ongoing building operations and adaptations)

It is important to recognize the role that each of these building user groups/stakeholders can play in helping attain and maintain ZNE performance, and to engage their participation and support in meeting ZNE performance goals. Each stakeholder group and the ways they touch/impact building energy use are described below.

**1) Building Occupants**

Building occupants are the ultimate end-users of building energy. They include workers, customers and other occupants for whom significant amounts of energy are expended to maintain comfortable space conditions, provide fresh air for, provide illumination for, and who directly use computers and other equipment and plug loads. In most commercial buildings, the occupants usually have very little direct control over the majority of the building energy end-uses.

There are an increasing number of high performing buildings which use natural or mixed mode ventilation. Some of these buildings require occupant control of operable windows and similar devices to manage natural ventilation. This increases the control that building occupants have over the successful implementation and energy savings of these systems. Some anecdotal reports indicate that some of these systems are confusing to building occupants (e.g., one naturally ventilated dormitory used a system of multi-colored lights to indicate when occupants should open widows for ventilation, which occupants found confusing and didn’t use to the extent envisioned). For these types of buildings, extra attention will need to be paid to ensuring the expected level of occupant participation.

**2) Building Operators and O&M Staff**

Building operators play a critical role in how much energy buildings use and are key to making ZNE designed buildings actually achieve ZNE. Building operators control the largest percent of building energy end uses of any user-group, and are the front-line “users” of the building controls and key building systems. They are directly responsible for the efficient operation of HVAC systems, space temperature setpoints, schedules, implementation of energy conservation strategies, control systems, occupant comfort, equipment maintenance, and must respond to all building-related emergencies and problems.

Building operators have not traditionally been considered “building users” and included in various occupant engagement programs. However, given the percent of building energy they control and the impacts they can have on building performance, it would be wise for ZNE policy makers and building owners to pay equal if not more attention on how to engage the building operators in energy conservation as they do to the building occupants.

It is critical that focus be paid to this group of users to ensure they are equipped and motivated to make the building perform. Opportunities to more fully engage and facilitate building operators in achieving maximum energy performance include:

- Provide the needed information served up in quick to interpret and actionable format for facilities staff to manage energy use. This will typically require additional data analytics and energy information presented in a way that empowers them to understand and actively manage building energy use. This will likely require some type of analytics and building performance dashboards that are beyond the capabilities of what typical BMS systems can provide.
- Ensure appropriate O&M systems are in place.
- Incent facilities personnel and building managers to effectively use available data to actually increase efficient operations of their buildings.
- Understand why operators do what they do (e.g., responses to employee complaints, BMS usability) and use this knowledge in interpreting and improving operations.

**3) Building Decision Makers**

The third group of building users is those who make key building management, investment and related decisions that have wide-ranging impact on building operation. Building decision makers will vary depending on building type and ownership, but can include building managers, owners, base commanders, corporate leaders, building portfolio managers, etc. While this group does not have day to day operational control over building performance, they nonetheless have significant influence over operations, control budgets, make major investment decisions, and set the general "tone" for building operators and occupants. This group plays a key role in long term ZNE performance.

Decisions to underfund O&M, defer maintenance, etc. can profoundly impact operations. Conversely, they can set strong performance goals, keep building operators incented and accountable for energy performance, and wisely guide building investments and budgets to ensure optimal operation. They also play an important role in communicating building performance to other user groups and other stakeholders, and engaging all building users to engage in helping achieve ZNE.

There are a number of opportunities for ZNE building designers and policy makers to more fully engage and incent building decision makers to help ensure long term ZNE performance. For example, building decision makers are not typically included in occupant engagement programs, nor are their needs discretely considered during the design of building performance dashboards and related systems. Building M&V and dashboard systems could include summary screens with key performance indicators useful for building decision makers; e.g., building performance benchmarks that they can follow up with building operators if they are not where they should be, or communicate successful performance to stakeholders; energy and dollar savings summaries that track performance of efficiency investments and justify continued investment to maintain high performance levels, etc.

**4) Planning & Design Support**

Planning and design support teams (these can be internal or contracted personnel) are charged with making significant building design decisions during construction, renovations, remodeling. These decisions will likely influence building energy use for the life of the building. It is important that these personnel be made aware of energy policy and goals, and encouraged and empowered to work towards innovative solutions that depart from "business as usual" in order to meet energy goals.

### 6.11.2 Impact of Building Occupants on Building Energy Use

A key question is: *To What Extent Does Occupant Behavior Influence Building Energy Use?* This is an important question for ZNE buildings. There is good data for homes, and the answer is easy—A LOT!

An NREL study of two side-by-side neighborhoods, one conventional and one designed with energy efficiency and renewable energy features shows that annual household electricity use varies by a factor of five or more for similar sized and equipped houses. In other words, occupant behavior (including homeowner installed equipment such as pools, spas, and double refrigerators) is *the most significant factor* driving home energy use. This finding is consistent with other residential building performance studies and collective author design experience. This clearly presents a problem for ZNE home designers, who have no control over what equipment the homeowner installs and how they use their homes.

The study referenced above was conducted by the National Renewable Energy Laboratory (NREL), and compares a 103 home conventional development in San Diego to the adjacent 306 home energy efficient Scripps Ranch development which incorporated a variety of "zero energy home" features and renewable energy systems[1,2]. This is the first subdivision built by a production homebuilder to explore ZNE.

On the commercial side, the answer is that occupants have less influence on building energy use than homes, but the data is not as clear. Plug loads make up a significant piece of energy use that is closely tied to occupant behavior. Plug loads are one of the largest and fastest growing end uses of the commercial sector. Between 2005 and 2030 they are expected to nearly double.[3] Estimates of their share of the total electrical load range between 25-50%. The analysis of LEED NC projects in the state of California (refer to the Appendix) have plug load fractions that range from 35% to 49% for California LEED rated projects (depending on building

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[1] Farhar, B., and Coburn, T. A "New Market Paradigm for Zero-Energy Homes: The Comparative San Diego Case Study." NREL Technical Report NREL/TP-550-38304-01. 12/2006. http://www.nrel.gov/docs/fy07osti/38304-01.pdf, http://www.nrel.gov/docs/fy07osti/38304-02.pdf

[2] Farhar, B., Coburn, T., and Collins, N. "Market Response to New Zero Energy Homes in San Diego, California." http://cgec.ucdavis.edu/ACEEE/2002/pdfs/panel08/04_347.pdf

[3] Mercier 2010, op. cit.

use type), and 32% - 45% for "ZNE Capable[1]" California LEED buildings. 2003 CBECs data shows a plug-load fraction of 34%, and the 2006 CEUS study shows 32%. Refer to Figure 45 for details.

Another interesting note is that as the regulated building loads (e.g., HVAC, lighting, DHW) become more efficient, the plug load increases. The analysis of the California LEED building data illustrates the impacts of this. Figure 45 also plots the plug load fraction of the "design" and "base-case" building. Plug and process loads are generally kept constant between these two cases. Increasing HVAC, lighting and DHW efficiency causes the plug load fraction to increase from 5% to 18%, depending on building use type. This is a significant change, and illustrates the increasing importance that controlling plug loads will have in ZNE buildings.

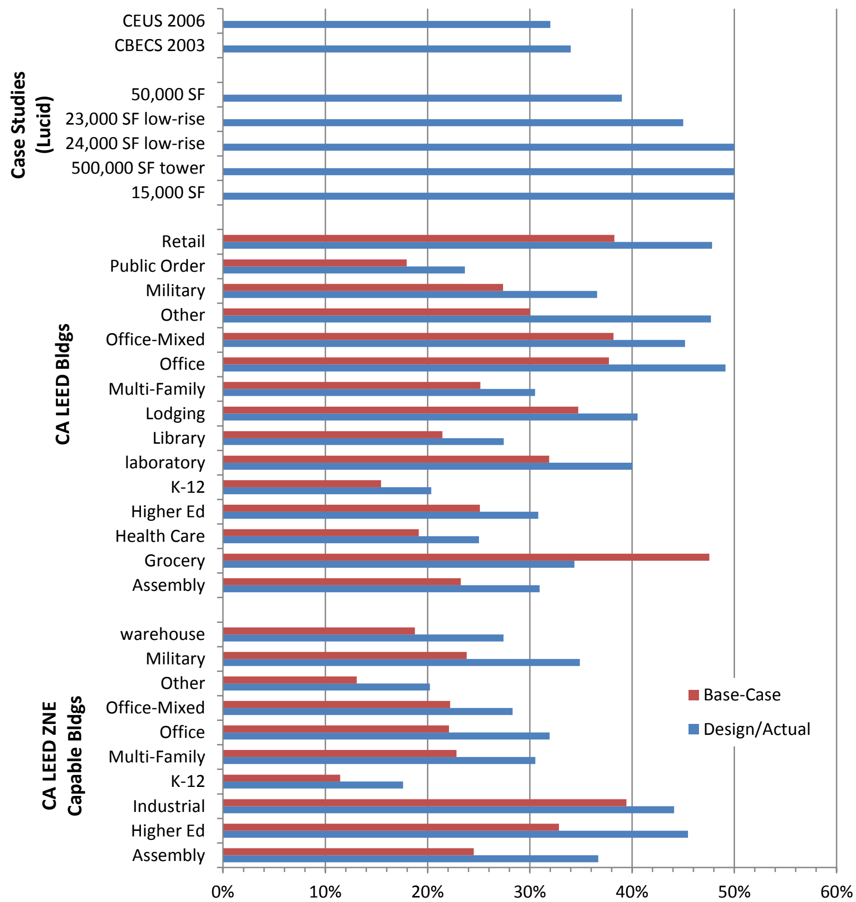


*Figure 43: Comparison of plug and process loads as percent of total electricity use (plug fraction)*

[1] ZNE Capable buildings have an EUI < 35 kBTU/SF

### 6.11.3 Comparison of Design Energy Estimates to Energy Bills

Building designers and energy modelers rarely follow-up to determine how well their design-phase energy estimates align with actual performance data. There is currently little demand from building owners and clients for this information. There several studies comparing design phase energy estimates to actual energy use as outlined in Appendix C.

Key factors influencing the difference between design (estimated) energy vs. actual energy use from the perspective of a designer include:

- Occupants not 'behaving' as expected

  Differences between modeled versus actual occupancy levels, occupant schedules, occupant activity, occupant installed equipment and plug loads, the extent to which occupants turn off this equipment after hours, temperature setpoints and related HVAC schedules, the level to which occupants participate in non-automated energy conservation measures (e.g., turning off task lights, closing blinds to reduce solar gains), etc. Design phase energy modeling relies on either best estimates of what the designers think about the occupants, or if detailed knowledge is lacking, standardized schedules based on building type.

- Weather not 'behaving' as expected.

  This year's extreme and uncharacteristic weather throughout the U.S. illustrates the year-to-year weather variability from the ~30 year average climate data used for energy modeling. This weather variation significantly impacts building energy use and onsite renewable generation, and will present significant challenges for ZNE buildings.

  There is an outstanding need to determine how to deal with yearly weather fluctuation in the ZNE context. There are two different approaches that can be taken: (1) design ZNE buildings for the "worst case" weather-conditions, or (2) normalize annual energy consumption to weather and compare this to the projected energy use base on average climate conditions.

  The first approach is analogous to how the HVAC design community uses worst-case design conditions to size HVAC equipment to ensure that it will meet space conditioning needs during the hottest and coldest conditions the building can be expected to encounter. Applying this approach to ZNE buildings would require significant "over-building" (and attendant costs) to ensure that a building would achieve ZNE even in the most adverse year. This approach would also help mitigate risk for the design team to reduce the likelihood of having a ZNE designed building not achieve ZNE.

  The second approach is analogous to how Energy Star Portfolio Manager[1], Energy Service Companies (ESCOs) engaged in energy saving performance contracting, and others take actual energy data and adjust, or "weather-normalize" it to estimate how much energy the building would have used *if* the weather was average, and then compare this to energy projections made using the climate data files. Applying this

[1] U.S. EPA. "ENERGY STAR Portfolio Manager Methodology for Accounting for Weather." Online. Accessed 9/2012. http://www.energystar.gov/ia/business/evaluate_performance/Methodology_Weather_20110224.pdf

approach to ZNE buildings has a number of policy advantages, but would lead to inevitable hard to explain situations where a "ZNE building" on paper is not a ZNE building in actuality.

Another weather related issue that causes mismatch between predicted verses actual energy use is the low spatial resolution of climatic files available for energy modeling. California's 16 Climate Zones cover large areas which include significant variations in local microclimate, wind exposure, elevation, shading and other factors. The hourly weather data in these climate zone files is based on a single representative city within each zone. There is need for climate data at an enhanced spatial resolution. In support of the 2013 Title 24 update, the California Climate Zone weather files were updated, and climate files for an additional 54 sites were generated. Although these sites are not currently used for Title 24 compliance, they could be used for ZNE building modeling to improve energy modeling accuracy.

A final weather-related issue that is increasingly important in the ZNE building context is climate change. California's climate is already warming, with statewide temperatures projected to rise between ~5 to 8 $^{o}$F depending on location by the end of the century[1]. This, along with an increase in extreme weather events (e.g., heat storms) will increase building HVAC energy use. Nighttime temperatures are rising faster than daytime temperatures, which can reduce the effectiveness of some of the low-energy HVAC strategies that high performing buildings often rely upon (e.g., utilizing high diurnal temperature swings and/or low nighttime temperatures for night-time ventilation flushouts and morning precooling). Warming temperatures will also reduce PV output[2]. The hourly climatic datasets used to estimate building energy use are based on historical weather patterns and do not reflect the change weather patterns ZNE buildings will likely see. As Chris Pyke, Director of Research for the U.S. Green Building Council notes, "We're designing tomorrow's buildings while looking through the rear view mirror of yesterday's weather and that's [a] fundamental problem.[3]"

- Equipment not 'behaving' as expected

  It is well documented that buildings never operate quite as designed out of the box. And that things break over time, schedules aren't updated, filters plug, and a host of other issues arise to degrade building performance. There are several strategies to avoid this fate such as building commissioning, the incorporation of acceptance testing into Title 24, promotion of fault detection and diagnostics (FDD) technologies and energy use feedback systems. It is critical that steps be taken to ensure that new ZNE buildings function as designed from the beginning, and that they experience routine retro-

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[1] For more information refer to the Cal-Adapt website (http://cal-adapt.org/temperature/century/), which synthesizes and visualizes much of the statewide climate change projection data, including providing interactive temperature projection maps. See also Cayan et. al., "Climate Change Scenarios and Sea Level Rise Estimates for California - 2008 Climate Change Scenarios Assessment - Final Report." California Energy Commission. 2009. http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2009-014-F

[2] PV output drops approximately 0.5% for every $^{o}$C temperature increase.

[3] The Daily Energy Report. "UMich & USGBC Study Finds LEED Buildings Are More Resilient." Accessed 10/1/2012. http://www.dailyenergyreport.com/umich-usgbc-study-finds-leed-buildings-are-more-resilient/.

commissioning or similar “tune-ups.” This effort should include attention to building user experience and interactions, as well as analyzing more technical components.

### 6.11.4 Understanding Social Science Perspectives on ZNE is Critical for Success

If good ZNE homes and buildings are to be achieved relatively cost-effectively, and if they are to appeal to prospective buyers, building users need to be incorporated realistically, rather than focus on technology without examining assumptions about what users want or will do. This requires observation about how people use buildings and considering new ways to incorporate this information. The following areas stand out as especially important for research and policy attention:

- **Realistic behavior description and feedback to design**. Improve understanding and description of what occupants in homes and commercial buildings do with respect to energy. Improve how behavior and its variability are reflected in building and technology design, research, and policy development.
  Energy-using systems in homes and buildings may often not be used as designed or as assumed in policies. Improved descriptions of user behavior that better match actual use can lead to better design and performance. In conventional construction, designers and users may eventually adapt to each others' expectations, but this feedback loop is uneven and can take many years. Given the aggressive ZNE market goals and the likelihood of innovative systems used in ZNE construction, this process could be accelerated by ensuring careful assessment and feedback on actual use and potential improvements in design as well as occupant education. Not doing so can lead to sub-par energy performance and occupant/buyer dissatisfaction, with potentially adverse effects on market growth.
  Further, better acknowledgement of the innate variability of behavior can help build more realistic expectations of building performance, versus the current use of synthetic "averages" in building energy policies (codes, programs et al)

- **Building operations.** Address the human side of building management and operations. In commercial buildings, building operations and management are key determinants of building energy use, but are often forgotten in the focus on technologies and occupant actions. Understanding why buildings are operated as they are can help support more realistic ZNE designs and reveal ways to reduce energy waste, e.g., by better incenting such reductions.

- **Influencing building users**. Improve the quality and delivery of education and energy use feedback to building users.

  Providing information to building users will not necessarily have a major impact on what all building users do. But more attention to the process of helping occupants learn about using the buildings they inhabit, and continued work on developing more useful forms of energy use feedback for ZNE designs, taking realistic account of why users do what they do, can help reduce energy use and improve user satisfaction with ZNE homes and buildings.

- **Automation vs. manual control.** Use observation and experimentation to improve automation and balance automatic versus manual control strategies.

  In part because of the unpredictability of user behavior, the building industry overall has embraced automation as a means of reducing energy waste. However, development and evaluation of automation has not adequately accounted for building users' desire for control or the potential energy savings from manual versus automated control.

Better integrating the human dimension in designing and selecting automation in energy service provision can help lead to lower energy use as well as more satisfied users.

- **Occupant satisfaction and building evolution**. Track occupant experience in ZNE buildings.

  If policy is to promote ZNE construction, it is important to help ensure – rather than simply assume -- that policies do not make the prospective occupants of these buildings worse off, e.g., through poorer air quality, inhospitable acoustic conditions, poor levels of control, etc. This will require evaluation of user experience and indoor environmental conditions, e.g., through post-occupancy evaluation and satisfaction assessments. High occupant satisfaction in ZNE buildings can help bolster the market case for ZNE. Assessment should also track how building users change the building, e.g., what systems they override or replace, and what uses they add.

- **Market.** Pay attention to what current and prospective ZNE buyers and building occupants want.

  Who buys, who occupies, who builds, and why, and what can be learned about the nature of future markets for ZNE homes and buildings? Rather than assume that the benefits of ZNE promoted in policy, research, and industry are also the hooks for potential buyers, use research to better determine what appeals about ZNE construction, what does not appeal about ZNE construction, perceived risks among buyers, and how buyer and occupant experience feeds back to the market.

# 7. STUDY RECOMMENDATIONS

The ZNE goals outlined by the CPUC and the CEC are still aspirational in nature and as such can have a powerful impact of providing a long-term direction to regulatory efforts. However, since the goals are aspirational, there is no mandate to meet the goals – and further, the levels of energy efficiency and renewables (as appropriate) need to meet cost-effectiveness screens established by the respective regulatory agencies.

With only about 30 commercial buildings nationally that have been documented to be ZNE and a handful of residential buildings being constructed to ZNE specifications, the market is really at a proof of concept stage where we know that ZNE is possible for at least some types and sizes of buildings, but there is a general lack of knowledge in the marketplace about ZNE, and still a variety of unknowns even among the most advance practitioners regarding costs, performance risks and benefits in the real work. To go beyond the innovator market, these issues must be addressed for each market.

As things currently stand, there is a real possibility that ZNE will not meet cost-effectiveness tests for either regulatory agencies and will not generate enough market traction to meet the 2020/2030 ZNE goals. There are some who therefore argue that the state should get serious about the ZNE goals by mandating ZNE through either regulatory or legislative approaches. However, legislating or mandating ZNE will not be easy nor will it be sound economic policy. If the argument for ZNE legislation is reduction in greenhouse gases, a good counter-argument can be made for targeting vehicle emissions and promoting dense transit-oriented communities instead of promoting distributed generation on all rooftops.

Furthermore, the goals of achieving ZNE are not entirely aligned with maximizing greenhouse gas reductions – the main argument for mandating ZNE. Maximizing greenhouse gas reductions from ZNE buildings would mean taking a broader view of sustainability beyond just evaluating the building's on-site energy use. This could mean evaluating all sources of emissions, such as those embedded within the construction materials of the building itself, as well as the emissions associated with other resource use in the building such as water and the transportation emissions associated with the occupants of the building. However, incorporating this broader view of greenhouse gas emissions into quantitative analysis is not easily accomplished, due largely to data limitations. More information is still needed regarding the non-energy sources of greenhouse emissions from buildings.

Depending on how the cost of solar PV reduces as compared to the cost of energy efficiency upgrades to buildings, the balance between energy efficiency and renewables may shift. This has the potential for a backsliding in the energy efficiency requirements currently envisioned for ZNE if solar PV costs reduce significantly. However, this is a scenario that is not in the overall interest of the state since reducing energy efficiency of buildings when combined with potential for actual energy use being higher than anticipated in ZNE designs as well as any performance issues with renewable generation would mean a net increase in energy use than envisioned.

However, these challenges do not mean that ZNE goals are not to be pursued with sincerity. Instead, in this section we propose a reasonable path forward for ZNE that maintains the core principles behind the ZNE goals without putting the state on a path of unintended consequences. If the state is serious about meeting the goals there are some immediate steps to be undertaken and decisions to be made and we provide specific recommendations for the same. This section outlines how the various pathways should be aligned to increase the probability of meeting the ZNE goals. While we outline the pathways, we acknowledge that achieving these recommendations are not easy and will require concerted effort by the regulatory agencies, utilities and others and will require additional efforts beyond the scope of this report.

## 7.1 ZNE Path Forward

### 7.1.1 Deep Energy Efficiency as an Organizing Principle

As a guiding principle for this project, the ZNE goals will be most beneficial to California if a proper loading order is established for pursuing any metric of ZNE for a given building. This will ensure that regardless of the metric used, the efforts towards achieving that metric are all moving in the same direction and towards a common goal.

The loading order or 'steps to ZNE buildings' includes:

- Minimizing building loads
- Optimizing system efficiency based on equipment efficiency and use
- Using highest efficiency appliances
- Optimizing building operations to better meet occupant and energy efficiency needs
- Improved occupant interactions with the building
- Renewable power generation when feasible and as a last step for a ZNE building

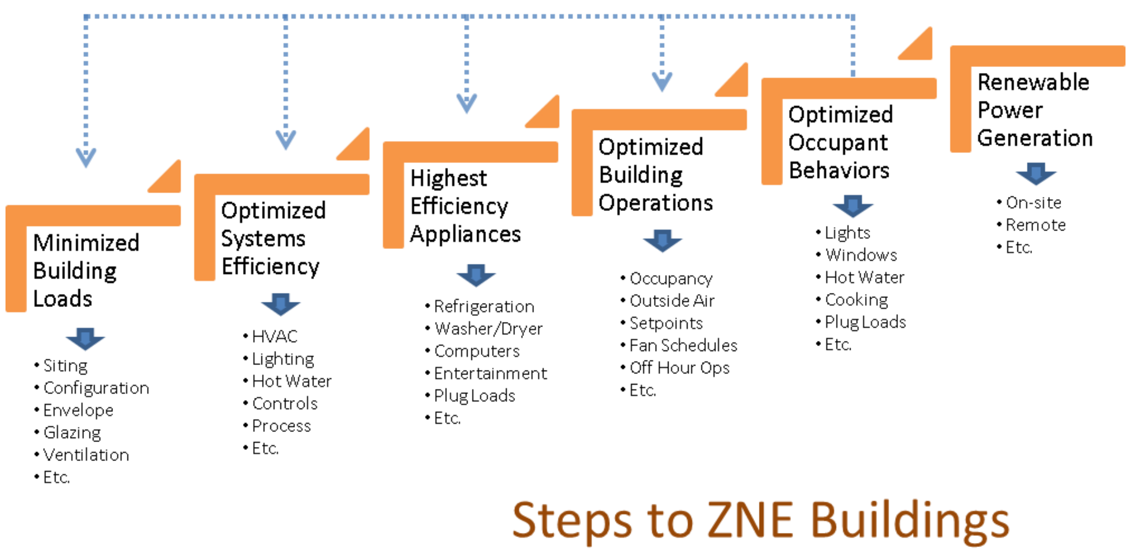


*Figure 44: Steps to Achieving ZNE Designs for Individual Buildings*

It should be noted that the steps above are not prescriptive in nature and that there are several overlaps among the steps. Each step and as a whole, a ZNE building will be driven by what is technically feasible and in the case of many building owners, what is cost-effective. There may be tradeoffs made between the categories and steps shown above for a given building based on these criteria.

The basic tenets of these steps to ZNE buildings apply across all buildings. There are certain common truths about ZNE that all stakeholders we interviewed agreed on:

- A ZNE building should be a highly efficient building in terms of how it is designed and operated
- A ZNE building should reduce customer electricity bills, and
- ZNE buildings should create societal benefits in terms of carbon emission reductions and reduced need for electricity generation facilities

Thus we conclude that specific energy efficiency targets – energy use intensity (EUI) in terms of kBtu/sf/yr consumed onsite – should be established for various building types and by climate zone to provide a common reference point for different definitions and metrics for ZNE. The Technical Feasibility Study will provide valuable data to support the creation of such energy efficiency targets.

Once the EUI targets are established for various building types, they can become the rallying point for the efficiency level to target regardless of the specific metric chosen. Thus, a building designed using the TDV metric or a building designed using site energy metrics should target the same site EUI in terms of kBtu/sf/yr.

However, it is equally important that the different metrics are marketed and used appropriately. This means that it is not important just to say ZNE but to specify what ZNE metric is being used such as 'ZNE TDV' or 'ZNE Equivalent' versus 'ZNE Site'.

### 7.1.2 One ZNE Metric May Not Prevail but Common Goal is Critical

The ZNE goals outlined in the Strategic Plan and IEPR and subsequent discussions have revolved around the concept of defining what ZNE means for policy makers. There are at least three approaches being proposed to or by regulatory agencies –

Strategic Plan – *A ZNE home employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid. ZNE is defined on a "project" basis and not "building" basis.*

IEPR – *The Energy Commission and CPUC should work jointly on developing a definition of ZNE that incorporates the societal value of energy (consistent with the time dependent energy valuation approach used for California's Building Energy Efficiency Standards)*

Findings from ZNE definitions group – *ZNE Equivalent defined as a property that achieves the societal value of energy (TDV energy) equivalent of ZNE with consideration of off-site renewable resources, or other factors to be determined by California policy makers.*

These discussions around 'definitions' conflate two separate but related ideas – a definition that defines the goal and metrics that are used to measure or quantify or translate the goals in practice.

From a definitional standpoint, the concept of equivalency that allows the building to meet the ZNE goals makes the most sense for the regulatory agencies since it:

- Addresses the need for promoting energy efficiency and renewables
- Addresses constraints on renewable energy generation, and
- Promotes whole building and community solutions that may lead to better greenhouse gas reductions

This report focuses on the metrics for quantifying ZNE goals, and outlines (as have many others before us) the various metrics for the ZNE goals, along with their relative strengths and weaknesses. We are fully aware that the regulatory agencies are working cooperatively to address any differences in their perspectives on the ZNE metrics. We encourage them to continue to do so and expedite these coordination efforts since they are foundational to their pursuit of the ZNE goals.

At the same time, we do not think it is a catastrophe if one metric for ZNE is not agreed upon by all concerned. Indeed it may be counter-productive to force a given metric on market actors who don’t find the metric to their benefit.

Conversely, we do not advocate an ‘anything goes’ approach to ZNE. If different metrics are claiming to do the same thing then there will be confusion in the market place and will cause more harm than good.

A single metric has proven elusive because each of the market actors - be they regulators, utilities or building developers/owners/operators - have different reasons and motivations for pursuing the ZNE concept:

- CEC – Promote cost-effective energy efficiency and renewables in buildings through codes when using the modified participant cost test metrics (namely TDV). A TDV-based metric of ZNE also requires less self-generation of renewable energy than all other ZNE metrics. CEC pursues the ZNE goals since they have societal benefits in terms of reduced emissions and need for fewer power plants.
- CPUC/Utilities – Promote cost-effective energy efficiency and renewables in buildings through programs and codes that meet the ratepayer benefit tests (PCT, TRC). ZNE goals help reduce greenhouse gas emissions through increased penetration of energy efficiency and renewables. CPUC pursues ZNE goals for the same reasons as the CEC, but additionally ZNE goals must also meet the needs of the IOU ratepayers.
- Developers/Building Owners – Early adopters of ZNE pursue ZNE goals in order to differentiate new construction or retrofit projects from the glut of existing buildings available for sale/lease. Any definition of ZNE building is thought of as being more self-reliant and comfortable for its occupants while lowering customer’s utility bills – which should add to the building valuation. Most developers and building owners interviewed for this study prefer a simple metric for ZNE that is easy to measure and market.
- Occupants – Occupant perspectives on ZNE are still nascent as there is not a lot of experience with living or working in ZNE buildings. Regulators and developers are projecting that occupants will find that ZNE is good for the occupants’ bottom-line in terms of lower utility bills, increased comfort and being ‘good for the environment.’ ZNE is often discussed by market actors (with limited input from actual occupants) as ’zero net energy bills’ for building owners/occupants.

Our proposed solution to address this issue is to make sure that the metrics are structured and promoted in a manner than distinguishes them from each other so it is clear how a given ZNE building is designed or operated to perform. Below we provide more details on this proposed solution.

**Mandate** → **Voluntary**

| | CEC: ZNE TDV | CPUC: ZNE Equivalent* | Market: ZNE Site |
|---|---|---|---|
| *Fuels Covered* | Electricity + Natural Gas | Electricity + Natural Gas | Electricity + Natural Gas |
| *Asset Value* | Yes | Yes | N/A |
| *Performance Index* | N/A | N/A | Yes |
| *Energy End Uses* | Regulated Only | Regulated and Unregulated | Regulated and Unregulated |
| *Cost-effectiveness Tests Required* | CEC TDV Test | CPUC Tests (e.g. TRC) | N/A |
| *Renewables On-Site* | Yes | Yes | Yes |
| *Renewables Off-Site* | Yes | Yes | N/A |
| *ZNE Equivalencies* | Allowed | Allowed | N/A |
| *EUI Target* | TDV/sf/yr equivalent to a kBtu/sf/yr target. Will vary by building type and climate zone. Could be expressed as HERS 0 or BEARS 0. | X Btu/sf/yr **including** approved Equivalencies. Will vary by building type and climate zone. | kBtu/sf/yr Will vary by building type and climate zone. |

* ZNE Capable as an alternative

Regulated End Uses → All End Uses

*Figure 45: Proposed ZNE Metric Taxonomy*

We recommend the following taxonomy from the perspective of the principal market actors as a starting point:

- **ZNE TDV (CEC)** – a building designed to meet the TDV based definition for ZNE preferred by the CEC and includes all cost-effective energy efficiency that is allowable through the codes and standards update process. This is inherently an asset rating since it is done prior to occupancy. A relationship needs to be established between code ratings (HERS and BEARS scores) and absolute EUI targets for ZNE. ZNE TDV buildings may incorporate renewables but only after all cost-effective and optimal levels of energy efficiency are achieved. Equivalency metrics for renewables that allow tradeoffs against locational efficiency may be explored.
- **ZNE Equivalent* (CPUC)** – a building that meets the energy efficiency EUI goals but does not mandate onsite or community renewable generation. Instead other factors such as offsite renewable generation, renewable energy offsets/credits, tradeoffs with transportation energy are allowed to achieve equivalency. The regulatory agencies and other stakeholders need to identify specific criteria that would allow this trade-off while ensuring that the equivalency is genuinely necessary and is of the correct magnitude.

  ***** As an alternative to ZNE Equivalent, a ZNE Capable building definition could be adopted by the CPUC which allows for similar levels of energy efficiency. Further discussion on this topic is in Section 6.6.2.
- **ZNE Site (Electric + Gas) Building (Market)** – a building designed to match the amount of energy used onsite or at a community level to energy generated onsite. This is a

*performance* metric which would only be realized after there is at least a year's worth of energy use and distributed generation (DG) output to compare. A ZNE Site building may not meet cost-effectiveness tests used by the CEC/CPUC, but since this is a voluntary level beyond code/CPUC program requirements, should not deter those who are truly committed to this definition.

It is possible for the ZNE TDV metric and the ZNE Equivalent metrics to converge depending on future efforts and coordination between the CEC and CPUC respectively which will significantly help the ZNE discussion by allowing one regulatory metric – ZNE Equivalent and one market metric – ZNE Site.

It is important to note that meeting a ZNE TDV or ZNE Equivalent target should not preclude someone from also pursuing a ZNE Site metric if they so choose. They would need more renewables on site and perhaps more energy efficiency, but it is technically and realistically feasible. The market may indeed prefer this arrangement since ZNE TDV or ZNE Equivalent buildings still leave some room in the market for those who want to differentiate their buildings from those that 'just meet the regulatory requirements.'

We expect further discussion among stakeholders and regulators to develop a more comprehensive taxonomy.

## *Codes as a Stepping Stone to ZNE Site*

While codes do and will continue to require measures that enable better operation of buildings, the inherent nature of codes – predicting energy use ahead of construction and occupancy – means that any code that is designed to make a building ZNE is essentially a design or asset rating. Add to this the fact that for reasons outlined in Section 6.5.1, codes and standards address a portion of the building's energy use and may not address all of the building's end-uses directly. Thus a ZNE TDV building will make a number of assumptions about end-uses that it does not regulate. Further, a code designed based on TDV will require lower amounts of renewables than a site-based metric. For all of these reasons, a ZNE TDV metric is easier to achieve than a ZNE Site metric. As a result, a building designed to ZNE TDV may or may not achieve a ZNE Site performance. However, it will get us closer to the ZNE Site goals on a larger swath of buildings sooner than most any other pathway by itself. A ZNE TDV ensures that the building can do no worse than what the code mandates. In terms of achieving the state's stated ZNE goals, ZNE TDV metrics based on TDV capture most of the benefits and are thus appropriate for policy setting. More analysis will be needed to ensure that a ZNE TDV metric can be designed which is also cost-effective and implementable by the building community.

It is important to note that meeting a ZNE TDV target should not preclude someone from also pursuing a site-based ZNE metric if they so choose. They would need more renewables and perhaps more energy efficiency than the ZNE TDV buildings, but it is technically and realistically feasible. The market may indeed prefer this arrangement since ZNE TDV buildings still leave some room in the market for those who want to differentiate their buildings from those that 'just meet code.'

## *ZNE Messaging*

While metrics and definitions are critical, the modalities of the metrics can sometimes overtake the value of the metric in terms of its marketability. A good example of this is the definition of ZNE based on TDV. Using TDV for code compliance and setting codes and standards is appropriate for all the reasons outlined in Section 6.6.2. However, the metric itself – what it means and how it is calculated – is hard to comprehend and even harder to explain easily. Thus there is a need to explain a ZNE TDV metric in an easy to understand manner that also enables comparison to ZNE Site metrics.

The CEC has proposed expressing residential building ZNE ratings in terms of the HERS index where HERS Zero will equal to a ZNE building. We support this concept for two reasons:

- The HERS rating utilizes TDV as its basis but does not use the TDV metric for displaying the rating but rather a simple numerical index. Thus it makes it easier to explain the rating and makes it easier to compare across buildings that may use very different approaches.
- The HERS rating is also in a sense 'absolute' – one is comparing the predicted performance of a home against a fixed target (zero). This gets away from the 'percent better than standard' approach currently in use. As standards change and improve, the 'percent better than standard' does not convey the same meaning with each code update cycle.

We further recommend that the HERS rating provide both the site energy consumption in kWh and Therm as it currently does but also provide the energy use intensity in kBtu/sf for both the given building as well as a ZNE building in order to enable comparison with the ZNE Site metrics.

On the commercial side, CEC has proposed to use the BEARS index which has similar benefits and we make a similar recommendation to add EUI ratings for ease of comparison to site metrics.

These metrics (HERS/BEARS) are asset rating metrics since they are provided prior to building occupancy. Thus there is a need for post-occupancy follow-up to have a true ZNE operational rating such as ZNE Site that addresses actual energy use and renewable generation.

CEC has proposed the CBEURT rating tool to rate existing commercial buildings and we are encouraged that they have chosen the same rating scheme for CBEURT as for BEARS. While this is good on one hand – consistency – it also has the potential to be very confusing since both metrics use the same graphic. We recommend that the ratings be delineated as clearly as possible by calling the zero as 'Zero Net Energy Code' and 'Zero Net Energy Performance' or similar such nomenclature.

The limited early examples of ZNE buildings were largely created by innovators, but the development of a Path to Zero element of the Savings By Design Program has led to the addition of additional projects. Support for these early projects is critical to accelerate the market transformation.

A report by the New Buildings Institute recommended the following additional steps related to creating and documenting examples:

- **"Practical guidance to help identify opportunities:** The marketplace needs clear summaries of the conditions where ZNE are most feasible (anticipated loads, climate), and the path to move toward those goals. Ongoing communication can be fostered by continually updating a set of case studies showing clear definition of the processes and techniques used as well as results and lessons learned with varying climates, building types and settings. Clear *studies of avoided costs* (both initial design and construction savings and ongoing energy savings) from energy efficiency-focused integrated design can help explain the potential and support needed financing of first costs.

- **Encourage measurement and communication of results**: ZNE buildings are already entering a “second generation” of more typical building types and ownership patterns; lessons learned from these examples could accelerate interest at both the market and policy levels towards zero energy and zero energy-capable buildings.
- **Develop a better basis for benchmarking performance**: As more successful zero energy-capable buildings emerge, we can shift the benchmarking focus from a broad peer group based on past commercial building national average EUIs to a forward-looking target based on demonstrated results of industry leaders.

### 7.1.3 Addressing the Evolving Market and Technical Barriers for ZNE

The early steps should focus on 1) increasing general awareness of the concept, 2) creating and documenting a wide variety of examples, 3) creating access to information for people interested in more details, especially such as owners and designers, 4) accelerating the flow of information among innovators and early adopters to foster better, more replicable examples as rapidly as possible.  A variety of early steps can happen concurrently.

#### *Increase ZNE Awareness*

Within the Commercial Buildings ZNE Action Plan, a Path to Zero Campaign is being developed. The plan indicates such a campaign should leverage the success of early adopters and feature “real-world experience and data on emerging technologies, practices and designs that deliver zero net and ultra-low energy buildings, alongside mechanisms to demonstrate effectiveness and create demand."

Such ground-up efforts to promote better awareness of ZNE buildings are needed and further it may be good to undertake similar efforts on a statewide basis for residential buildings. There may in fact be value to a combined Path to Zero campaign that targets places where people stay (homes, apartments, condos etc.) and where they work (offices, schools, hospitals etc.)

#### *Understand the Motivations of Potential Building Owners/Tenants*

Further research is needed into who buys, who occupies, who builds, and why, and what can be learned about the nature of future markets for ZNE homes and buildings. Rather than assume that the benefits of ZNE promoted in policy, research, and industry are also the hooks for potential buyers, use research to better determine what appeals about ZNE construction, what does not appeal about ZNE construction, perceived risks among buyers, and how buyer and occupant experience feeds back to the market.

#### *Understand Role of Building Operations, Maintenance, and Occupants*

Many of the research recommendations for understanding and influencing building users outlined below apply equally to conventional construction as to ZNE construction.  But there can be special value in attending to these issues in the case of ZNE.  In particular, ZNE policy goals could provide the impetus to improve how efficiency is designed and executed: not just as a set of technical measures geared to narrow models of what building users do and want, but as a mode of building and learning that better integrates actual behavior and takes advantage of new capabilities in data collection and analysis, in sharing experience, and in evaluation that integrates both engineering and social/behavioral sciences.

There is little empirical data on how people use energy in buildings. Much has been simply assumed based from an engineering perspective. There are many opportunities for improving knowledge – for example, measured data on residential thermostat setting – that could lead to better technology design and better policy.

Current building codes and design tools often rely on assumptions about average or typical behavior that poorly reflect the diversity of actual behavior. This shorthand may not lead to technology design that suits the distribution of actual behaviors it might be paired with. There is a need to build more sophisticated treatments of the role of occupant behavior in defining, interpreting, and closing the building performance gap.

Despite the many studies that report successes for energy behavior change, there is substantial skepticism about how well behavior change programs can work – in what circumstances, with what results, for how long, with what other consequences, and how reproducibly. One difficulty is that there are real-world limitations on how well these studies can be done statistically. But there is now a need to elevate behavior change research out of rather simple models in which individual behavior is transformed in reaction to top-down "information" into a more sophisticated and complete understanding of the many forces that shape what people do and why.

The literature review revealed many examples where the design of many controls and building systems (e.g., window shades, Building Automation Systems, programmable thermostats, device power management) fell short with respect to actual use. To some extent, user education and social learning can help improve how users interact with these systems. Some of the strongest prospects for changing use, however, may lie in empirically assessing actual use and improving device and system design accordingly, e.g., how does the form of a device (a control, a window, etc.) or space or even social organization influence what people do within it?

## *Reducing the Cost of ZNE*

Regardless of the definition/metric used for ZNE, the costs of achieving this level of efficiency and/or renewables in buildings will pose an important barrier to greater adoption of ZNE in the next 2-5 years. Regulatory and market efforts need to be applied to this problem to try to bring down costs of construction, materials and labor. This will take a combination of the following strategies:

- Better design practices – while it is possible to get to ZNE by throwing a lot of technology at buildings, it is more cost-effective to do an integrated design that may indeed reduce the number or size of systems needed for a ZNE building, thus reducing costs.
- Incentives and Rebates – provide upfront and substantial incentives for the early adopters and early majority of participants similar to the CSI program approach to PV rebates. If such an approach is deemed too risky or out of sync with the realities of CPCU EE policies, then at the least, programs should offer greater incentives for ZNE buildings than those targeting lower levels of efficiency.

- Financing – enable financing schemes that provide the right signal to market actors and financial institutions to properly value energy efficiency and renewables. Lower the barriers to getting attractive financial terms for projects that strive to achieve ZNE performance.
- Awareness campaign – increased awareness of ZNE benefits will increase the number of people that participate in ZNE efforts. This may create over time economies of scale that will drive down product costs.
- Training – similar to the awareness campaign, training of the work force will ensure that measures required for ZNE are installed in an optimal time and process resulting in overall project cost reductions.

## 7.2 Policy and Regulatory Recommendations

Achieving the ZNE goals will require coordinated approaches from all parties to ensure that all energy efficiency, demand response and renewables policies are aligned with the ZNE goals. In this section we outline the specific policy approaches that the CPUC and CEC would need to address to pursue their ZNE goals.

### 7.2.1 Critical Planning Issues Must be Addressed to Achieve the ZNE Goals

The ZNE goals outlined in the Strategic Plan and the IEPR are policy goals to inform long term planning. However, if they are to be achieved, the ZNE goals can no longer be considered long term goals as 2020 is only eight years away. The CPUC and CEC need to set specific priorities for their respective efforts and make regulatory decisions with the ZNE goals in mind if they are to be realized.

#### Recommendation: Establish a Memorandum of Understanding around ZNE Goals

The CPUC and CEC have the policy tools available to push towards ZNE goals, there is a need for an ongoing forum to evaluate the complex set of issues and recommendations presented in this report and those that will no doubt arise in the years to come. We therefore suggest that the CPUC and the CEC consider a process of evaluating the issues and policies around ZNE separate from and in addition to the more voluntary efforts of the ZNE champions network. One such approach – short of a formal rulemaking – is to institute a memorandum of understanding (MOU) between the CPUC and CEC that provides a venue where all ZNE related issues can be addressed dispassionately and with a focus of providing concrete policy directions.

#### Recommendation: Use Cost Effectiveness to Inform ZNE Policy

There are many important differences regarding how the cost-effectiveness of ZNE projects and programs are likely be evaluated by the CEC, the CPUC and the private sector (market). These differences are captured by the different cost tests described in Section 5.5 (TRC, PACT, PCT, TDV, etc.) and outlined in the Figure below.

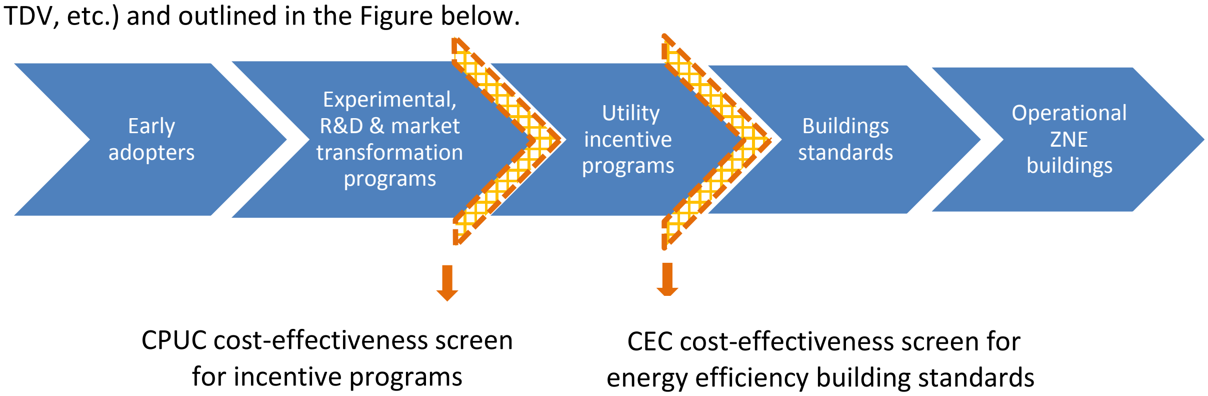


*Figure 46: Cost-Effectiveness Screens to ZNE Goals*

While a single definition of cost-effectiveness is not appropriate or needed, the differences between agencies and the market in evaluating cost-effectiveness may increasingly cause confusion as policies and programs are developed in pursuit of the ZNE goals unless there are concerted efforts to a) understand the differences, b) explain the differences and c) align targets for energy efficiency between agencies/approaches.

Better tools are needed by building designers to evaluate the tradeoffs inherent in ZNE building design, including the cost-effectiveness of different design choices. Likewise, policymakers need to have a better understanding of the costs and benefits of ZNE policy choices they will face over the years between today and 2020 and 2030.

A particular challenge on cost-effectiveness is that with each successive code cycle, there will be fewer saving to be achieved per building than the previous cycle and the savings that can be achieved will likely entail higher costs. There is a real risk that a ZNE Site level performance may not meet the current cost-effectiveness metrics for both the CPUC and CEC.

Given current uncertainty around renewable energy policies and incentive structures, there is a risk that rooftop PV will not be cost-effective in 2020 using a participant cost test metric or the TRC or TDV cost-effectiveness metrics. Although there are many uncertainties regarding the future cost of solar PV, this possibility must be accounted for in designing a roadmap to achieve the state's ZNE goals. State policies, such as market transformation programs, that help incentivize continued reductions in the cost of both renewable distributed generation and energy efficiency are needed to help bring down the cost of ZNE buildings.

California policymakers have encouraged "market transformation" of the rooftop solar PV market through the use of incentives: the California Solar Initiative, the New Solar Homes Partnership and net energy metering rules. As a result of the market transformation goal, these programs have not been constrained by cost-effectiveness tests. A similar market transformation approach could be applied to the development of ZNE buildings, by developing policies to continue to bring down the cost of renewable distributed generation as well as energy efficiency.

There is significant uncertainty looking forward to 2020 and beyond regarding key policies and regulations which will influence the cost-effectiveness of ZNE going forward, particularly in the areas of retail rate design and net energy metering policies. As these policies are being reconsidered in current CPUC proceedings, the ways that these policies will influence both the utility business model, as well as the future achievability of the state's ZNE goals, should be factored into the decision-making process.

In addition, the competing needs for rooftop space on buildings, and the limited availability of appropriate rooftop space for PV on some buildings, including in high-density developments, imply that some flexibility may be needed regarding where a ZNE building's source of self-generation is physically located.

Larger distributed PV systems tend to be lower cost on a per unit basis than smaller systems. This implies that the cost of achieving ZNE targets could be lowered by utilizing renewable generation from a single project across multiple buildings. However, current solar PV incentives and most existing policies are not designed to encourage larger, non-rooftop distributed generation projects. Policies could be developed to encourage "ZNE communities" rather than simply "ZNE buildings." If correctly designed, this option could open community renewables to other customers in a way that does not shift costs to nonparticipants in the policy's market intervention.

A building that is a net exporter of electricity to the grid falls under the "net surplus power" rules of net energy metering (NEM), such that the building owner is compensated for their surplus power at a market price for power, rather than the wholesale retail rate. This means that building owners have little economic incentive to offset their natural gas use with onsite electricity generation. Rather than encouraging all-electric buildings or onsite electricity production to offset a building's natural gas usage to achieve a ZNE Site building, other options, such as the use of biogas offsets may be better alternatives to explore under a ZNE Equivalent scenario.

Designing "ZNE Capable" or "ZNE Equivalent" buildings with higher levels of energy efficiency, may be a more important and more practical policy goal than achieving a ZNE target with on-site renewable generation. Distributed renewable generation should not need to be physically located on a building's lot in order to meet a "ZNE Equivalent" definition.

## Recommendation: Develop Equivalency Metrics for ZNE Goals

This study recommends that the concept of ZNE Equivalency is critical to making the ZNE goals feasible and address valid concerns about requiring renewables onsite for each and every building. A number of equivalency metrics have been proposed by others and we have outlined them above. We recommend that the CPUC and CEC collaborate on developing the parameters of the equivalency metrics – be they renewable credits, locational efficiency or vehicular miles traveled.

A particular area of research relevant to ZNE Equivalency is to evaluate the feasibility and metrics for community scale solar and community scale ZNE 'projects' as opposed to ZNE building.

Another issue where equivalency metrics may make sense is for offsetting natural gas energy use in buildings. A potential equivalency would be to allow a building owner to purchase biogas credits to offset the building's natural gas consumption. Currently, it is not feasible to deliver biogas to most California customers, but biogas offsets, not necessarily delivered biogas, could provide a way for a building to achieve ZNE in a more cost-effective way than offsetting natural gas use with on-site solar PV generation. The use of biogas offsets for natural gas use does not appear to be a part of the current understanding of ZNE buildings, however, policymakers may want to investigate this option as a potential way to lower the cost of achieving ZNE equivalency.

## Recommendation: Evaluate Grid Impacts of ZNE buildings

Meeting the 2020 ZNE residential goals will most likely require a dramatic increase in the PV installation rate, above and beyond the state's "million solar roofs" goal. The amount of new solar PV needed to meet the state's residential ZNE goal could be between 5,000 MW and 11,000 MW by 2030, depending on the definition of ZNE as well as other factors. 11,000 MW of distributed PV development is of a similar magnitude as the total amount of new solar that is currently estimated to come on-line to meet the state's 33% renewable portfolio standard by 2020. Achieving the state's 2020 residential ZNE goals will likely require new policies to support onsite and community solar PV installations, since rooftop solar PV may not be cost-effective without incentives or other policy support by 2020.

Importantly, the total amount of PV that would be needed in 2020 to meet the ZNE goal depends greatly on the level of energy efficiency improvements achieved in ZNE residential buildings. In this report, we have assumed that fairly aggressive levels of energy efficiency improvements can be achieved in residential buildings by 2020 based on the findings of the Technical Feasibility study. If these "exemplar" levels of energy savings are not achieved, more solar PV would be required to meet the ZNE goals.

More research is needed into the grid impacts of achieving the state's ZNE goals. At currently low levels of PV penetration, the grid impacts of ZNE are less about technical challenges than about the need for more clarity regarding the cost and allocation of potential distribution grid upgrades. Small numbers of ZNE homes in a neighborhood pose limited grid integration challenges, but very high penetrations of ZNE Site buildings on single substations would require:

- More flexible interconnection screening rules or a more streamlined interconnection review process, (progress is currently underway through recent and planned reforms to Rule 21);
- Investment in new or upgraded distribution equipment for voltage regulation, fault detection, and anti-islanding;
- Installation of smart inverters on PV systems and regulatory changes to allow smart inverters to provide voltage regulation services.

The short-term flexibility requirements of distributed PV systems on ZNE homes are expected to be less pronounced than those associated with the central station renewable plants anticipated to meet the 33% RPS. However, additional quantitative analysis of system flexibility for distributed solar is still needed. While ZNE PV systems may contribute to future transmission network costs and upgrades associated with high penetration distributed generation, there is no clear quantitative analysis of these effects to date.

### 7.2.2 Internalize ZNE Goals in Portfolio Planning

There are a variety of ways that early market activity can be stimulated and supported. Policies and programs need to actively support market activity to create a more robust set of ZNE buildings if the ZNE goals are to be realized.

#### Recommendation: Support and Learn from Early Adopters

If the ZNE goals are to be achieved, early successes should be rewarded through recognition and marketing support to spread the message of the benefits these early adopters have realized. The efforts of these early adopters and their successes and failures need careful follow-up to understand the technological and policy approaches required to move the rest of the market. The essential challenge for achieving the ZNE goals is to learn from the experiences of the early adopters and apply those lessons learned to motivate and as needed require those not naturally inclined to change. We say this because achieving the ZNE goals will require changes in current industry practices for design, construction and operation.

#### Recommendation: IDSM Strategies Will Assist Meeting ZNE Goals

The CPUC is well-suited to provide leadership on the integration of energy efficiency, demand response and renewables into a common set of programmatic activities. Integrated Demand Side Management (IDSM) strategies have been piloted in the 2010-2012 IOU portfolios of programs. Indeed the ZNE Pilot program, for which this study is a deliverable, is part of this IDSM strategy.

To achieve ZNE goals will require careful coordination of the EE, DR and DG programmatic activities including incentive levels, application processes, savings claims, marketing and outreach as well as project financing. An integrated approach through the IDSM process will play a crucial role in providing the right resources to early adopters and the early majority to achieve building designs and EUI performance levels that meet the ZNE definitions put forth in this report, all of which include EUI metric targets. Further we encourage the IOUs and CPUC to orient the IDSM offerings to a common goal of encouraging ZNE Equivalent buildings.

#### Recommendation: Target ZNE through Programmatic Activity

Starting with the 2013-2014 portfolios of programs, we encourage the IOUs and CPUC to identify specific pathways to encourage ZNE performance through programs. For new construction programs in particular, we encourage setting ZNE performance thresholds, based on EUI targets that are matched with appropriate design assistance and incentive levels. We further encourage new construction programs to target a broader implementation of the ZNE Pilot efforts by highlighting early successes and promoting efforts of early adopters.

#### Recommendation: Take a Longer-Term View of Cost-Effectiveness for ZNE Elements of New Construction Programs

The pathway to increasing market penetration of the energy efficiency component of any ZNE definition (i.e. the EUI metric targets) will likely require an explicit focus on developing and transforming the new construction market. As such, it may not be appropriate to hold programs that target ZNE goals to current CPUC program cost-effectiveness standards. The CSI and NSHP programs could be used as models, including these programs' use of pre-planned and progressive reductions in incentives over time to encourage early adoption and to provide urgency to project developers who want to qualify for the higher incentives early in the program.

Measure cost-effectiveness assessments are unlikely to be appropriate for new construction ZNE buildings, or for deep retrofits to achieve ZNE. Rather, a portfolio-level or whole buildings approach may be needed to evaluate cost-effectiveness.

### Recommendation: Focus on Target Markets that have Multiple Reasons to Pursue ZNE Goals First

For commercial buildings, target both program activities and codes to advancing the "more interested" markets, such as schools and other publicly owned buildings. The commercial buildings market is extremely diverse, and ZNE goals are both more attractive and more feasible in some sub-markets for reasons of low cost of ownership, demonstration of leadership, or alignment with carbon reduction goals.

For the residential markets, market research is needed to identify the motivations and definitions of target buyers to assist the development community in effectively reaching the more interested markets.

Diffusion begins with a very small set of innovators, perhaps 1 percent to 2 percent of the market, who are inspired to create ZNE properties. In an example of how the market might move towards ZNE, approximately 10 years ago the earliest adopters of LEED-NC tended to be private schools, colleges and universities, environmental groups and corporate offices—all entities with a business interest in being seen as innovative and future oriented, and also markets where more time spent on design was allowable within the business framework. More recently, LEED-NC has become almost a market requirement for new commercial office real estate in urban centers, but not until tenant interest, relatively low costs of compliance, and marketing benefits made green construction less risky than standard construction.

A similar pattern of innovators leading to early adopters leading to broad market adoption is anticipated for the ZNE market. Strategies that consciously support a market transformation strategy should be able to accelerate the market adoption curve by emphasizing markets that focus on the future, desire to be seen as leaders, or obtain other market benefits from adopting advanced strategies. Other factors that can help advance market adoption are market organization and control points, technical feasibility for the building type, and reasonable cost/benefit scenarios.

Key target groups that, with the right cultivation and support, can help advance ZNE adoption more rapidly are:

- **Education**—Both K-12 and higher education have already demonstrated an interest in deep energy efficiency and ZNE projects. Among the key reasons why k-12 schools are an early adopter market are:

  The K-12 market is well organized and easy to reach, both at the owner level and at the design community where a small number of firms specialize in schools.

  Educational buildings are operated for long periods of time by their owners, and the benefits of lower operating costs are an important consideration in the budgeting process.

  Educational buildings offer opportunities to engage students and the community in learning activities related to energy, building science and environmental relationships. Schools are preparing students for the future, and the buildings can be a teaching tool as well as a symbol of thinking about the future.

From a technical perspective, energy densities in schools are relatively low, and most buildings are low rise with reasonable solar access, making zero-net energy projects more feasible than in many other markets.

And, perhaps most importantly, the success of the Collaborative for High Performance Schools (CHPS) over the last decade has already paved the pathway to higher performance schools. CHPS has been strongly supported by utility energy efficiency efforts for the ability of schools to deliver savings. While CHPS was founded in California, it has now been adopted in 10 states, demonstrating the strength of the model.

At the university level, several ZNE and very high efficiency buildings have already been developed, for example, on the UC Merced and UC Davis campuses. A focus on leadership and the future can be important to the identity and marketing of higher education. Like K-12, buildings are in use for many years, and low operating costs are important. Both individual and campus scale projects are possible.

- **State and Local Government Buildings** – The Governor has already recognized the role of government leading the market by example to ZNE and has issued an Executive Order to accelerate the transition of state buildings to ZNE by 2025 for both new and existing facilities. Similar opportunities for leadership exist at the local government as well. Again, the long service life and ownership constancy of government buildings make ZNE goals more important than markets with tenant changes over time. A recent national meeting of multiple states and cities targeted education and state/local government buildings as the most appropriate markets for ZNE.
- **Warehouses** – Warehouse buildings have perhaps the most cost-effective and quick path to ZNE performance due to two main reasons – a) low energy use and b) ample roof space for PV. Warehouses in fact could potentially become net energy producers which may have a role in a community scale ZNE setting or for providing PV to other buildings that are built to ZNE Capable or ZNE Equivalent levels.
- **Retail**— While the retail market is quite diverse, elements of retail, particularly chain dry goods that build to suit, are another large commercial market with relatively low energy intensities and some leadership in deep efficiency. Walmart, Target and other major retailers have been active in the DOE Retailers Alliance and participants in new construction programs. Because chain retailers with larger building footprints build to a prototypical design, a given design/technology/control solution set can be applied to many projects with limited variation, reducing design costs and supporting bulk purchase arrangements.
- **Offices**—Offices are the largest commercial building type in California at approximately 1 billion square feet. Office properties are the most active market in ENERGY STAR benchmarking. However, ownership is quite diverse with public, corporate and commercial real estate interests. Public and corporate owners are more likely to participate in the early stages; commercial real estate interests will follow only when costs, risks and the business case for ZNE are more fully understood. Within the office market, the best initial candidates for ZNE will be low-rise buildings, although deep savings are possible for all office types.

The general approach to all of the leading markets can be similar, combining a market specific outreach and communication approach with the well-established statewide Savings By Design program providing technical support and incentives. To reach deeper savings and ZNE goals, the role and elements of the Savings by Design must be enhanced and more clearly focused, as demonstrated by early successes with a Path to Zero program element within Savings By Design (and a similar pilot effort at the Energy Trust of Oregon).

While building codes may be the ultimate strategy that will bring ZNE to the whole market, it is important to begin working with leading markets and early adopters to better understand costs, bring emerging technologies to scale (and reduce prices), and help the design/construction/building operations industry work to assure performance and reduce risks. Pushing regulatory strategies too far and too fast could lead to significant resistance from owners and developers.

The business case for each market and submarket of commercial buildings is different, based on access to financing, market position, intended use or ownership of the building over time, and a variety of other issues. Building the business case (costs, performance risks, building value, market perception of leadership or productivity, etc.) in each market will be critical, so expanding real world examples in each market will be important to track and share within the market. Building this solid body of evidence in the early adopter buildings within each market will be critical to convince the majority of owners that ZNE buildings can move to a reasonable option for consideration, and then finally to a market expectation and/or a code reality.

## Recommendations: Conduct Research to Overcome Technical Barriers

The systems being used in some of the early ZNE Site buildings are innovative and there is limited market experience with the systems. Further, some of these systems need more maturation before they can be adopted on a larger scale. Continued efforts are needed to evaluate promising technologies through emerging technologies programs and other research efforts. This includes developing appropriate system-specific performance metrics, developing controls protocols, developing installation protocols and validating the effectiveness of the technologies.

### 7.2.3 Define a Codes and Standards Path to ZNE

Codes and Standards programs at the CEC and the IOUs (under CPUC oversight) will play a pivotal role in achieving the ZNE goals. Of all the pathways available to the regulators, codes and standards offers the most direct method to mandate new construction measures capable of achieving ZNE EUI metric targets for buildings. In order to do so however, codes and standards need to evolve as follows:

#### Recommendation: Make Quality Construction the Foundational Element of Title 24

In order to meet the ZNE goals, construction quality must be of the highest standard and both building envelope and systems must be installed as designed/intended. There are a number of measures assessing construction quality that Title 24 must include as requirements. Title 24 already includes a number of these measures such as heating, ventilation and air-conditioning (HVAC) refrigerant charge testing, acceptance testing and fault detection and diagnostics. However, there is still a need for substantial improvement to Title 24 to address quality construction such as (but not limited to):

- Framing: Reduce thermal bridging in construction through advanced framing techniques
- Insulation: require QII (Quality Insulation Installation)
- HVAC installation standards
- HVAC diagnostics standards
- Compact and efficient domestic hot water (DHW) designs

#### Recommendation: Move to a EUI Target for Codes

The language typically used to express code changes is in terms of percent improvements over the previous standards. This language is counter-intuitive to achieving the ZNE goals. Since we have only two code cycles to 2020, and another three until 2030 each successive code update must target a greater portion of the regulated energy use of the building than the previous standard. However, the absolute magnitude of savings (TDV, kWh, Therm) may actually be lower in each successive code update. Thus a percent better than previous code language is actually misleading and may lead to confusion at best and opposition at worst. Instead, laying out a clear goal of a code performance target has the advantage of simplicity and ease of comparison to other ZNE metrics.

Using an energy use target metric for the ZNE definitions (instead of a more prescriptive approach) will give the right signals to the market to innovate and find lowest-cost solutions. The Technical Feasibility Study results will provide valuable data to support the creation of such energy efficiency targets.

As outlined in Section 7.1.2 we recommend that the code metrics be aligned with ZNE EUI metrics by providing a clear path from ZNE TDV buildings to ZNE Capable, Equivalent, and Site buildings.

### Recommendation: Evaluate TDV Metric to Better Account for Increased Penetration of Distributed Renewables Generation

As the contribution of PV self-generation to overall electricity generation increases, there will be fundamental changes to the marginal value of electricity generation which in turn will affect the TDV values used for codes. We recommend that the C&S roadmap to be started by the CPUC and CEC in 2013 should focus on this issue to identify future directions for TDV. The use of TDV to value renewable self-generation may also need to be reconsidered if the state's net energy metering policies change significantly.

### Recommendation: Identify Ways to Overcome Federal Pre-Emption

As outlined in section 6.5.1, a number of states and the IECC have adopted innovative methods to overcome federal preemption of appliance efficiency. We encourage the CEC to consider these approaches as part of the C&S roadmap and 2016 Title 24 process.

### Recommendation: Address Increasing Plug Loads and Appliances Energy Use

The direct path to addressing plug loads and appliances is through codes and standards (Title 20 for appliance efficiency and Title 24 for controls and integration into ZNE codes). As explained in section 6.5.1 there are challenges in doing so due to federal preemption but there are also several potential approaches to navigate around the preemption barrier. We recommend that the CEC explore these approaches starting with the 2016 Title 24 updates.

However, codes and standards alone cannot move to the intended goals without assistance from voluntary efforts aided by utility and third-party incentive programs. New construction programs could potentially include incentives for high-efficiency plug loads and appliances subject to verification of the same. Some programs already have pre-requisites on plug load and appliance efficiency such as requiring EnergyStar rated appliances. These approaches could be expanded through new construction programs for both residential and commercial buildings.

Regulatory agencies and the utilities could also work in collaboration with national appliance and plug load rating initiatives such as EnergyStar to ensure that these ratings target the 'best in class' systems based on their energy efficiency performance.

Finally, but perhaps most urgent is the need for better information on how, when and how much energy is used by plug loads and appliances in buildings. Current datasets are limited in their predictive capabilities and their estimates of energy use based on limited field data. We recommend that the CPUC and CEC respectively fund studies to evaluate the current 'baseline' conditions for plug loads and appliance energy use in residential and commercial buildings including time of use and energy use data.

### 7.2.4 Pathways to Meeting 2020 and 2030 ZNE Goals

#### *Residential 2020 Goals*

In this section we outline the specific next steps necessary to put the state on the path to achieving the 2020 goals. There is virtual consensus among all stakeholders that meeting the 2020 goals for new construction are a significant challenge. The existing building retrofit goals are even more challenging and perhaps not realistic considering the state of the economy and the economics of residential retrofits. In this section we focus on the new construction goals in particular since these are more feasible and specifically outlined in the Strategic Plan.

Achieving the 2020 goals for ZNE new construction will require substantial changes to both current construction practices as well as programmatic approaches used to encourage efficiency in buildings. For construction practices, there is a need for massive workforce education on construction techniques such as advanced framing, ducts in conditioned spaces and others. These are techniques that are cost-effective but the current construction industry practices and level of knowledge of the workforce as a whole are not aligned to achieve them. There is a similar need to educate the building design and engineering community that serves the residential market to better understand integrated design principles and practices.

Achieving these goals will require a combination of pathways as argued earlier in this report. Specifically for residential buildings however, it is clear that the 2020 goals will not be achieved unless the 2019 Title 24 standards require ZNE building design and construction practices as seen in Figure 47.

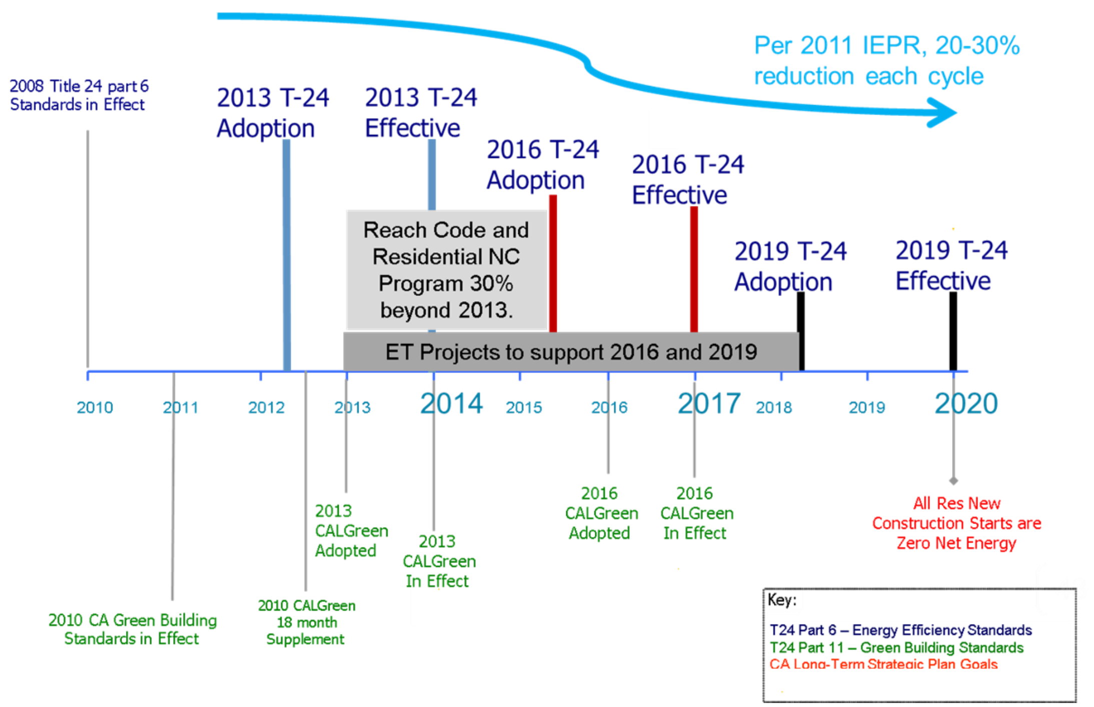


*Figure 47: Path to Res ZNE 2020*

This gives the state two code cycles to take the market from where it currently stands to a ZNE level of specifications. This is an enormous challenge and one that Title 24 by itself cannot tackle alone. As mentioned earlier in this report, the only way Title 24 can require something is by showing it is cost-effective, market ready and technically sound.

This highlights the need to align the other pathways – specifically energy efficiency programs, emerging technologies programs, building science and occupant behavior research, financing options, workforce education and training – in the next couple of years towards the ZNE goals. Thus the 2013-2014 transition portfolio becomes critical to the ZNE goals and the full program cycle 2015-2017 even more so.

The 2016 title 24 standards (the next Title 24 update) development process will start in 2013 and will be completed by late 2014. Thus 2016 Title 24 updates will depend on the progress made in the next two years through the other pathways.

The 2019 title 24 standards (the last title 24 update before the 2020 goals) will likewise depend on changes made in 2013-2014 and 2015-2017. If programs and other efforts do not transform the market enough that ZNE is cost-effective and market ready for a majority of the market, the 2019 Title 24 standards cannot achieve ZNE TDV level.

### *Commercial 2030 Goals*

The 2030 goals – by virtue of being later – are often viewed as being easier to achieve. However, the 2030 goals represent a broad range of commercial buildings which poses a different kind of a challenge. There are certain building types (e.g. warehouses) where achieving ZNE will be easy from both a technical and market perspective whereas others (e.g. hospitals) where achieving ZNE on scale may not be feasible.

As with residential buildings, eventually ZNE codes and standards will be needed to move the majority of the market to ZNE. One option is to think that the code just prior to 2030 (2028 Title 24 if current code cycles continue) to target all buildings to be ZNE all at once. However this approach is flawed in two respects:

- It does not take into account current synergies in the market where certain buildings are more likely to be early adopters of ZNE
- It does not provide a steady transition to ZNE that allows for time to assess impacts of early ZNE regulations and make changes as needed

We therefore support an approach first proposed by McHugh and slightly enhanced in this study where there is a phased adoption of ZNE in codes as seen in Figure 48.

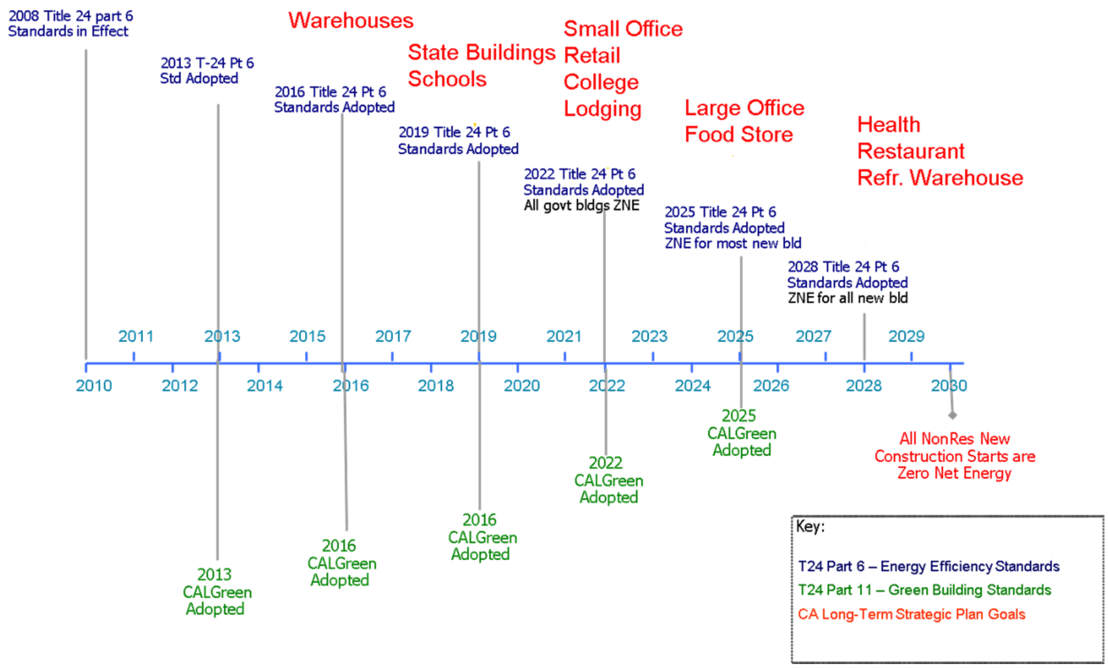


*Figure 48: Path to Nonresidential ZNE 2030*

Phasing the code adoption in this manner has the following advantages and implications on the other pathways:

- Buildings that are easier to achieve ZNE (warehouses) as well as priority target markets as outlined above at a sustained pace
- ZNE goals for codes align with the state targets for state-owned buildings to reach ZNE
- Energy efficiency programs can and should target EUI levels needed for each building type prior to the code cycle that building type is targeted for ZNE. This will help focus the efforts of new construction programs and also help take advantage of the market synergies where early adopters are pushing the rest of the market.
- Buildings that are more complex – either in terms of the technologies involved or the ownership structures involved – are targeted later which provides enough time to work out the details of strategies needed to get them to ZNE on scale.

## 7.3 Next Steps

In this section we present policy recommendations for meeting the 2020/2030 goals. For the sake of brevity we do not repeat the overall recommendations made in Section 7.2 but highlight a few key decisions that need to be made in the short term:

### 7.3.1 Recommendation: Develop a Codes and Standards Roadmap to Achieving ZNE

The CEC and CPUC are set to begin this roadmap in 2013 for residential buildings. We encourage the agencies to expand the roadmap to include nonresidential buildings as well and outline specific milestones that apply to codes and standards development.

Most importantly we encourage the agencies to identify how the other pathways identified in Figure 7 need to be aligned to meet those goals. Section 7.2 provides suggestions on this.

### 7.3.2 Recommendation: Align the New Construction Program Portfolio to ZNE Equivalency Goals

New construction programs are currently active in promoting the general ZNE concept. However, these efforts are in the pilot stages and need to be substantially enhanced in 2013-2014 onwards to reach a broader section of the market.

As part of this effort, we recommend that programs use ZNE EUI metric targets for buildings to achieve in order to meet the ZNE goals. Results from the Technical Feasibility study would be useful to establish these targets.

A significant challenge is the cost-effectiveness of programs which will be adversely affected by these enhanced incentives and support. However, if the ZNE goals are to be achieved, we recommend that the IOUs and CPUC to keep the broader market transformation goals in mind when funding and evaluating new construction programs.

### 7.3.3 Recommendation: Align emerging technologies programs to ZNE goals

Though it is challenging to predict when technologies may develop and what new technologies may arrive in the market place, it is possible to outline the needs of a ZNE building by any definition using the results of the Technical Feasibility study and this study to identify a roadmap for the emerging technologies programs. As an example, there are several codes and standards proposed measures that need further laboratory and field testing such as evaporative cooling systems. In other cases, there are technology needs that are not met – such as smaller air conditioning systems with higher efficiency levels. Beyond technologies themselves, much more information needs to be collected on the occupant interaction with systems and controls. These needs should form the basis of emerging technologies research roadmap.

### 7.3.4 Recommendation: Develop and encourage financing of ZNE buildings

The CPUC has initiated efforts to create policies that encourage private lending institutions to value and support energy efficiency efforts. These policies should be aligned with the ZNE goals. Specific efforts must be undertaken to align building ratings and labels to the needs of financial institutions when they compare buildings for loan appraisals.

### 7.3.5 Recommendation: People and Technology are Intertwined and their Interactions Need to be Better Understood

Interdisciplinary (technology, social sciences, design, engineering, etc.) perspectives on building energy use prediction and assessments of actual building energy use are necessary if the policy goals are to meet reality.

There is variability in energy use in buildings but policy is currently driven by assumptions about 'average' or 'idealized' energy use patterns and behaviors. People will adapt the building, systems, controls and features to their needs and wants. This is not to say that they will adversely affect the carefully crafted building and system designs, but they will make things work *for them* if they can. There is little basis to assume that people will act in accordance with design assumptions or with instructions on proper use if there do not seem to be enough advantages to doing so from the occupants' perspective. But people can and do adapt to new designs and learn how to use buildings. Therefore, strategies for educating occupants on how to maximize their building's energy efficiency attributes should be developed and shared with ZNE building occupants.

If is often assumed that providing more control to building users will result in energy use penalties or inefficiencies in building operation. Regulatory efforts are thus structured to promote automation and centralized controls over distributed controls or occupant control. This assumption is an oversimplification based on limited data on the variability of human interactions with buildings. Careful assessment of how specific design assumptions work in practice, feeding back to changes in designs and design assumptions, as well as user education and expectations, can lead to ZNE designs that support ZNE performance but are not seen by users as major compromises.

Further research is needed on the variability of energy use and the 'how' and 'why' occupants use energy in buildings. Research is needed on how much energy use patterns and behaviors can be influenced by policy approaches (programs, codes, marketing, etc.). Research is needed on how to incorporate occupant expectations and behavior into programmatic approaches.

### 7.3.6 Recommendation: Research is needed into Customer Decision-making

It should not be assumed that ZNE homes and buildings have innate appeal to all prospective buyers and occupants. Rather, research into why people invest in ZNE homes and buildings now, and why they do not, can help build ZNE market intelligence, e.g., on market segments, on features and storylines that appeal to potential buyers, and on how buyers see risks and costs. This study did not conduct research into this important aspect of ZNE goals. This study recommends that market characterization studies are necessary to understand the motivations and barriers to a 'demand' for ZNE buildings.

### 7.3.7 Recommendation: Research Needed on Existing ZNE Buildings

The early adopters have taken the risks needed to design and construct buildings that meet the various ZNE definitions outlined in this report. Field research on these buildings is required to answer a number of questions still outstanding including:

### *Field Performance Assessments*

ZNE is inherently a performance concept in the minds of most stakeholders and as such there is interest and value is looking at the early adopters of ZNE to evaluate how the ZNE designs are working in practice. There are individual efforts being conducted by utilities and private entities to evaluate how the combination of technologies and strategies are working in practice. These efforts need to be expanded and standardized so as to enable comparison of predicted performance with actual performance across buildings, climate zones and ownership/tenancy structures.

### *Occupant Interaction with Buildings*

Investigate how occupants interact with ZNE buildings as related to energy use and occupant experience, including assessing the heterogeneity of these interactions with respect to different social contexts and building designs, and better accounting for use/users as a source of uncertainty. Further evaluate the degree of energy impacts of interventions such as education and energy use feedback devices, recommend improvements, and characterize limitations. Investigate tradeoffs between automated and manual control of energy-using devices and systems, both in terms of energy use and occupant experience, and use results to improve design.

### *Plug and Miscellaneous loads*

Evaluate how plug loads and miscellaneous loads contribute to building energy use and affect achievement of the various ZNE definitions. Variability in user choice and user interactions with the building may have a proportionately larger influence on the energy use of ZNE buildings versus conventional buildings, as the energy efficiency of the building envelope and systems in ZNE buildings are higher.

## 7.3.8 Recommendation: Research Needs for ZNE Grid Impacts

The grid interconnection costs for high penetration distributed PV systems on ZNE buildings are still largely unknown. While it may be impossible to predict these costs until California experiences high penetration distributed PVs, we have identified some specific areas of research that would provide guidance going forward.

- *Local voltage stability.* Although it is not anticipated that distributed PV systems will lead to rapid short-term fluctuations in California's net load, it is possible that local distribution systems will experience transient voltage behavior that compromises the performance of local electronic devices. ZNE community pilot projects present unique opportunities to investigate these transient voltages and their impacts if voltages are recorded with high temporal resolution over various load and renewable conditions throughout the local distribution system. ZNE community pilot projects should also provide a unique test bed for smart PV inverters that are capable of mitigating these voltage fluctuations.
- *Operational flexibility.* New modeling methods will be required to determine if California has enough operational flexibility to meet demand with high penetrations of renewables. These methods must include adequate treatment of sub-hourly load and renewable fluctuations, renewable forecasts, imports, hydropower flexibility, renewable curtailment, and alternative scheduling algorithms to identify whether flexibility can be

achieved through operational changes or will require procurement of new flexible capacity. Quantification of flexibility requirements is not only an important step toward meeting the 33% RPS, but it will also provide a baseline for examining the incremental flexibility need associated with the ZNE goals.

- *Interconnection cost data availability.* The local grid impacts of ZNE can likely be managed with upgraded distribution equipment. This means that in a future with high penetration of distributed PVs, interconnection costs may increase and the allocation of these costs may need to be considered in the context of evaluating the cost effectiveness of ZNE communities. Currently there is very little standardized interconnection cost data available, partially because there are relatively few completed interconnection studies for ZNE communities and partially because each system has unique distribution engineering considerations. Going forward, it would be useful to create a standard method for utilities to characterize and report interconnection costs so that the grid impact costs and implications of ZNE can be better understood.

- *Allocation of distribution upgrade costs and benefits.* Currently, renewable generation interconnection costs, that are identified prior to project approval, are incurred by the project developer, increasing the project cost. Small residential systems typically do not require distribution equipment upgrades at the time the system is installed, so there is essentially no direct cost of interconnection. If distribution upgrades are required after the distributed generation is in place, these costs will eventually be collected from all utility ratepayers through retail rates. As the penetration of PV systems increases, however, distribution upgrade costs are likely to become more frequent and more costly, making cost allocation a more important issue. Under the current interconnection tariff, interconnection costs will be disproportionately allocated to the first developer that fails the interconnection screens in an area, while later developers may reap the benefits of an upgraded distribution circuit for free. This may introduce an additional barrier to adoption for early ZNE communities. In anticipation of these cost and benefits allocation issues, policy makers should explore new models for distribution upgrade cost allocation.

- *Transmission system effects.* There is concern that high penetration distributed generation may lead to poor utilization of the transmission infrastructure and congestion on specific lines containing both high penetrations of distributed generation and load pockets, potentially requiring transmission infrastructure upgrades. However, there is a need for more quantitative evidence of the thresholds at which these issues arise. Research should be directed toward determining if there are critical ZNE or distributed generation build-out scenarios that give rise to transmission effects, quantifying the potential costs of these effects, and exploring different cost allocation options.

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