Zero Net Energy Home Demonstration

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ABBREVIATIONS AND ACRONYMS

ETC	Energy Training Center (in Stockton, CA, operated by PG&E)
ETCC	Emerging Technologies Coordinating Council
HMG	Heschong Mahone Group, Inc.
PG&E	Pacific Gas & Electric Company
ZNE	Zero Net Energy

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EXECUTIVE SUMMARY

PROJECT GOAL

The Pacific Gas & Electric company (PG&E) commissioned a Zero Net Energy (ZNE) Demonstration Home Display at the Energy Training Center (ETC) in Stockton. This ZNE Home Demonstration consists of a room containing a series of display panels that illustrate key elements of design, construction and maintenance of ZNE Homes. ZNE describes a home, connected to the power grid, which produces as much energy in a year as it consumes. California's Long-Term Energy Efficiency Strategic Plan[1] (CLTEESP) establishes a goal for all new residential construction to be built to ZNE standards by 2020. The ZNE home demonstration project is intended to serve as one of various efforts to move the market towards this goal.

The ZNE Home Demonstration is targeted to residential designers, builders, subcontractors, homeowners, and the general public within PG&E service territory. The goal of the ZNE Home Demonstration is to show how integrated design approach and proven design principles come together to achieve a ZNE residential project. The project is intended to complement and support other PG&E efforts for moving the market towards ZNE, including ZNE classes, PG&E rebates and incentives, and other programs.

PG&E contracted the Heschong Mahone Group, Inc. (HMG) to evaluate the effectiveness of the ZNE Home Demonstration. This report presents the results of our evaluation.

PROJECT DESCRIPTION

Utilizing the expertise of established ZNE practitioners/educators, PG&E developed a ZNE demonstration home display and introductory video that provides education on ZNE principles and technologies. The free-standing display is installed within a 1,500 ft^2 area in an existing structure known as the "Display House" at PG&E's Energy Training Center (ETC) site in Stockton, California. The ETC provides continued education and training on the application of energy efficiency measures to approximately 12,000 construction professionals annually.

To evaluate the ZNE home demonstration, HMG began with a literature review of previous evaluation studies of demonstrations or other educational programs. We then interviewed project team members to understand the project background, objectives, and their suggested performance metrics. Based on these findings, HMG designed and administered baseline and assessment surveys to ETC customers to assess their awareness, knowledge, and attitudes regarding ZNE; and to inform a framework for evaluating and improving future demonstration sites. Baseline surveys were administered before the demonstration opening, and assessment surveys administered after the opening date. The objectives of the surveys were to:

- Investigate the need for the demonstration
- Assess whether the goals of the demonstration were met

[1] http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9-9F62-1BBB14A8D717/0/EEStrategicPlan.pdf

- Investigate the impact of the demonstration on its customers, including their changes in awareness, knowledge and attitudes, and what actions they intend to take as a result.

PROJECT FINDINGS/RESULTS

Based on customer survey results, there is a need for ZNE education in this market, and the ZNE home demonstration is meeting many of the project team's stated objectives and impacting customers. Survey results showed that less than half of respondents were previously aware of the CLTEESP goal to achieve ZNE in residential new construction by 2020, and that the demonstration increases customers' awareness of this goal. Survey results also showed that the demonstration persuades visitors of the feasibility of ZNE, as responses increase from 3.6 to 4.2 out of 5 after visiting the demonstration. The survey may also increase the likelihood of ETC customers seeking out PG&E rebates and incentives, and incorporating energy efficient products and strategies. The ETC customer population is already moderately interested in ZNE building practices, and provided mostly satisfied feedback on the demonstration. These finding supports the claim that this demonstration is contributing towards the larger effort of moving market towards ZNE.

Customer survey results also indicate that demonstration is delivering at least a few of the outcomes described in PG&E's logic model for demonstration showcases. For example, the demonstration supports the outcomes that "customers have a better understanding of integrated solutions" and "increased intent to purchase technology / products".

Our evaluation findings for this demonstration generally agree with results from the literature review of previous demonstrations or educational efforts. Previous demonstration evaluations have found them to be effective at educating participants, but there have been mixed results as to whether the demonstrations support encouraging energy savings actions. The ZNE home demonstration was designed to introduce general ZNE concepts and lessons, instead of specific energy saving measures or strategies. Consequently, direct energy savings actions were not expected to occur.

Survey limitations included a small sample size and misinterpreted survey questions, rendering results indicative but not statistically significant.

PROJECT RECOMMENDATIONS

Our recommendations include providing marketing collateral from resource-based programs held near the demonstration to emphasize participation, annually surveying the ETC attendees to better understand how to tailor information based on customer demographics and feedback, and increasing traffic to the demonstration through signage and publicity. We also recommend that PG&E assess demonstrations after they are launched to compare them to their intended objectives and to logic model outcomes, and make improvements as necessary.

Because of the general approach and goals of the demonstration, we did not measure direct energy savings in this evaluation. To determine possible energy savings as a result of other demonstrations, PG&E could use a methodology similar to the Indirect Impact Evaluation Protocol presented in the California Energy Efficiency Evaluation Protocol:

- Document educational activities,

- Administer pre- and post-tests to understand behavioral changes taken
- Translate behavioral changes to energy or demand savings using deemed or calculated savings estimates
- If needed, develop an attribution factor to apportion energy savings to the demonstration (compared with other programs or influences)

INTRODUCTION

This section presents an introduction to the ZNE home demonstration, followed by an introduction to the evaluation.

The California Energy Efficiency Strategic Plan has set a long-term goal that all new residential construction in California be ZNE by 2020. One of Pacific Gas and Electric's (PG&E) strategies in support of this goal is to inform the local building industry of ZNE benefits, concepts, and practical applications. By providing a basic framework of ZNE knowledge to policymakers, tradespeople, and contractors, and increasing stakeholders' interest and awareness of ZNE, PG&E intends to push the building construction and retrofit market towards a ZNE approach.

PG&E has launched various efforts in pursuit of this strategy, including a ZNE class series, ZNE pilot program, ZNE design workshop, and other projects and programs. In addition, PG&E installed this ZNE home demonstration as part of this larger effort to push the market towards ZNE.

PG&E has leveraged the well utilized Energy Training Center (ETC) in Stockton for the ZNE home demonstration. The ETC has an existing "Display House" used for training into which the demonstration has been installed, as well as a strong user base of market actors. The facility serves about 12,000 customers per year, including roughly 7,000 different customers enrolling in classes. (Some students attend more than one class.) Current ETC customers include, among many other subcategories: builders; tradespeople, including HVAC, electrician, and solar technicians; home performance professionals including contractors and auditors; and real estate management professionals. Given a demonstrated commitment and appreciation for new ideas in energy efficiency, ETC customers are considered a good audience for the demonstration. In addition, most ETC customers primarily work on residential projects.

HMG was contracted to evaluate the ZNE Home Demonstration, with a focus on assessing the effectiveness of the ZNE demonstration site. In addition, HMG provides recommendations based on our findings. Finally, this evaluation could serve as an example for future demonstration evaluations.

The evaluation was carried out by reviewing relevant literature to inform methodology and analysis, interviewing project team members to understand goals and metrics, and surveying ETC customers before and after the demonstration opening to collect data and feed insights for this and future demonstrations.

ZNE HOME DEMONSTRATION DESCRIPTION

MOTIVATION AND OBJECTIVES

As described above, the California Energy Efficiency Strategic Plan includes a goal of all residential new construction achieving ZNE by 2020. This goal is ambitious, and there are various efforts underway to move the market towards achieving this goal. The ZNE Home and a companion ZNE Classroom Demonstration currently under construction are among PG&E's first ZNE-specific educational demonstrations. These two demonstrations will lay the foundations for more aggressive outreach efforts to engage builders and other practitioners in understanding and implementing ZNE strategies. Given the location and minimal time commitment required to view it, the

ZNE Home Demonstration offers the opportunity for ETC instructors to incorporate the ZNE demonstration into their courses, or recommend that students visit during break hours. The ZNE home demonstration is intended to complement other efforts by PG&E, such as training curriculum (including courses taught at the ETC), rebate and incentive programs, other demonstrations, and other programs and projects. The project team cited the ZNE goal as the primary motivation for the ZNE Home Demonstration.

To fulfill PG&E's role of moving the market toward this goal, the demonstration project team sought to engage an audience without much prior knowledge of ZNE, generate interest, and impart a big picture message of ZNE benefits. Because this demonstration describes residential new construction practices, the markets where the most traction could be gained is in detached single family dwellings, attached housing, or low-rise multifamily development.

According to the demonstration project team, potential performance metrics for this demonstration include the number of visits to the ETC site, intent to enroll in ZNE classes, and intent to use of PG&E resources such as rebates or educational tools by demonstration visitors. Specific success metrics are provided in Assessment Objectives section of this report.

Demonstration Project Team

The demonstration was developed by a team of professionals (the "project team"). Throughout the document, we refer to the following members of the project team:

- PG&E project manager: Oversaw demonstration project and team
- Content designers (ZNE and energy efficiency experts): Created the content for the demonstration
- Exhibit designer: Created the lay-out and flow of the demonstration, based on the content provided by the content designers
- ETC supervisor: Provided input on the use of the demonstration and its integration into ETC curriculum, and manages the demonstration once installed
- ETC staff: Provided input on the use of the demonstration, helped administer surveys

Design and Flow

The demonstration is kiosk-based and begins with a 3-minute introductory video - shot at an actual ZNE home - displayed at the entrance. The video is meant to grab a customer's attention immediately upon entering. Following the video are several panels of text and photographs on the walls of the home, distributed over the course of nine stations. These stations are numbered, to suggest an order for customers, but project team members (including the content designers and exhibit designer) expect that customers may not visit each station, and/or may not visit the stations sequentially. This could be because certain stations may appeal to some customers more than others, or if certain stations are crowded. The project team members expect occupants to spend between 15 and 30 minutes at the demonstration.

DEMONSTRATION CONTENT AND APPROACH

The demonstration is designed to deliver high level messages using text and images, as opposed to a hands-on approach implementing specific measures or technologies. This approach was chosen for two reasons. Most importantly, the project team members expect that many customers will have minimal prior knowledge about ZNE, thus making it more important to impart the overall ZNE approach before delving into details. Secondarily, the short time frame for developing the demonstration made it difficult to create hands-on exhibits. Future phases of the project could provide more details on strategies for achieving ZNE, like measure-based information or more experiential exhibits, and integrating the 'Display House' that the Demonstration is currently housed in – which is often used for hands-on training in classes for other construction details.

The stations illustrate ZNE-home building design, construction, and maintenance strategies. Technologies like LED and fluorescent lighting, heat pumps, and advanced framing are outlined as examples and encouraged throughout the stations. The nine stations of the demonstration are:

1. Defining ZNE – CA's Long-Term Energy Efficiency goal for NZE new residential construction; factors that affect energy use (serving as an introduction to the rest of the panels); building simulations; other definitions of ZNE; and other energy loads at a home
2. Mindset & Design Principles – strategies to prioritize when starting the ZNE path including setting goals, building a team, and researching strategies; design principles that guide a ZNE home like simplifying and selecting 'best-fit' technologies; video overviewing benefits of ZNE and overview of ZNE design process including renewables, enclosure, heating and cooling systems, and occupant lifestyles
3. Load Distribution & Plug Loads – design considerations to mitigate some of a home's largest energy consumers; for lighting, install CFLs or wall scones; for appliances, select the right size and apply for rebates; use electronics to turn off when not in use; use variable speed pumps and LED lights to reduce swimming pool energy usage
4. Teamwork & Goal-setting – integrating collaboration among design specialists; form a team with experience, modeling capability, building science knowledge, and construction expertise; facilitate a process to meet early and often, agree on basic parameters, and cultivate patience for revisiting issues
5. Design Fundamentals – building geometry including size, shape, and orientation; environmental considerations including sun, shade, wind, and shelter
6. Building Enclosure – benefits of a high performance enclosure like reduced energy costs, simpler systems, and improved occupant comfort; details on air sealing, insulation, advanced framing, windows, roof, and moisture management
7. Systems – Selecting and sizing HVAC and water heating equipment; installing and commissioning a system based on high performance rather than price
8. Construction Quality – constructing buildings as designed; selecting materials and equipment based on real operating conditions rather than labels; choosing a collaborative team with relevant experience; and success tips like developing a quality management plan, intermediate and final testing, daily construction logs and basing contract payouts on whole house performance

9. Occupancy Considerations – control options including smart power strips and 'green switches'; informing the end-use consumers with equipment manuals and monitoring devices that have data collection, easy interfaces, and analysis capabilities;

Figure 1 and Figure 2 provide examples of the video and displays. Images of all nine panels are provided in the appendices.

FIGURE 1. SCREENSHOT OF ZNE VIDEO

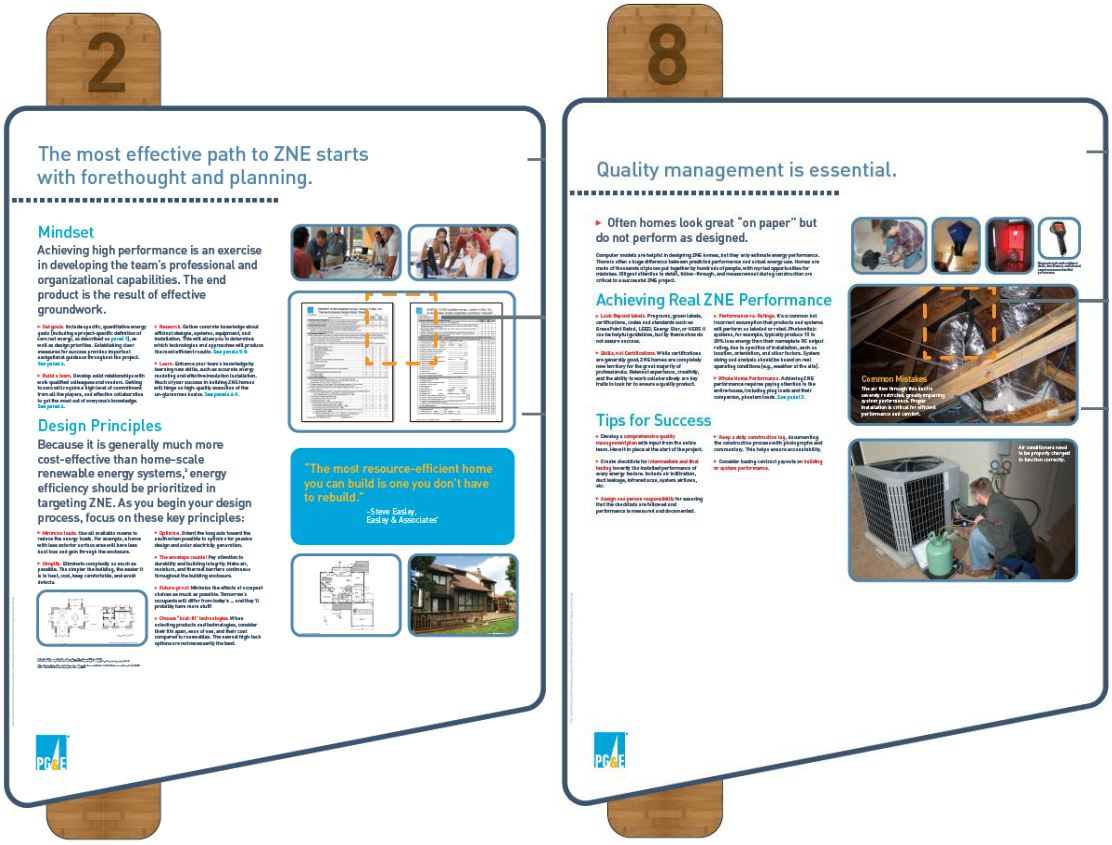

FIGURE 2. SAMPLE IMAGES OF DEMONSTRATION STATIONS (#2 AND #8)

LOCATION OF ZNE HOME DEMONSTRATION

The ETC is located in a primarily industrial area of Stockton, a city in California's Central Valley. Within the ETC facility, the ZNE home demonstration is located behind the main building which contains most classes and the lunchroom. The main ETC building includes the lobby, classrooms, cafeteria, several existing showcases, and staff offices. The ETC parking lot is in front of the ETC main building. Consequently, many ETC customers will not pass by the ZNE home demonstration (e.g., on their way to a class, lunch, or the restroom).

The ETC was chosen as the demonstration site for two main reasons. First, its customers include many residential contractors and tradespeople. Second, this facility has an existing 'Display House' into which the demonstration could be easily installed. (The home is not occupied, but is used only for exhibits.)

The photos below show the existing home facility, and its location behind the main ETC building.

FIGURE 3. EXISTING "HOME" FACILITY AT STOCKTON ETC

FIGURE 4. LOCATION OF "HOME" FACILITY (ON RIGHT) RELATIVE TO MAIN ETC BUILDING (GRAY BUILDING ON THE LEFT AND IN THE BACKGROUND)

FIGURE 5. SITE OF ZNE HOME DEMONSTRATION, IN THE LIVING ROOM OF THE EXISTING "HOME" FACILITY

DEMONSTRATION INTEGRATION INTO ETC CURRICULUM

The ZNE Home demonstration is meant to complement and support classes at the ETC. The ETC provides a variety of courses, and includes exhibits and labs (e.g., a lighting lab) for hands-on learning. Courses cover a range of topics, such as HVAC maintenance and design, duct installation and testing, Photovoltaic (PV) site analysis and sizing, whole house design, energy modeling, water auditing, industrial refrigeration, and certification test preparation.

A sizeable fraction of courses are aimed at HVAC contractors. Currently, ZNE classes represent 5% of the ETC class schedule. According to the ETC supervisor, the ZNE class series generally appeals to audiences with a home performance interest.

The demonstration is designed for instructors of relevant courses (such as HVAC) to incorporate the demonstration into their curriculum, and for ETC customers to visit the demonstration during class breaks, either on their own accord or by encouragement of ETC staff and instructors. The project team intends to increase overall traffic to the ETC by attracting new users, including market actors that influence policy or decision-making in home building and HVAC performance.

EVALUATION DESCRIPTION

HMG was contracted to evaluate the ZNE home demonstration, including understanding and describing how the demonstration meets PG&E customer needs, how the demonstration affects their awareness, knowledge, and attitudes about ZNE, and how this could translate into energy savings actions.

To achieve these objectives, HMG began with a limited literature review of studies that have evaluated demonstrations or other educational programs. We then interviewed project team members to understand the project background, objectives, and their suggested success metrics. With these findings, we administered customer surveys to ETC customers enrolled in classes, which provided the most critical data for the evaluation.

Similar to most of the education program evaluations that we reviewed, this study investigated changes in awareness, knowledge, attitudes, and intended behavior. We did not attempt to translate the behavioral actions into energy or demand savings. This was for several reasons but most importantly, the focus of the demonstration was to convey high level lessons, not strategy-level education. Thus, it would be difficult to reliably and accurately convert the knowledge gained into behavior changes tied to specific measures. In addition, this demonstration was intended to serve as one of several projects and programs that encourage ZNE building practices in residential new construction. It would be difficult to reliably attribute an energy savings action directly to this demonstration (or any educational program); instead, the action could be attributed to multiple PG&E or statewide efforts, including this demonstration. The short time frame of this evaluation made it difficult to develop an accurate attribution factor to apportion savings specifically from this demonstration, versus savings from ETC classes or other programs.

This report presents the results of this evaluation, and our overall findings and recommendations. We provide recommendations at multiple levels, including suggestions for this demonstration, future demonstrations, PG&E curriculum, and future demonstration evaluations.

BACKGROUND

The California Energy Efficiency Strategic Plan has set a goal of achieving ZNE in all residential new construction projects by 2020. While there are varying definitions of ZNE, the definition referred to in the demonstration is "a home, connected to the power grid, which produces as much energy in a year as it consumes."

With less than 1% of the new residential construction market pursuing a ZNE strategy, current developments are still at a proof-of-concept stage. As we discuss in the Results section, the majority of ETC customers surveyed were not aware of California's 2020 goal. The relatively small fraction of ZNE in current new construction and the lack of understanding of ZNE or the California Strategic Plan goal by many market actors highlight the need for market intervention to achieve the goal of achieving ZNE in all new construction residential projects by 2020.

The ZNE home demonstration could serve as part of a collection of efforts to provide this market intervention. As described in Assessment Objectives, the demonstration is intended to convey high level ZNE concepts, increase customer's interest in ZNE, and describe that ZNE is feasible if the proper mindset and strategies are used. These higher level lessons could support additional educational efforts, rebate and incentive programs, codes and standards, and other offerings that teach, incent, or mandate the detailed strategies and measures for achieving ZNE. Thus, in conjunction with other PG&E or statewide curriculum and programs, the ZNE home demonstration could assist in addressing the knowledge gap that must be overcome to move standard residential industry practice towards ZNE.

Several educational demonstration projects, as well as evaluation frameworks, have been implemented in the recent past. During the course of our literature review, we found examples by Southern California Edison (SCE) creating hands-on exhibits at two technology application centers; a green demonstration home in Utah aimed at the general public; and indirect impact evaluations of various technical training programs by PG&E, Built It Green, the PACE Energy Savings Project, and SCE. The results of these educational demonstrations are discussed in detail in the Results and Appendices sections. Generally speaking, demonstration projects were found to be effective at educating participants on energy efficiency and motivating them to take action. There have been mixed results as to whether the demonstrations support encouraging specific energy savings actions, but the costs of these programs are relatively small.

ASSESSMENT OBJECTIVES

The objective is to evaluate the effectiveness of the ZNE home demonstration. Through the evaluation, HMG investigated the demonstration objectives, whether these objectives were met, the effect of the demonstration on customers, and how a visit to the demonstration could translate into actions that could reduce energy use in the future.

The overall purpose of the demonstration is to help prepare the market towards the goal of achieving ZNE in residential new construction by 2020. The main demonstration objectives are to introduce customers to the concept and definition of ZNE, and convey that it can be achieved in residential new construction with the application of the proper mindset and teaming approach. This includes building a team with energy efficiency and building science expertise that meets early and often; focusing on proper design and high quality construction; and using the proper loading order for achieving ZNE, including emphasizing energy efficiency before renewables.

Besides conveying this big picture message, the project team cited introducing ZNE benefits and generating interest in ZNE as demonstration goals. Specifically, the demonstration was designed to inform and influence:

- Customers' understanding of ZNE
- Customers' appreciation and interest in ZNE
- Attendance in and demand for ZNE courses
- Customers' ZNE building practices
- Inclusion of ZNE in customers' business models or marketing
- Use of PG&E rebates or incentives for energy efficient measures or strategies

HMG's evaluation objectives are to provide recommendations for demonstration improvements, evaluation, and market traction in ZNE design, as outlined in the Evaluation Description. The evaluation involved measuring how well the demonstration met the objectives outlined by the project team per above. HMG collected survey responses specific to each of these performance metrics both before and after the demonstration opened for viewing. By analyzing the change in responses before and after the demonstration, HMG was able to provide many of the evaluation objectives.

METHODOLOGY

To gather data for the ZNE home demonstration evaluation, HMG began with a limited literature review of studies that have evaluated demonstrations or other educational programs. We then conducted project team member interviews to understand the project background, objectives, and their suggested success metrics.

Based on these findings, we designed customer surveys, which were distributed and collected by ETC staff and instructors. This included a baseline survey, which customers completed before the demonstration opened, and an assessment survey, which customers completed after visiting the demonstration. The surveys provided the most critical data for the evaluation.

LITERATURE REVIEW

HMG reviewed publications from the following sources for the literature review, including resources inside and outside of California. We searched the following websites and databases for relevant materials:

- California Measurement Advisory Council (CALMAC)
- American Council for an Energy-Efficient Economy (ACEEE)
- Emerging Technologies Coordinating Council (ETCC) for California
- Northwest Energy Efficiency Alliance (NEEA)
- Energy Center of Wisconsin (ECW)
- California Center for Sustainable Energy (CCSE)
- Market Assessment and Program Evaluation (MAPE) Clearinghouse
- Applied Public Policy Research Institute for Study and Evaluation (APPRISE)
- International Energy Program Evaluation Conference (IEPEC)
- Northeast Energy Efficiency Partnerships (NEEP)
- California Energy Efficiency Evaluation Protocols
- California Evaluation Framework

HMG focused on finding publications that evaluated educational or informational energy efficiency programs, particularly demonstration projects. Within the publications that HMG identified, we focused our review on the following information:

- Scope and goals
- Data collection methods and survey instruments
- Performance metrics (energy and non-energy)
- Energy savings estimates (if provided)
- Key findings

In addition, HMG reviewed program and project materials, including the demonstration exhibit text and video, and PG&E's Emerging Technology Program Implementation Plan (PIP) and logic model for demonstrations.

PROJECT TEAM INTERVIEWS

HMG interviewed project team members in September 2012 (prior to the demonstration opening) to gather information on the demonstration purpose, approach, learning objectives, intended audience, integration into PG&E and ETC curriculum, success metrics, and more. These interviews provided the project background. They also informed the development of the survey, analyses, and recommendations, as they clarified the goals of the ZNE Home demonstration project. Detailed results of these interviews are provided in the Appendices.

CUSTOMER SURVEYS

The customer surveys represent the most critical data collection tool for this evaluation, because these provided information on customers' existing awareness, knowledge, and attitudes about ZNE, as well as the changes in these areas and in intended behavior due to the demonstration. HMG developed customer surveys based on results of the literature review and project team interviews, and then surveyed ETC customers enrolled in classes. The surveys included:

- Pretest survey to test the clarity and effectiveness of our survey questions - conducted between October 16 and October 19
- Baseline survey before the demonstration opened - between October 22 and October 26 (the scheduled opening date of the ZNE home demonstration)
- Assessment survey that visited the demonstration - between October 29 (the Monday after the opening, and the first day that classes could tour it) and November 2, 2012.

The pretest survey was the basis of the baseline survey questions and was used as a field test of the survey questions. The baseline survey collected information on customers' awareness and understanding of ZNE and its feasibility, and their interest in ZNE in general and in a ZNE demonstration. Since pretest and baseline surveys included the same questions (with one exception highlighted in the results section), we refer to both set of results as 'baseline' in the survey analysis.

The assessment survey collected similar information for comparison, and also included questions on how customer understanding or attitude changed after visiting the demonstration.

CUSTOMER SURVEY DESIGN

Both baseline and assessment surveys gathered information about the ETC customers':

- Profession,
- Reason for coming to the ETC,
- Prior knowledge of ZNE and understanding of ZNE principles,
- Interest in ZNE,
- Attitude regarding ZNE feasibility in residential new construction, and
- Additional training they would like the ETC or PG&E to provide.

The baseline survey also asked customers if they were aware of the California Strategic Plan goal of achieving ZNE in all residential new construction by 2020.

The assessment survey also included questions gauging a customer's satisfaction with the demonstration and each of its components (stations), and reasons for dissatisfaction. The assessment survey also asked if the ETC customers have shown increased understanding of ZNE after visiting the demonstration, including:

- Interest in ZNE or a ZNE related class,
- Understanding of the ZNE approach and ZNE benefits,
- Likelihood of incorporating ZNE into their marketing or business model,
- Likelihood of using an energy efficient technology or strategy and of using a PG&E rebate or incentive,
- Likelihood of developing a professional network with others interested in ZNE,

Both surveys were designed to be short. The baseline survey[2] consisted of nine questions, with an estimated five minutes for completion. The assessment survey was 12 questions (some of them multi-part), with an estimated ten minutes for completion. The surveys provide primarily coded (multiple-choice) questions to reduce the time for a customer to take the survey, to facilitate analysis, and because ETC staff believed that most ETC customers would not complete an open-ended question. HMG provided a raffle for a small prize as an incentive for customers to complete the assessment survey. We provide both surveys in the Appendices.

Customer Survey Administration

Before finalizing the baseline survey, we administered a draft version of it to ETC customers as a pretest. The only ETC classes held during the pretest timeframe were held off-site. HMG adjusted the survey based on pretest results, by slighting modifying the wording for a few questions, and making major modifications to one question (as described below). HMG, with the assistance of ETC staff and instructors, distributed the final baseline surveys during the week before the scheduled opening date of the ZNE home demonstration. In both cases, HMG asked instructors to distribute the surveys in class.

HMG, with the help of ETC staff and instructors, administered the assessment survey the week after the demonstration opening. The classes offered during this timeframe appealed to a range of professions, and gathered a diversity of ETC customers for the baseline survey, although some professions like HVAC contractors and general contractors were the majority. We asked ETC instructors to incorporate the demonstration into their class, or to encourage students in their classes to visit the ZNE Home Demonstration, and to distribute the survey to their students afterwards.

Customer Survey Analysis

We analyzed the customer survey data to understand if and how the demonstration met the original project objectives, and how the demonstration may result in actions that save energy or change behavior in the future. We analyzed data using the following approaches:

[2] This baseline survey was also designed to collect information for a ZNE classroom that PG&E will install at the ETC in December 2012.

- We used pie charts to present the percent of each profession that responded to the survey.
- We used frequency graphs for some numerically scored questions (scale of 1-5) to present the frequency of each response. We used this approach to analyze responses including the respondent's prior knowledge of ZNE, and the rating of each station.
- We calculated mean values and standard deviations to compare related questions on average, rather than by frequency. This included questions on perception of ZNE feasibility, the respondent's changes since visiting the demonstration, satisfaction with each station, and satisfaction with the overall demonstration.
- We categorized open-ended responses for the few open-ended (i.e., not multiple choice) questions on the surveys, reviewed the responses to determine if any could be grouped, and then totaled the number of each response. We also used this approach to analyze the "other: specify" responses.
- We isolated analysis to a few key questions based on respondent's self-reported profession or previous ZNE knowledge, to investigate if these factors affected responses.

Using the comparisons of baseline responses with assessment responses, we quantified some of the success metrics identified by project team members. However, because the learning objectives of the demonstration are broad (e.g., defining ZNE), we cannot provide reliable estimates of how these impacts could translate into energy (kWh) or demand (kW) savings.

Demonstration and ETC Attendance

For the demonstration to be effective, it must be visited by ETC customers. Project team members also cited as a demonstration objective that it would increase enrollment and eventually, traffic, to the ETC. Consequently, we assessed attendance to the demonstration and if any ETC customers came specifically to see the demonstration.

We worked with ETC staff and instructors and used the customer survey to gather this information. Because the ZNE home demonstration is located at the end of a circuitous path through and outside of the ETC building, we assumed that customers would need to ask ETC staff or instructors for access to the demonstration. We asked ETC staff and instructors how many customers they took as part of a course and how many they let in that toured the demonstration on their own. We also analyzed responses to the question on the assessment survey of whether the customer's primary reason for coming to the ETC was to attend a course, or to visit the demonstration.

RESULTS

The following sections present results from the literature review, project interviews, and customer surveys. We present overarching conclusions in the Evaluation and Recommendations sections.

LITERATURE REVIEW

We provide the following findings based on our limited literature review.

METHODOLOGIES USED IN PREVIOUS EVALUATIONS

Various studies have researched the impacts of educational, informational and demonstrative programs. These studies generally include findings on participant satisfaction, the relevance of the information presented to their broader curriculum (in the case of a demonstration) and/or their professional work, and if the participant plans to (or has) made changes in their behavior based on the program.

The California Energy Efficiency Evaluation Protocols[3] (the "Protocols") includes an "indirect impact" evaluation protocol for programs that seek to change the behavior of consumers through energy efficiency information, education, marketing, promotion or outreach. The Protocols provide three levels of indirect impact evaluations: a "Basic" protocol, in which evaluators measure net behavioral changes (but not how these translate into energy savings), a "Standard" protocol, in which the evaluators convert these changes to energy savings using deemed or calculated assumptions, and an "Enhanced" protocol, in which evaluators verify these energy savings using in-field measurements or observations.

Most of the studies reviewed followed a procedure similar to the Basic protocol: the evaluators assess behavioral changes, but do not convert these to energy savings. One of the studies, the Opinion Dynamics Corporation Indirect Impact Evaluation of the Statewide Education and Information Programs estimated energy or demand savings from these programs (similar to the "Standard" protocol) by estimating the energy or demand savings based on participant self-reported information. None of the studies we reviewed used the "Enhanced" protocol.

HMG did not find a detailed framework for attributing program savings to informational or educational programs. The Protocols provide a useful starting point: it recommends linking behavioral changes to energy or demand savings by using the deemed or calculated savings assumptions that are used in rebate or incentive type programs. However, it may not be appropriate to apply all of the same rebate or incentive program assumptions for actions taken because of the educational program. For example, free ridership values for these energy efficiency actions may not be the same. Also, if the educational program is encouraging participants to also participate in a resource-based program, there must be a method to split savings between the educational program and resource-based program. The Protocols do not provide a method for attributing savings to the different programs.

[3] The California Energy Efficiency Evaluation Protocols, prepared for the CPUC by the TecMarket Works team, 2006. Available on CALMAC: http://www.calmac.org/events/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf

Based on our review of various evaluation studies of demonstrations or education programs, we identified the following common themes:

- Collect background information (e.g., profession) about customers
- Identify goals of the resource (demonstration, class, etc.) and ask customer survey questions specific to those goals
- Use scales (e.g., 3, 5, or 7-point) to quantify metrics, such as understanding, attitudes, or intentions
- Ask about intention for actions or behavior at the time the resource is delivered (e.g., when the customer visits the demonstration or takes the class).
- If possible, ask later if these intended actions were followed
- If possible, use statistical methods to understand differences in behavior due to the educational program, including differences in awareness, knowledge, attitudes, or actions that are planned or that have been taken.
- If possible, translate behavioral changes that occurred because of the program into energy savings.

We provide more detail on these themes below.

Collect Customer Data

In addition to collecting data on how a participant interacts and learns from an educational tool, the customer surveys in evaluation studies include data collection on the participants and/or customers demographics. Detailed demographic information allows the evaluator to draw meaningful conclusions about subsets of their sample population. Also, this level of demographic detail has allowed some evaluations to project energy savings numbers based on rough estimations of where a respondent fits into the market, and how much influence that market actor could potentially have in a given year.

Identify Goals and Performance Metrics

For an evaluation that does not directly look at energy savings, it is imperative to clearly define the goals of the evaluation and the metrics on which the evaluated program will be judged upon. By establishing performance metrics that quantify the typically abstract program goals of educational programs, it becomes possible to quantitatively compare programs and their effectiveness. To gather information on these metrics, participants are often asked to rank their initial, or their increase, in knowledge, attitudes, intentions, or other parameters on a numerical scale.

Understand Participants' Intentions or Behavior

To understand how a non-resource program such as a demonstration or class could translate into energy savings, evaluations ask participants about their plans for changes in their behavior. This could include purchasing or installing a particular measure or using a strategy encouraged through the demonstration or class. If time allows, an evaluation will follow-up with participants to gather data on these types of actions.

Translate Behavior into Energy Savings

The Indirect Impact Evaluation of the Statewide Education and Information Programs estimated net energy savings from actions taken by program participants. The majority of these programs provided specific technical information (e.g., building energy code requirements) as opposed to general information. The authors acknowledge that there are caveats to these estimates, but that they believe it is possible to determine the magnitude of annual energy savings from many education and information programs. In some programs, they extrapolated savings back to the population from which they sampled (e.g., participant population). In others, they based savings only on the participants that could be contacted.

They found a range of savings from 53 to 16,950 MWh per program. Compared to resource-based (e.g., rebate or incentive) programs, these savings are relatively small. However, the authors also note that the costs for these educational programs are also relatively small. Programs targeting mid-stream actors, including the Building Energy Code Training (BECT) program, achieved high savings, because of their potential multiplier effect. The authors note that, "We also found this type of multiplier effect in our evaluation of the Energy Centers". Their Energy Center assessment was based on a case study of ten market actors, which showed energy savings from 15 to 150 buildings per market actor.

Findings from Previous Evaluations

This section provides a brief overview of findings from previous evaluations.

In a process evaluation of the Southern California Edison (SCE) energy centers (the Agricultural Technology Application Center and Customer Technology Application Center), the evaluators found that the exhibits were generally well integrated with classes and provided good support of hands on interaction. But the exhibits provided poor support of directly encouraging action, segment-specific needs, or providing second-language support.

In the Indirect Impact Evaluation of the Statewide Education and Information Programs , evaluators found that education and information programs were effective at educating participants, increasing their energy efficiency knowledge, and motivating them to take an energy saving action. These actions could include installing CFLs (consumers), enforcing certain code requirements more (inspectors), or applying green building principles in home design (builders). This study also estimated energy savings from the behaviors taken by participants in these educational programs. While the energy savings were small relative to resource-based programs, the study authors noted that the costs of these programs were also relatively small. They also found that programs targeting mid-market actors, such as contractors or code officials, were more effective at achieving higher energy savings, because of the multiplier effect. (Mid-market actors work on multiple projects per year, compared with home owners, tenants, or other market actors involved with one project.)

The study of the Utah House, a green home demonstration aimed at the general public found that there was a statistically significant knowledge gain from the demonstration, including for energy efficiency. In addition, based on follow-up surveys, a substantial number of customers (63%) implemented at least one action based on their visit to the demonstration; these actions were most commonly installing a CFL, water efficient toilet or faucet. The authors did not try to translate

these actions into energy savings. As shown in Figure 6, the house has fully installed components that are called out within the brochure.[4]

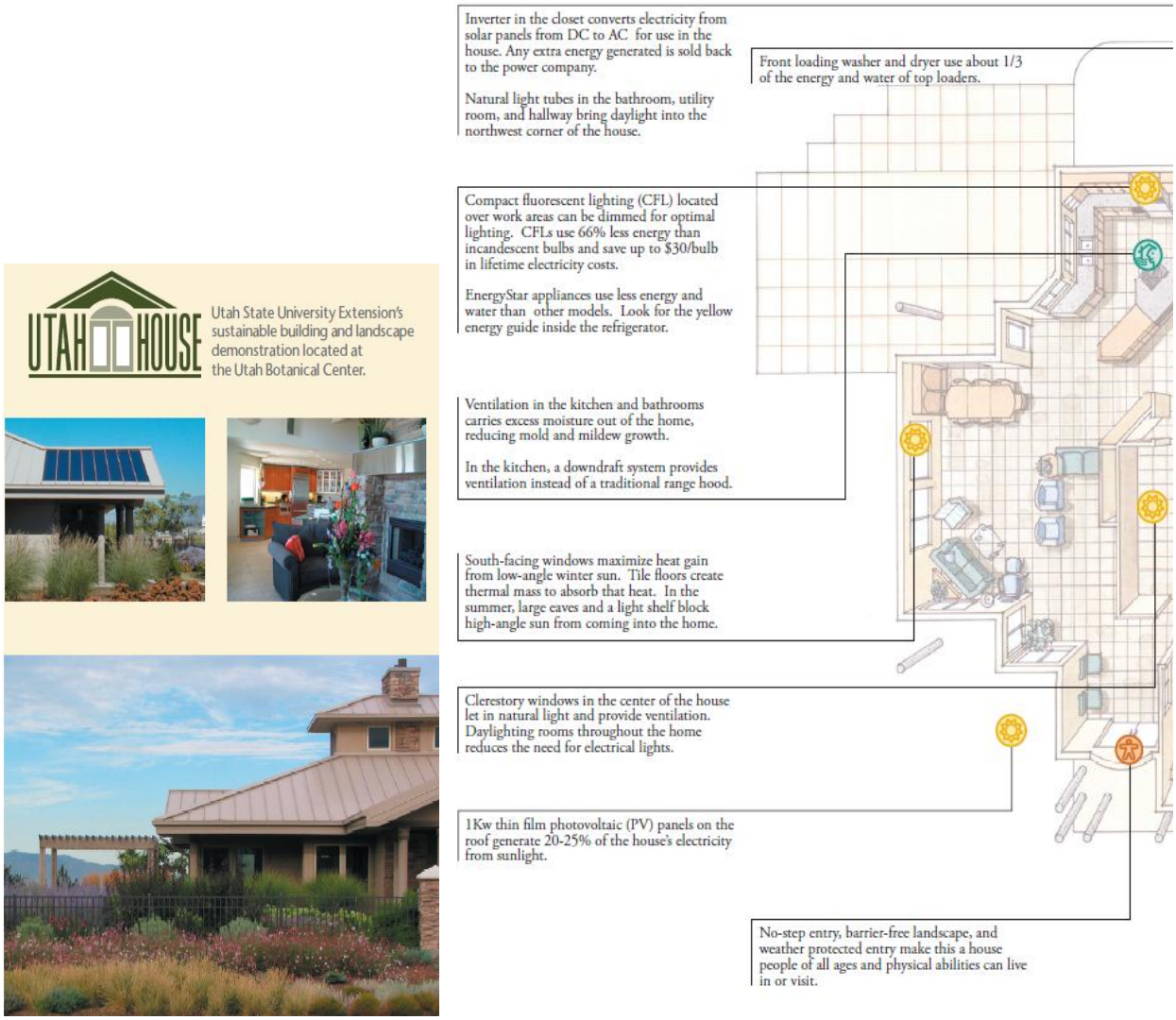

FIGURE 6. UTAH HOUSE BROCHURE

Thus, previous evaluations of demonstration projects have found them to be effective at educating participants. But that there have been mixed results as to whether the demonstrations support encouraging energy savings actions, and many evaluations do not attempt to estimate directly attributable savings.

[4] http://theutahhouse.org/htm/house

PROJECT TEAM INTERVIEW SUMMARIES

We interviewed project team members to gather information on the demonstration project purpose, approach, learning objectives, intended audience, integration into PG&E and ETC curriculum, and more. We interviewed the following team members:

- PG&E project manager
- Content designers (3 ZNE and energy efficiency experts)
- Exhibit designer
- ETC supervisor

We provide a summary of findings below. Full interview notes are provided in the Appendix.

PROJECT BACKGROUND AND MOTIVATION

As motivations for the demonstration, several team members cited the California Energy Efficiency Strategic Plan goal of residential new construction achieving ZNE by 2020, and PG&E's role of moving the market towards this goal. The content designers and ETC supervisor also believe that most ETC customers have little existing knowledge about ZNE, or their knowledge may be misconstrued. This belief is based on their personal interactions with ETC customers. (All three content designers regularly teach at the ETC facility.)

DEMONSTRATION PURPOSE AND LEARNING OBJECTIVES

All team members agreed that the overall purpose of the demonstration is to introduce customers to the concept and definition of ZNE, and convey that it can be achieved with the application of the proper mindset and teaming approach.

This mindset and approach includes:

- Building a team with energy efficiency and building science expertise that meets early and often
- Focusing on proper design and high quality construction, and
- Emphasizing energy efficiency before renewables.

Besides conveying this big picture message, the content designers cited introducing ZNE benefits and generating interest in ZNE as demonstration goals. The exhibit designer cited the strategies presented in the demonstration stations as another learning objective.

Both the exhibit designer and content designers referred to the need for a "Phase II" of the project. If developed, it could provide more details on strategies for achieving ZNE. This could include more measure-based information, or more hands on exhibits.

PROJECT AUDIENCE AND ACCESS

The project team members agreed that the intended audience for the ZNE Home demonstration includes all ETC customers, such as general contractors, building

trades people (e.g., HVAC contractors, electricians, insulation installers, solar installers), energy auditors and raters, and others.

The expectation is that most customers to the ZNE home demonstration will be ETC customers that have come to attend a class. These ETC customers may visit the ZNE demonstration as part of a course, or on a class break. However, the demonstration could attract new customers to the ETC. The ETC supervisor also cited how ETC curriculum will make use of the ZNE demonstration, including incorporating it into classes.

Performance Metrics

Team members provided several measurements for performance for the demonstration. These include increasing:

- Customers' understanding of ZNE
- Customers' appreciation and interest in ZNE
- Attendance in and demand for ZNE courses
- Customers' ZNE building practices
- Inclusion of ZNE in customers' business models or marketing
- Use of PG&E rebates or incentives for energy efficient measures or strategies

We used the findings from the interviews to inform our draft customer surveys.

Customer Survey Results

HMG surveyed students from two ETC classes for the pretest of the baseline survey the week of October 15th, resulting in 40 survey responses. Classes happened to be held off-site, but respondents are representative of ETC customers and PG&E's target market of professionals who take classes on-site. For the baseline survey, four ETC classes were surveyed the week of October 22nd, resulting in 43 responses. (Ideally, the ratio of baseline to pretest surveys would have been higher. However, we were constrained by the limited number of classes during the baseline collection period.)

Because only small adjustments were made in general from the pretest to the baseline survey, the responses for the pretest and the baseline surveys have been combined (and named as 'baseline' results). The one exception is for question 4 in the pretest survey, which asked respondents to rank ZNE design strategies. This question significantly changed in format from the pretest survey to the baseline survey and was moved further down to question 8 in the baseline survey. We removed the results of the pretest survey in our analysis, because of the significant changes to the question. Thus, the 'baseline' sample for only this question remains at 43, while all other questions have a baseline sample size of 83.

The assessment survey was administered to four ETC classes the week of October 29th, resulting in 27 valid survey responses. More surveys were not collected, because the deadline for this evaluation report was November 9. Also, the classes were, on average, smaller than classes held the weeks prior to the ZNE Home Demonstration opening.

The 27 responses are a relatively small sample size and make it difficult to draw statistically significant conclusions. Nonetheless, we have indicative results that inform aspects of the ZNE Home Demonstration's effectiveness.

Results are displayed below, typically with means and standard deviations, and support the overall analyses in the Evaluation Findings section. Raw results are available in the Appendices. For bar graphs, we present baseline survey results in blue, and assessment survey results in red.

PROFESSION

Both the baseline and assessment survey began with the following question:

"Which of the following best describes your job title / position? Circle all that apply:

- *General contractor*
- *HVAC contractor*
- *Electrician*
- *Insulation contractor*
- *Energy auditor*
- *Home performance contractor*
- *Solar installer*
- *MEP designer*
- *Other (specify):"*

Many respondents identified with more than one professional category, and thus the number of total responses in Figure 7 exceeds the number of respondents. The professions most often selected by ETC customers for the baseline and assessment surveys fell under General Contractors, HVAC Contractors, and Energy Auditors. Some of the larger groups that identified with other professions can be grouped into envelope specialists (6 in the baseline survey), energy consultants and HERS raters (5 in baseline survey and 3 in assessment survey), and HVAC service technicians (5 in baseline survey). HMG combined these respondents with the predefined categories of insulation contractors, energy auditors, and HVAC contractors, respectively. Examples of more "Other" jobs that were written-in and that we did not combine include utility employees, property management, sales, consultant, and student.

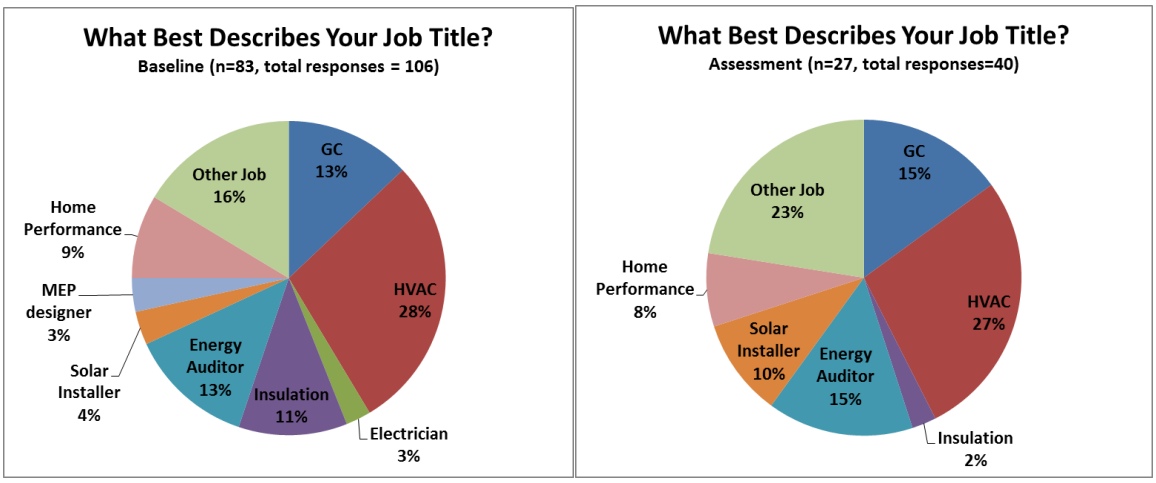

FIGURE 7. RESPONSES FOR BEST-DESCRIBED JOB TITLE / POSITION

Simply sharing a profession with someone does not indicate similar skills, experience, or interests. However, the comparable proportions of professions in the two surveys suggest that respondents of each survey are approximately equal representations of general ETC customers.

ZNE KNOWLEDGE

Three questions address ZNE knowledge: self-declared knowledge, knowledge of California's Long Term Energy Efficiency Strategic Plan goal, and ranking ZNE design strategies according to the order suggested in the ZNE Home Demonstration.

In the baseline survey, customers were asked the following question:

"On a scale of 1-5, what is your current knowledge of Zero Net Energy (ZNE) buildings? Circle one.

1: None

2: A little – Have heard of ZNE, but unfamiliar with general concept

3: Basic understanding – Understand general principles, but not details for achieving it

4: Detailed understanding – Understand detailed ZNE strategies, but have not worked on a ZNE project

5: Expert – Have worked on a ZNE project"

The assessment survey included a similar question: "*On a scale of 1-5, how would you describe your knowledge of ZNE, <u>before</u> visiting the demonstration?*"

Figure 8 indicates that the baseline and assessment respondents had roughly similar experience with ZNE prior to visiting the demonstration, and few declare themselves to have detailed or expert understanding. The mean for the baseline respondents was 2.5, and for the assessment respondents 2.6, or halfway between 'little' and 'basic' knowledge. Both survey results had medians of 3. The data supports the staff interview respondents' position that the building construction community has little or no prior ZNE knowledge and requires greater ZNE education.

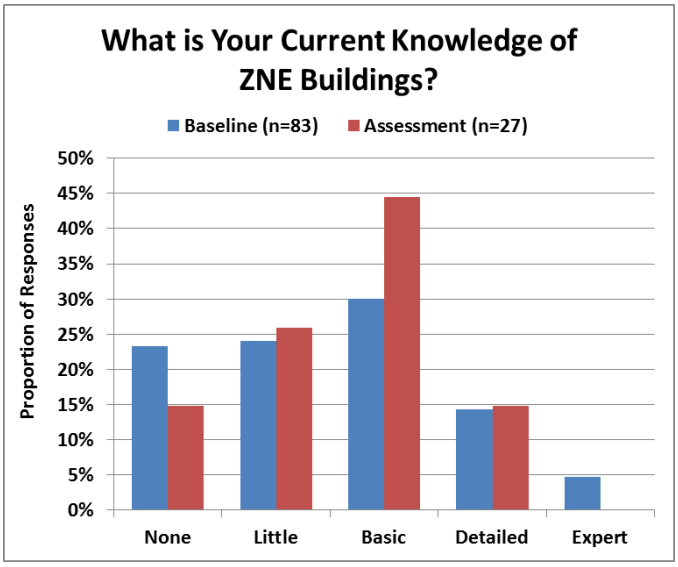

FIGURE 8. SELF-DECLARED ZNE KNOWLEDGE BEFORE VISITING DEMONSTRATION

To further assess ZNE knowledge, respondents were then asked the following:

"The California Energy Efficiency Strategic Plan calls for all new residential construction to be ZNE by 2020.

Were you aware of this? (Circle one) Yes No"

In the assessment survey, we presented this follow-up question:

"Did you learn this because of the demonstration? Yes No"

On the left of Figure 9 is the proportion of respondents who knew about California's Long Term Energy Efficiency Strategic Goal. There are similar proportions in each survey of respondents who are aware of the 2020 goal, with a slightly higher proportion (48%) of the assessment survey respondents claiming that they had previously been aware of the 2020 goal in the assessment survey. The right of Figure 9 shows how many of the assessment survey respondents indicated that they learned about the goal due to the demonstration.

Both surveys showed the less than half of respondents were aware of the 2020 goal prior to visiting the demonstration. Over two thirds (67%) of assessment survey respondents claim that they became aware of the 2020 goal because of the ZNE Home Demonstration.

The survey data thus showed contradictory results: 48% of assessment respondents claim they knew of the 2020 goal before viewing the demonstration, but 67% still claimed that they learned of the goal because of the demonstration. This may be attributed to misunderstanding the question; six of the assessment respondents claimed to have both been aware of the 2020 goal and also become aware of the goal because of the demonstration. Regardless, a strong majority of the assessment survey respondents indicated that they became aware of the 2020 goal due to the demonstration.

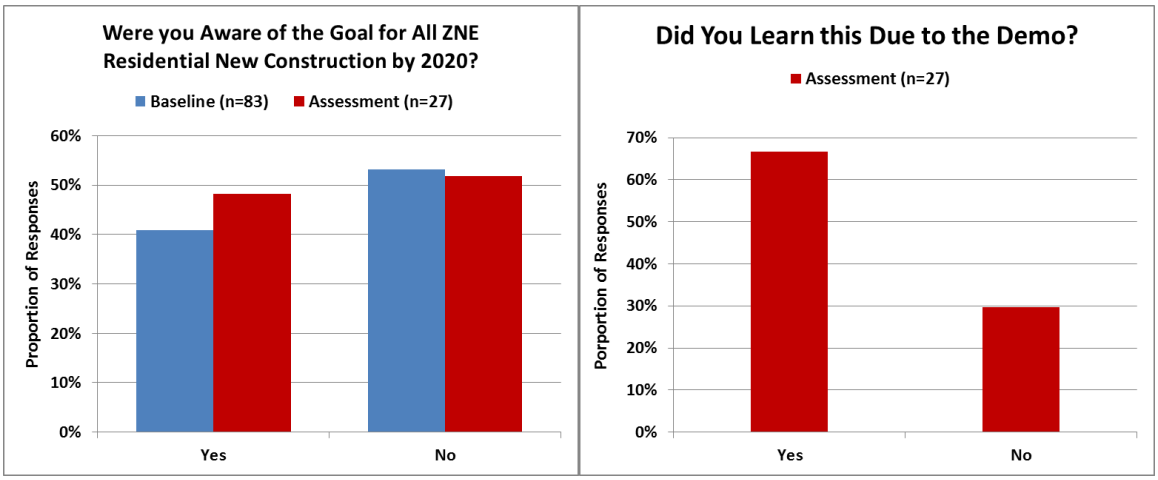

FIGURE 9. RESPONDENT KNOWLEDGE OF THE CA STRATEGIC PLAN GOAL

Customers were also asked to order four strategies to most effectively design a ZNE new construction residence. This question was the only one that HMG significantly changed after the pretest, after results indicated a high rate of misinterpreted or blank responses. The final version of the question in the baseline and assessment survey is below:

"Please order the following strategies to most effectively design a ZNE new construction building (1st = strategy best started first, 4th = strategy best started last).

Establishing a team with a ZNE mindset and meeting early and often

1st 2nd 3rd 4th

Sizing renewable energy (e.g., photovoltaic, solar hot water)

1st 2nd 3rd 4th

Reducing energy loads (e.g., envelope lowers conditioning/lighting needs)

1st 2nd 3rd 4th

Specifying efficient equipment 1st 2nd 3rd 4th "

Based on the demonstration information, HMG organized responses for the most effective way to *design* a ZNE new construction building into 'expected' and 'unexpected.' 'Expected' answers order the strategies in the following way: 1 - Establishing a team with a ZNE mindset; 2 - Reducing energy loads; 3 - Specifying efficient equipment; and 4 - Sizing renewable energy. 'Unexpected' answers order the strategies in any other order than the 'expected' answer, as long as each strategy is labeled once. If a respondent left part or the entire question blank, or labeled more than one strategy the same number as another strategy (e.g., assigned the first and second strategies both "1st"), HMG grouped the answers into the category, 'misunderstood/blank.' We presume respondents who gave answers falling in this category did not understand the question, did not know the answer and so did not attempt answering, or skipped the question.

Figure 10 shows the distribution of answers for the baseline and assessment surveys. The proportion of expected answers increased for the assessment when compared to the baseline survey, indicating that customers who viewed the ZNE Home Demonstration were more likely to provide an expected answer.

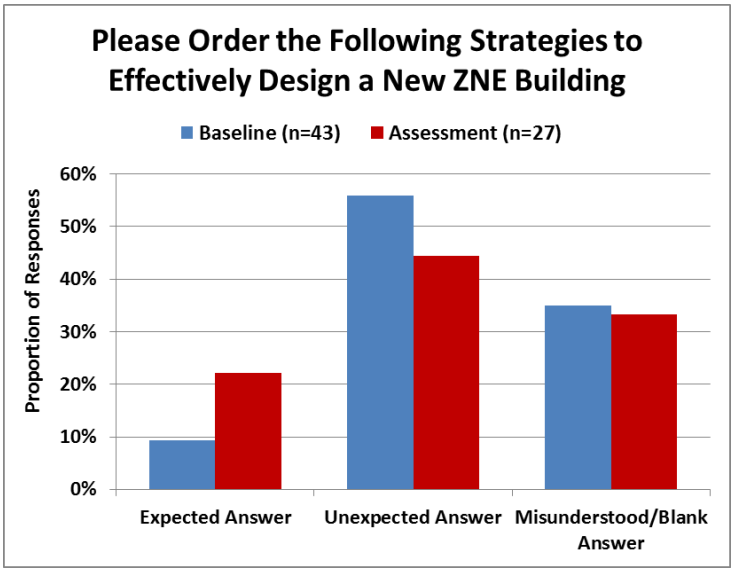

FIGURE 10. RESPONSES TO ZNE STRATEGY ORDERING QUESTION

Note that the baseline sample size is 43, because these results cannot be combined with the 40 pretest survey responses. We discuss what characteristics may correlate with an 'expected' answer in the Overall Findings section.

ZNE INTEREST

In the baseline survey, ETC customers were asked about their general level of interest in ZNE, and the reasons for this interest, on a 1 to 5 scale in the baseline survey, with 5 being most interested.

"On a scale of 1-5, please rank your interest in the following:

- *Learning about ZNE in general*
- *Visiting a ZNE demonstration home*
- *Visiting a ZNE demonstration classroom*
- *Building a professional network with others interested in ZNE*

Please rank why you are interested in ZNE:

- *To incorporate ZNE into my business model or practices*
- *To better understand ZNE practices in general*
- *To better understand a particular measure or strategy. Please specify:*
- *To meet the needs of a current project"*

Figure 11 shows that average interest levels were generally high, with the highest interest for learning about ZNE in general and visiting a ZNE demonstration classroom. The black error bars represent the 2 standard deviations around the average respones (one standard deviation above the mean and one below the mean), which contain 68% of responses.

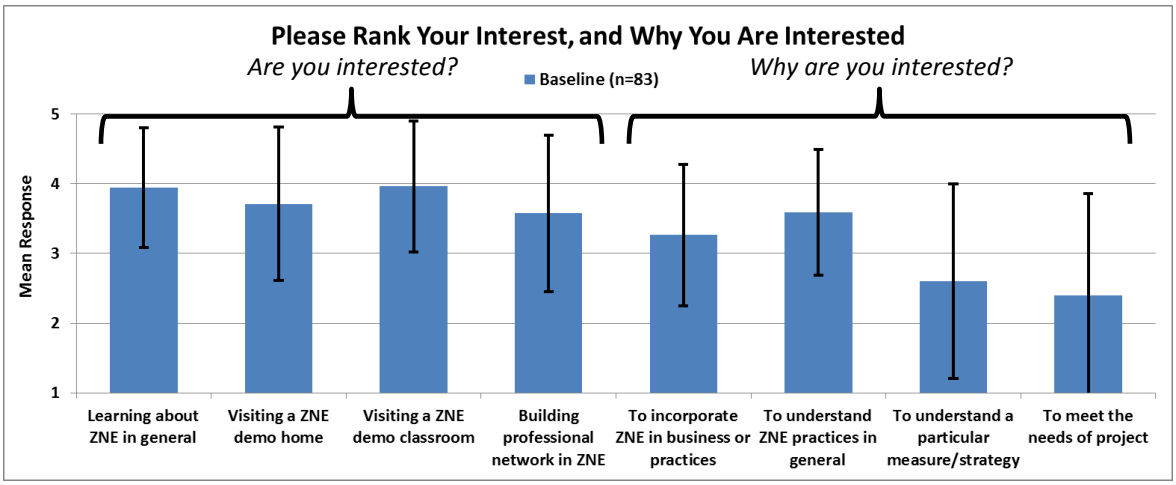

FIGURE 11. BASELINE INTEREST LEVEL IN ZNE AND REASONS FOR INTEREST

In terms of why respondents reported an interest in ZNE, understanding general ZNE practices generated the most interest, while understanding a particular strategy and meeting the needs of a current project were the lowest interest-generators.

The question also provided a blank space for respondents to provide a specific ZNE strategy which interested him/ her. Only 12 of the 83 respondents wrote in specific ZNE strategies, with four related to HVAC, three related to renewables, and three to envelope design. The low rate of write-ins, coupled with an average interest of 2.6 out of 5 for understanding a particular ZNE measure/strategy, indicate that the respondents were more interested in ZNE at a conceptual level rather than a detailed level.

LIKELIHOOD OF TAKING ENERGY-SAVING ACTION

The assessment survey included questions on a 1 to 5 scale for how various aspects of knowledge, attitudes, and actions relating to ZNE changed after viewing the demonstration.

"On a scale of 1-5, how has the following changed since you visited the demonstration? [1 = Much Less, 5 = Much More]

a. Your interest in ZNE

b. Your likelihood of researching ZNE or taking a ZNE class

c. Your understanding of ZNE benefits

d. Your understanding of the general ZNE approach

e. Your understanding of how your ETC class (if applicable) fits into a general ZNE approach

f. Your likelihood of purchasing an energy efficient product or using an energy efficient strategy

g. Your likelihood of using a PG&E rebate/ incentive for an energy efficient product or strategy

h. Your likelihood of developing a professional network with others interested in ZNE"

Respondents generally claimed a positive change in all categories listed. As shown in the figure below, the mean response to most sub-questions was between 3 and 4, and there was a small difference in means among sub-questions. The standard deviations are relatively small, also indicating that responses had a small spread.

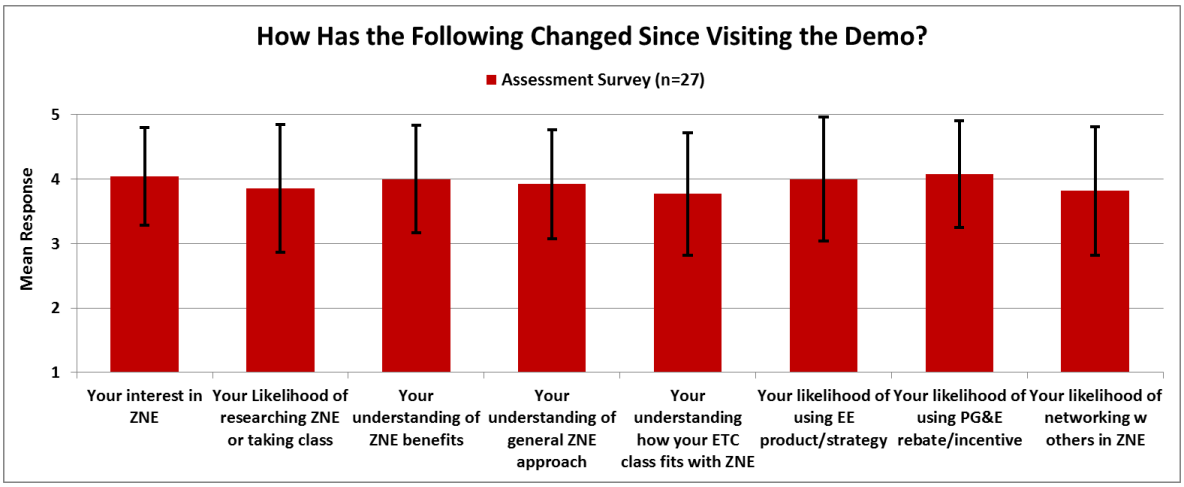

FIGURE 12. CHANGE IN AVERAGE INTEREST AND UNDERSTANDING LEVELS AFTER DEMONSTRATION VISIT

One reason for this small difference in results for each individual sub-question was that many respondents drew one large oval around the same number for all sub-questions, or circled the same response for all. This indicates that the individual results for each sub-question may not be reliable, as some respondents did not appear to critically consider each one.

To better understand results for each sub-question, HMG also analyzed the results of this survey question *excluding* responses that circled the same value for all sub-questions. We present the results below in Figure 13. (Note that the number of responses – the "n" value - is lower.) As shown, the results are similar to when all survey responses are considered. Thus, even customers who considered each sub-question individually had similar reactions to those who may have considered them as a group.

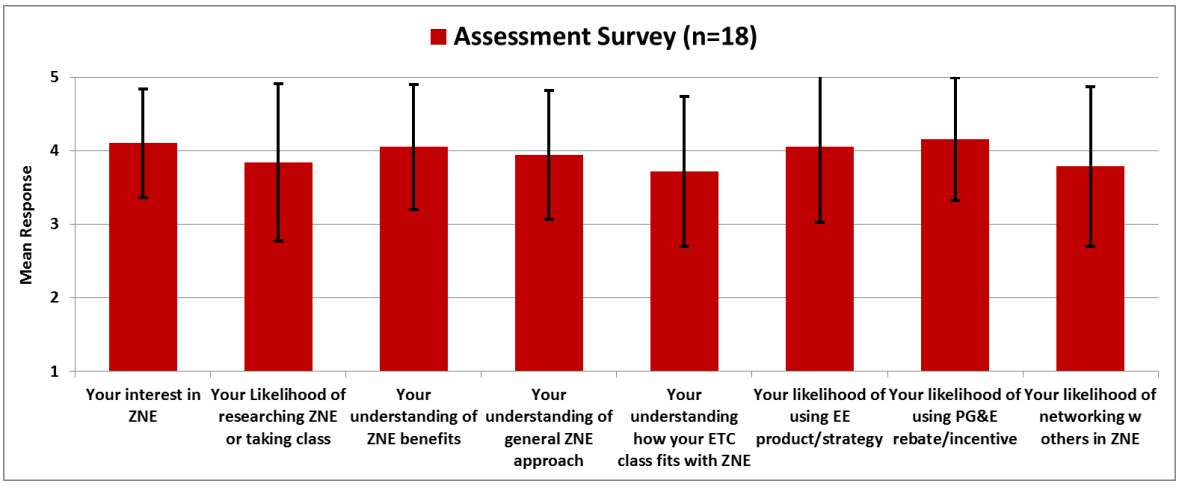

FIGURE 13. CHANGE IN AVERAGE INTEREST AND UNDERSTANDING LEVELS AFTER DEMONSTRATION VISIT, EXCLUDING RESPONSES WITH SAME VALUE CIRCLED FOR ALL ANSWERS

PERCEIVED FEASIBILITY OF ZNE

HMG asked baseline customers of their perception of ZNE feasibility, on a scale of 1 to 5, with 5 being the most feasible. This question asks for immediate feedback.

"On a scale of 1-5, how feasible do you think it is to achieve ZNE in residential new construction?"

The baseline survey showed an average response of 3.6, indicating that respondents generally consider ZNE more feasible than not.

Additionally, we asked the assessment customers what their perception of feasibility was at two points in time; both before and after viewing the demonstration.

"How feasible did / do you think it is to achieve ZNE in residential new construction

a. Before visiting the demonstration?

b. After visiting the demonstration?"

ETC customers who viewed the ZNE Home Demonstration responded that their perception of ZNE feasibility was much lower before viewing the demonstration (an average of 2.8), and that their perception after viewing the demonstration is more feasible (an average of 4.2). Although the baseline and assessment questions ask for slightly different perceptions – one immediate and the other at two points in time – their results generally agree. As shown in Figure 14, responses indicate that the perception of ZNE feasibility is lower for ETC customers who have not viewed the demonstration, and that the perceived feasibility of ZNE increased after viewing the demonstration.

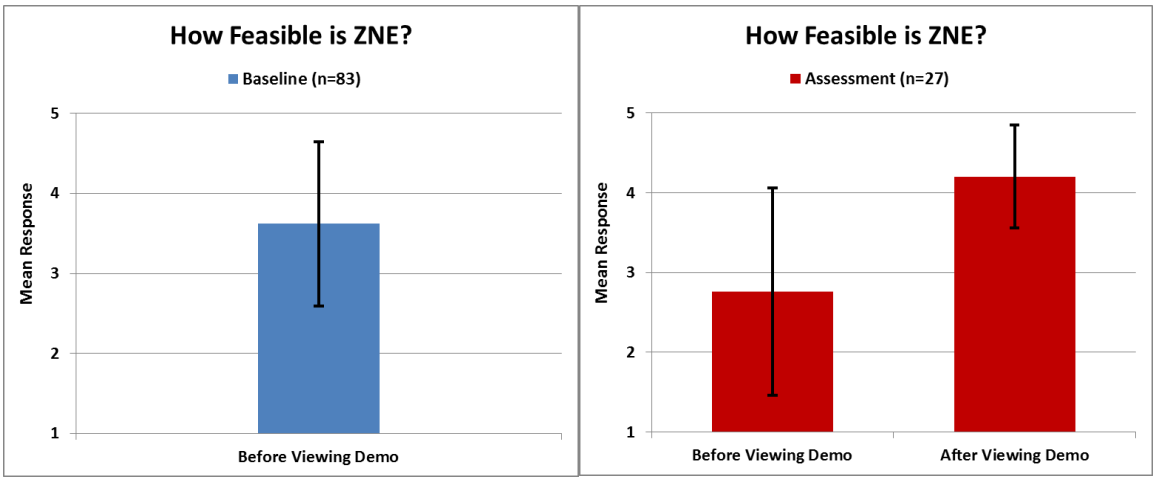

FIGURE 14. PERCEIVED FEASIBILITY OF ZNE, BEFORE AND AFTER VIEWING DEMO

USEFULNESS OF DEMONSTRATION COMPONENTS

HMG asked each respondent of the assessment survey to rate the usefulness of each demonstration station on a 1 to 5 scale, with 5 being the most useful.

"Which station(s) did you find useful?

Station	*Not Useful*				*Very Useful*	
Video	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Overview, Defining ZNE	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Mindset & Design Principles	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Load Distribution & Plug Loads	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Teamwork & Goal-setting	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Design Fundamentals (size, shape, orientation)	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Building Enclosure (sealing, insulation, windows)	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Systems (HVAC and photovoltaics)	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Construction Quality (performance and testing)	*1*	*2*	*3*	*4*	*5*	*Did Not Visit*
Occupancy Considerations	*1*	*2*	*3*	*4*	*5*	*Did Not Visit"*

Results are shown in Figure 15 below. The average response for all stations except for the video, was 3.5 or above. Results for the video are not shown, as it was kept off the whole week because of classes in session in the demonstration space.

An average of only 20 ETC customers rated these stations, and the remaining respondents left the station rating blank or indicated that they did not visit. Also, many customers circled the same value for all stations, indicating that they may not have considered a ranking for each station individually. The percentages of station ratings left blank or marked as "did not visit" expectedly correlate with the small deviations in mean rating – a higher percentage of responses not rating a station results in a lower average rating for that station.

Results also show that most visitors visited most stations.

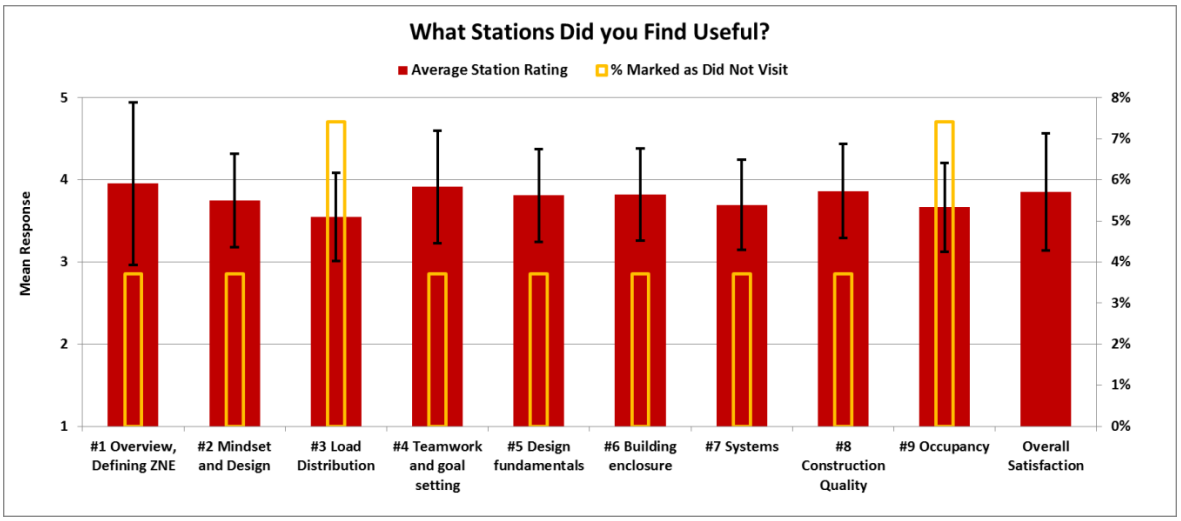

FIGURE 15. SATISFACTION WITH STATIONS, AND % OF RESPONSES BLANK OR DID NOT VISIT

OVERALL DEMONSTRATION SATISFACTION AND WRITE-IN FEEDBACK

The assessment survey also asked customers for their overall satisfaction with the demonstration, on a 1-5 scale. The overall satisfaction with the demonstration was relatively high, with an average of 3.8.

HMG asked baseline survey respondents to write-in further training that they would like from the ETC. None of the 13 write-in responses in the baseline survey could be categorized together, and for the sake of brevity we include all 13 in the appendices.

Similarly, we asked assessment survey respondents to write-in the most useful portions of the demonstration, reasons for dissatisfaction with the demonstration (if any), and other information or training from the demonstration or the ETC in general. 17 ETC customers responded on the useful aspects of the demonstration, many relating to the general ZNE approach, like "proper insulation," "getting all trades together," and "a lofty goal is realistically expected." Suggested improvements were diverse, but among the 11 total responses, four customers suggested that ZNE brochures would be helpful, and two customers indicated they would like more hands-on demonstrations. Please see the Appendices for the raw results.

FEEDBACK FROM ETC INSTRUCTOR

HMG received feedback from one instructor who encouraged his class to view the boards for about 10 minutes during the lunch hour. The instructor provided the following information:

- The sequence of the stations made sense
- Concepts from the board were used in the instructor's lecture, particularly the importance of collaborative efforts between decision makers and installers
- He scored the station design and value as a teaching tool as 4.5/5

- The instructor would encourage or mandate students to take a look and facilitate a 10-15 minute dialogue afterwards to discuss changes in future building standards.

EVALUATION FINDINGS

Below we summarize our overall findings based on our study results. We also provide an assessment of the 'technology' (the demonstration) compared to outcomes in the PG&E demonstration showcase logic model, and compared to ETCC criteria.

OVERALL FINDINGS

In this section we present findings on two aspects of the demonstration –

- Market need for the demonstration
- Success in achieving the demonstration objectives

MARKET NEED FOR DEMONSTRATION

The demonstration design is based on the assumption that its audience had limited understanding of the general ZNE approach, or had misconceptions about ZNE. Given this, the demonstration is meant to address the lack of knowledge – a basic first step to move the market towards ZNE building practices.

The survey findings indicate that there is a market need for this demonstration: The majority of ETC customers were not aware of the 2020 goal (for all ZNE residential new construction) prior to visiting the demonstration, and the average self-reported knowledge of ZNE prior to visiting the demonstration was low to medium (<3 out of 5). Also, most ETC customers could not rank order ZNE strategies prior to visiting the demonstration.

To determine if the demonstration changed this knowledge, the evaluation collected information on respondents' knowledge of the California Energy Efficiency Strategic Plan goal for ZNE residential new construction by 2020, and their ability to rank-order ZNE design strategies.

INCREASED KNOWLEDGE OF 2020 ZNE GOALS

Of those who did not previously know about the 2020 goal (15 respondents), 87% said that they learned about the goal because of the demonstration. As shown in Figure 9, the demonstration was successful at educating 67% of the all ETC customers surveyed about the 2020 goal. These results indicate that the placement of the goal on Station #1 was effective, but also highlights a need for the ZNE curriculum at the ETC.

ABILITY TO RANK-ORDER ZNE STRATEGIES

Results outlined in Figure 10 regarding the ordering of ZNE strategies show that the assessment respondents performed better than baseline respondents. HMG found that the strongest indicator of achieving the 'expected' answer was the respondent's self-declared knowledge of ZNE prior to seeing the demonstration. On average, respondents who gave the expected answer also ranked themselves higher in ZNE knowledge, as shown in Figure 15**Error! Reference source not found.**.

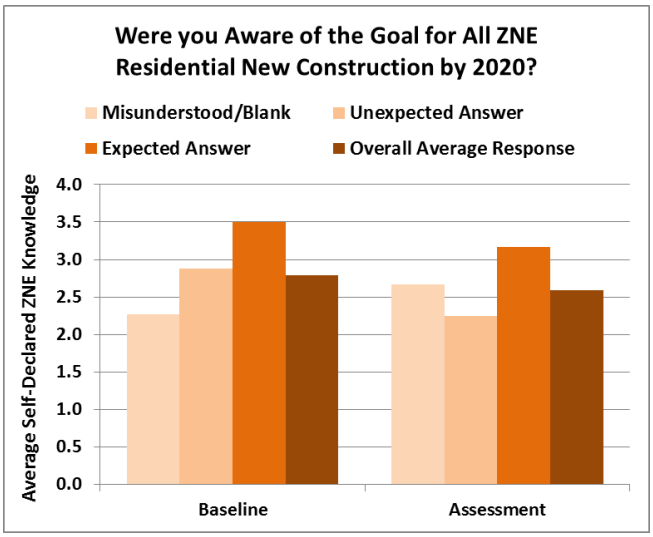

FIGURE 16. ZNE-RANK QUESTION RESPONSE COMPARED TO AVERAGE RATING OF SELF-DECLARED ZNE KNOWLEDGE

For example, in the baseline survey, those who gave an expected answer had given an average rating of 3.5 for self-declared ZNE knowledge, higher than the 2.9 and 2.3 ratings for the groups who gave unexpected and misunderstood/blank responses, respectively. This rating of 3.5 is higher than the average rating of self-declared ZNE knowledge for the entire baseline sample (2.8). The high number of blank or misunderstood responses suggests that the question may have been poorly worded.

Comparing the baseline and assessment results, we see that the average assessment survey respondent were fairly similar in self-reported ZNE knowledge as baseline survey respondents (2.6 versus 2.8 overall rating). However, assessment survey respondents were able to answer the strategy-ordering question at a higher rate than the baseline survey respondents (22% versus 9% of respondents respectively, as shown in Figure 10). Thus, the ZNE Home Demonstration may have helped in improving knowledge of the average visitor on how strategies should be ordered to effectively design a new construction ZNE residential home.

FULFILLMENT OF DEMONSTRATION OBJECTIVES

The primary focus of this demonstration was to provide general ZNE information that would begin to translate into behavioral changes and transform the long term market. The findings for the questions in Figure 11 and Figure 12 have been divided into energy benefits and long term benefits, outlined below.

ENERGY BENEFITS

The demonstration encourages customers to incorporate design and behavioral choices that would result in ZNE building practices with the understanding that associated energy savings will follow.

Project team members identified these choices to be:

- Incorporate ZNE strategies into customers' business models or marketing

- Using energy efficient measures or strategies, and
- Using a PG&E rebates or incentives.

In the Results section, results from the baseline and assessment surveys were matched with respective means and standard deviations, to gauge if the demonstration can be correlated with likely behavioral changes.

In Figure 11, the baseline respondents indicated that they were only mildly interested in ZNE to incorporate ZNE practices into their business (an average rating of 3.3 out of 5). In Figure 12, the assessment respondents indicated that the likelihood of using a PG&E rebate or incentive is higher than before (4.1 out of 5) after viewing the demonstration. Most baseline respondents indicated little interest in understanding particular ZNE measures or strategies (an average rating of 2.6 out of 5). However, after visiting the demonstration, assessment respondents reported they are more likely to use an energy efficiency strategy (4 out of 5).

This likely illustrates that the ETC customers surveyed successfully linked the information presented in the demonstration to energy efficiency measures for which there are PG&E rebates/incentives available. While this may be short of incorporating ZNE in their practices immediately, the efficiency measures are a key component of achieving ZNE putting the projects on the path to ZNE.

The standard deviations for the responses suggest a relatively small 'spread' – for example, a standard deviation of 1.0 around a mean of 4.0 means that 68% of all results were contained within the 3 and 5. These small spreads, combined with the increases in mean to very similar questions, indicate that the ZNE Home Display was moderately effective in encouraging the importance of ZNE building practices, at least immediately following the demonstration.

Because the ZNE Home Demonstration provides high level information, rather than strategy-specific education, we could not translate these behavior changes into specific measures or strategies implemented. Thus, we could not estimate the resulting energy (kWh) or demand (kW) savings from these behavior changes. Nonetheless, an indication that the market has a broad change in mindset is an important step to encouraging specific actions later.

Long Term Market Transformation

Project team members stated that one of the objectives of the demonstration is to increase customers' interest in ZNE and understanding ZNE in general. Networking with other professionals in ZNE will also encourage innovation and alignment throughout the market. Project team members also stated that the demonstration should convey to customers the benefits of ZNE and that ZNE is feasible, although it must be approached with the right mindset and strategies. These objectives would lead to long term market transformation, but not measurable short-term energy savings. For example, the demonstration may encourage ETC customers to market ZNE to their clients, and to incorporate ZNE strategies and principles into their building practices over the long term.**Error! Reference source not found.**

As shown in Figure 11 and Figure 12, ETC customers indicated slight increases in average rated interest in general ZNE approaches and networking in ZNE. However, the respondent ratings are all generally above 3, and the standard deviations for each set of answers in the baseline survey contain the average rating for the comparable question in the assessment survey, and vice versa. This makes it hard to distinguish an impact by the demonstration, but may indicate that the ZNE Home

Demonstration mildly increases interest in ZNE practices and networking, but customers are already largely interested. This may be a general characteristic of ETC customers, who tend to be knowledge driven and desire to be on the forefront of the energy efficiency market.

Of these questions, the largest impact can be found in conveying the feasibility of ZNE. Depicted in Figure 14, the mean response is that ZNE is more feasible (4.2 out of 5) after viewing the demonstration. While this rating is still within the standard deviation of the baseline rating of 3.6, it is outside of the standard deviation of the assessment 'before' rating of 2.8. These figures suggest that the display conveyed appropriate technologies and strategies that began to convince ETC customers of the feasibility of ZNE design.

Many baseline respondents also indicate that they are not interested in applying ZNE practices to a current project. This question received a larger variance in responses – perhaps those who have projects with clients interested in energy efficiency may be very interested, while those who work with clients who don't prioritize energy efficiency may have little interest.

Assessment results general reflect favorably on the demonstration's performance metrics. Respondents indicate they have a better understanding of the ZNE general approach and benefits, as well as being more likely to take a ZNE class. The fact that respondents indicate that they better understand how their ETC class fits with ZNE indicates that the demonstration objection of supporting ETC curriculum is at least partially met.

Feedback on Each Strategy (Station) in Demonstration

The demonstration presents nine different stations, each of which focuses on a ZNE strategy. The customer assessment survey asked demonstration customers for the usefulness of each station on a 1-5 scale, and also included an option for the customer to select "Did not visit". Figure 17 shows the rating frequencies per station. The most frequent rating for every station (except for the video, which unfortunately was turned off for the duration of the assessment survey), was a 4 out of 5. (many respondents simply circled all '4's, which may have led to the similar score for all stations).

The stations that were most frequently not ranked include #5 Design Fundamentals and #9 Occupancy. Station #9 was not ranked or visited by 8 out of the 27 respondents.

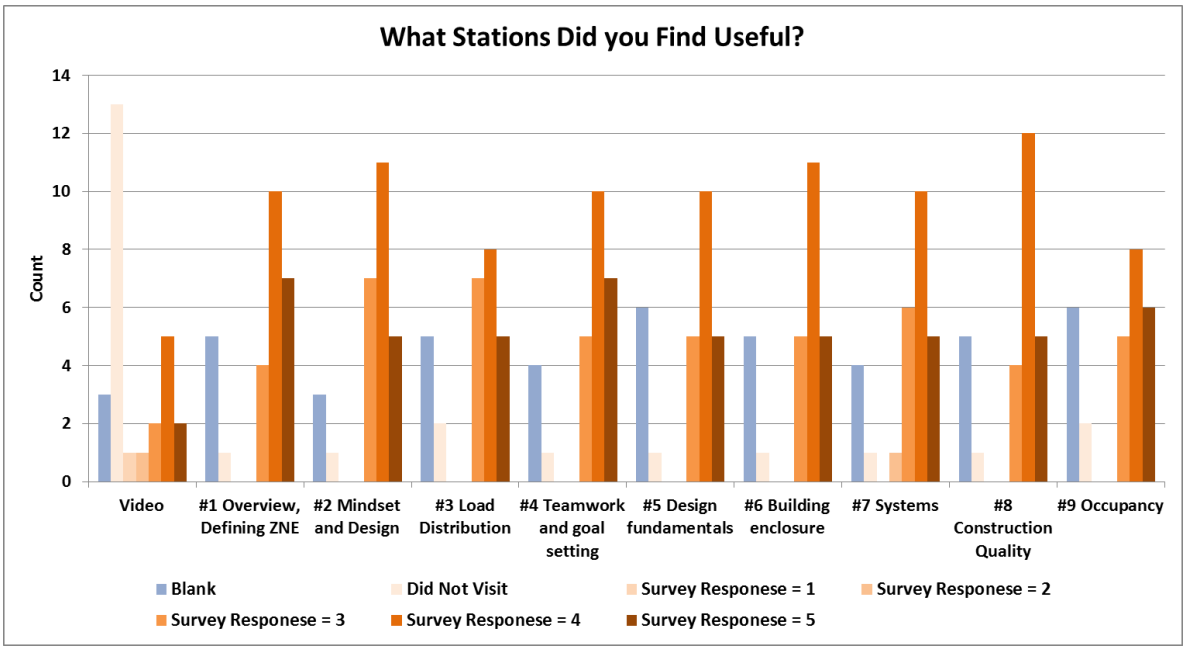

FIGURE 17. RATING FREQUENCY PER STATION

We believe this may be attributed to the placement of station #9, which is past the entrance/exit door. As shown in Figure 18, customers enter the space at the entrance and view station #1, move counter clockwise around the space to view each station, and must go past the entrance to reach Station #9 which may be blocked by the entrance door and thus not ideal for customers to reach.

FIGURE 18. LOCATION OF STATION #9

CUSTOMER COMMENTS AND SATISFACTION

Customer satisfaction was relatively high with the demonstration as a whole, as most assessment survey respondents gave a rating of 4 out of 5 (see Figure 19).

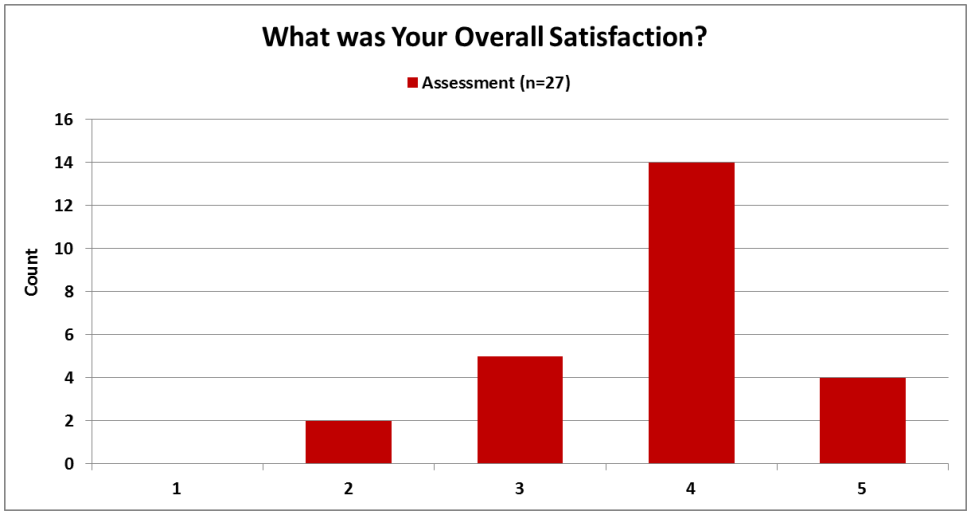

FIGURE 19. RESPONSE FREQUENCY TO OVERALL SATISFACTION WITH DEMONSTRATION

HMG also asked respondents what they thought was the most useful part of the demonstration. While there was no clear grouping of write-in responses, the following have been grouped by how they answered the ZNE strategy-ordering question, and thus their knowledge and absorption of ZNE practices:

- Those who gave 'expected' answers commented that they got an appreciation for the feasibility of ZNE and the ZNE mindset. One respondent valued the specific aspect of proper insulation. Conversely, another respondent claimed that the demonstration provided "basic info, nothing new."
- Those who gave 'unexpected' answers commented that they appreciated learning of the "2020 plan," home enclosure efficiency, the definition of ZNE, testing procedures, saving energy in cheap ways, and the fact that oversizing units is much less energy effective.
- Those who misunderstood the question or left blank responses thought the most useful aspects included information on blower door test and combustion, measuring electrical usage, and equipment sizing systems.

Feedback was limited, but when asked what could be improved about the demonstration or training at PG&E in general, customers expressed desires to receive brochures, see the video, receive information on specific strategies, and participate in more hands-on demonstrations. Except for creating more hands-on demonstrations, all of these comments are complementary and can be addressed relatively easily.

Comparison to Demonstration Showcase Logic Model Objectives

PG&E had previously developed a program implementation plan (PIP) for its emerging technology program (ETP) for the 2010-12 program cycle[5]. The PIP provides a logic model for the demonstration showcases, a subprogram within ETP. The demonstration showcase logic model describes short-term, mid-term, and long-term outcomes. Below, we evaluate how the ZNE home demonstration is meeting some of these objectives.

There are nine total outcomes for demonstration projects in the logic model, including the following four:

1. Short-term outcome: Customers have a better understanding of integrated solutions
2. Mid-term outcome: Increased intent to purchase technology / products
3. Mid-term outcome: Reduction in market barriers
4. Long-term outcome: Meeting long-term CLTEESP & Policy Objectives

Based on these evaluation results, the ZNE home demonstration contributes to the first, second, and third objectives, and may contribute to the fourth. Because the demonstration emphasizes the importance of integrated design and a coordinated team approach, it provides customers with a better understanding of integrated solutions. The customer survey results also show that respondents are more likely to

[5] The Program Implementation plan for the 2010-2012 Emerging Technology program is available here: http://eega.cpuc.ca.gov/Documents.aspx

purchase an energy efficient product or use an energy efficient strategy after visiting the demonstration.

The demonstration also contributes to reducing market barriers. Draft findings from a current study[6] identified market barriers to ZNE, including: 1. lack of information regarding ZNE goals, technologies and strategies needed to achieve it, benefits of ZNE, skills needed for installation of ZNE technologies; and 2. cost. The ZNE home demonstration at least partially addresses the lack of information, by providing education on technologies and strategies, as well as benefits.

Finally, the ZNE home demonstration is contributing towards meeting CLTEESP and policy objectives, by educating customers about the CLTEESP goal of all residential new construction achieving ZNE by 2020.

In addition to the alignment noted above, the ZNE home demonstration may meet other outcomes show in the ETP demonstration showcase logic model, but we could not assess these using the data collected. However, we note that none of the ETP demonstration showcase outcomes in the logic model include direct energy savings; the only related outcome is in "aiding EE programs in reaching desired energy and demand goals". This emphasizes the importance of demonstration projects in supporting other utility programs. Based on our customer survey results showing an increased likelihood of customers applying for P&E rebates or incentives after visiting the demonstration, the demonstration appears to be achieving this goal.

DEMONSTRATION ATTENDANCE

HMG assessed if the ZNE Home Display increased the number of customers visiting the ETC. The feedback collected through the ETC's customer surveys, and verified by the ETC staff, indicated that no new customers arrived solely to view the ZNE Home Demonstration. This is not necessarily surprising, as all ETC customers go to the ETC to attend a class rather than to visit any other part of the building, and the ZNE Home has not yet been publicized on a wide level.

In addition, HMG found that, at least for the first week after its opening, no customers were visiting the demonstration on their own (e.g., on their lunch break). Instead, all demonstration visitors were coming as part of an ETC class.

Barriers to attracting customers to the demonstration include its location within the ETC facility, and security issues. The building in which the demonstration was installed is separate from the building where most courses are held and where lunch is served. This may reduce traffic of ETC customers to the demonstration, because they do not pass by it going to class. All of these issues could reduce traffic to the demonstration.

Our results may have been affected by limited public opening hours for the demonstration during the evaluation period. For the first four days of the assessment survey period (Oct 29 - Nov 1), classes were held in the ETC 'Display House' because the main ETC spaces were occupied. This restricted access to the home demonstration outside of the lunch hour for most other ETC customers. Once

[6] Road to ZNE: Mapping Pathways to ZNE Buildings in California. PG&E. Draft released November 2012.

the ZNE Classroom opens, classes will no longer be held in the ETC demonstration house, and the ZNE Home Display will be more widely available to ETC customers.

EVALUATION LIMITATIONS

Surveys typically require large sample populations to establish statistically significant results. For this project, HMG was working with several limitations that render the results 'indicative' but not statistically significant

- HMG had one week to gather assessment data and one week to complete a report, limiting possible data gathering and analysis
- Because of limited timing, we were not able to pretest the assessment survey as well
- A class of 11 were not able to attend the ZNE Home Demonstration, because an ETC course was being conducted in that space, reducing the potential sample size
- Many respondents misunderstood or chose not to guess on the ZNE-strategy ordering question.
- Some respondents incorrectly interpreted the question regarding knowledge of the 2020 goal by selecting that they knew of the goal both before the demonstration and also because of the demonstration

Despite these limitations, HMG was able to draw overall findings, which we summarize below.

SUMMARY

Given the information above, the following conclusions can be drawn about the performance of the ZNE Home Demonstration:

1. It likely addresses a market need by informing ETC customers of the California Strategic Energy Efficiency Plan goal of ZNE new residential construction by 2020
2. It likely addresses a market need by providing general ZNE information, and results show that it can improve ETC customers' ability to order ZNE strategies in the expected way
3. It likely increases the likelihood of ETC customers seeking out PG&E rebates and incentives and incorporating energy efficient products and strategies, at least immediately after the demonstration, which may lead to direct energy savings in the future
4. It may increase interest in ZNE, though ETC customers surveyed were generally interested in ZNE practices prior to the demonstration
5. It likely persuades some ETC customers of the feasibility of ZNE design strategies
6. It received generally satisfied feedback from the survey respondents

The following figure shows how the demonstration is, or is not, achieving the objectives intended by the project team:

Demonstration Objective	Achieved?	Comment
Introduce general concepts of ZNE	Y	Demonstration presents definition of ZNE and other basic concepts
Educate customers on goal for ZNE in residential new construction by 2020	Y	Survey shows customer knowledge of goal increased after visiting demonstration.
Correct misperceptions about ZNE	Y	Customers were more likely to correctly rank order ZNE strategies after visiting the demonstration.
Increase customers' perceived feasibility of ZNE	Y	Customers' ranking of perceived feasibility increased after visiting demonstration
Increase customers' likelihood to install energy efficiency product or strategy, or use PG&E rebate or incentive	Y	Customer assessment survey results showed that customers were more likely to install a measure or use a rebate. However, PG&E could add brochures for PG&E rebate and incentive programs to provide a next step.
Increase customers' interest in ZNE	Y	Baseline surveys showed customers are already interested in ZNE, and assessment surveys showed that interest increases slightly after visiting demonstration
Support ETC classes and PG&E curriculum	Y	Customers reported an increased understanding of how their class fit into the ZNE approach, and at least one ETC instructor sees the demonstration as an effective teaching tool
Increase traffic to ETC or expand its customer base	N	Based on ETC staff and survey results, the demonstration did not attract any new customers to the ETC during its first week.

In addition, the demonstration is meeting at least 4 of the 9 outcomes described in the logic model for demonstration showcases in the PG&E Emerging Technology Program Implementation Plan. The outcomes met include:

1. Short-term outcome: Customers have a better understanding of integrated solutions
2. Mid-term outcome: Increased intent to purchase technology / products
3. Mid-term outcome: Reduction in market barriers
4. Long-term outcome: Meeting long-term CLTEESP & Policy Objectives

Assessment Results Compared to ETCC Criteria

Below we describe how the ZNE home demonstration project meets the ETCC criteria, based on our evaluation findings. The 'technology' is a presentation or

demonstration of an emerging group of technologies, as opposed to the technologies themselves, so some of the ETCC criteria do not apply.

ETCC Criteria	**Response**
Based on the results, is the new technology better than the incumbent technology? Define "better."	The incumbent technology can be the utilities' existing energy efficiency and distributed generation incentive programs. The demonstration is significantly different from incentive programs, but these types of programs work together to shift the market toward ZNE. One is not necessarily 'better' than the other; they work in collaboration. The demonstration provides the building industry, policymakers, and homeowners with overarching strategies on ZNE that, if pursued, could lead to the construction of ZNE homes and deep energy savings.
What kind of energy savings and demand reduction does the new technology provide?	The demonstration is a non-resource program, so PG&E will not claim any direct energy or demand savings. However, our evaluation has shown that the demonstration effectively educates customers about the existence of California's Energy Efficiency Strategic Plan goal and the general approach to ZNE, and encourages customers to install energy efficient products or strategies. The demonstration helps to lay a foundation for future energy and demand savings in collaboration with other PG&E ZNE efforts. These strategies could include an increase in the use of energy efficient technologies, researching or enrolling in ZNE courses, and networking with other professionals using ZNE principles.
Beside energy savings and demand reduction, are there other benefits over the incumbent technology? For example, the new technology provides better control of temperature, increase productivity, less maintenance, etc.	Demonstrations allow for immediate feedback on educational effectiveness via survey responses. The project team can thus alter the demonstration as needed to account for changing market conditions. According to PG&E's logic model for this program, demonstrations can also address information search costs, performance uncertainties, organizational practice, and overcome asymmetric information or opportunism. These efforts contribute to an informed market that reaches a tipping point in favor of ZNE practices.
Are there market barriers that may prevent the adoption of the new technology?	PG&E must actively inform ETC customers of the demonstration and encouraging them to attend, especially because the demonstration is not located in a central part of the ETC facility. This project did not evaluate market barriers to achieving ZNE in residential new construction. But based on our experience with other projects, market barriers that may reduce the adoption of achieving ZNE include a lack of consumer (e.g., home owner, developer) demand for and interest in ZNE, lack of building contractor knowledge regarding ZNE strategies and technologies, and incremental

	cost of efficient measures. This demonstration attempted to address the first two barriers: By increasing building contractors' awareness of ZNE practices, benefits, feasibility, and how it fits into the California Strategic Plan, the demonstration project team believes that contractors will convey this information to their customers. The demonstration also provides general knowledge about ZNE strategies and technologies.
Any limitations in energy or demand savings applicability.	None, since no direct savings will be claimed.
If the technology or practice doesn't save energy or reduce demand directly, estimated impact in enabling energy and demand savings by other technologies or practices.	Survey results show that demonstration visitors are likely to have increased interest in incorporating energy efficiency strategies and applying for PG&E incentives and rebates. Depending on the specific rebates and if customers apply these rebates, the market may be further pulled toward homes specified toward ZNE. According to the PG&E's Emerging Technologies Opportunity Summary for the ZNE Home Demonstration, approximately 456 new homes in Northern California (a 2% market penetration) could be built to ZNE specifications in 2013, which, at an average home electricity use of 5,900 kWh/yr, could save 2.7 MWh of electricity each year.
Other relevant performance measures and limitations	Survey results indicate that customers increased interest in general ZNE approaches, ZNE benefits, and their perception of ZNE feasibility improved.
Incremental cost for materials and installation, if applicable, and basis for this.	Not applicable. As a demonstration project, there is no base technology for comparison.
Product useful service life, if available, and basis for this.	The project team believes that the demonstration could be used for years, but that it should be updated periodically to reflect changes in strategies, technologies, and customer feedback.

RECOMMENDATIONS

The ZNE Home Demonstration is one of various PG&E projects to promote ZNE goals. It supports other PG&E efforts, such as curriculum and resource-based programs.

While the demonstration appears to have achieved its objectives, we provide the following recommendations for further enhancing its contributions and effectiveness.

RECOMMENDATIONS FOR THIS DEMONSTRATION AND FUTURE DEMONSTRATIONS

EMPHASIZE ENERGY EFFICIENCY PROGRAM PARTICIPATION

Based on the Assessment Survey, respondents indicated a high likelihood of utilizing PG&E rebates and incentives as a ZNE project strategy. To further reinforce the availability of PG&E energy efficiency programs, marketing collateral from the programs can be provided at or in close proximity of the demonstration. This would also contribute towards an overall goal of aiding energy efficiency programs in reaching desired energy and demand goals, one of the long-term outcomes for PG&E demonstration showcases.

ADD INTERACTIVE ELEMENTS

In the current demonstration, the demonstration consisted of educational panels in an existing home demonstration that provides hands-on elements for other training purposes. Recommendations from survey respondents indicated a desire for the ZNE demonstration to also include similar hands-on elements.

INCREASE TRAFFIC TO DEMONSTRATIONS

Based on the first week after opening, ETC instructors are making use of the ZNE home demonstration and incorporating it into classes. (This may be at least partially because HMG encouraged ETC instructors to take students to the demonstration, so that we could collect survey responses.) If this trend continues, many ETC customers will visit the demonstration as part of a class.

However, the demonstration project team members hoped that ETC customers might visit the demonstration before or after their class, or during their lunch break. However, at least during the first week of the demonstration opening, there were no individuals that visited the demonstration on their own according to ETC staff. (All demonstration visitors came as part of a class.) This result may be in part because the ZNE home demonstration is located in a separate building from where most ETC events occur. Because students do not pass by the demonstration on their way to class, lunch, or the restroom, they may be less likely to know of the demonstration's existence and/or be less motivated to visit it.

The ETC main building is fairly full, so we understand why this demonstration was located in an auxiliary building. However, we recommend that PG&E make efforts to centrally locate future demonstrations. In addition, for this demonstration or for others located in less-trafficked areas, PG&E could provide signs promoting the

demonstration in the lunchroom, restroom, or other well-used areas, and signs with arrows to direct customers to the demonstration. Alternatively, PG&E could add other demonstrations, exhibits, or other customer draws to the area around the ZNE home demonstration, to draw more ETC customers to this section of the ETC facility. The upcoming installation of the ZNE classroom demonstration next to the ZNE home demonstration should help attract customers to the area.

Understand Changing Market

The initial demonstration evaluated in this report was designed based on the demonstration's design team assumptions about attendee demographics and knowledge. In most instances, the assumptions proved to be justified according the survey results. However, as ZNE awareness and knowledge becomes more prevalent in the building construction community, future demonstrations may require additional market intelligence to determine the type of educational information desired by future attendees. Thus, we recommend PG&E and the ETC conduct annual market surveys of their training center attendees to better understand how to tailor demonstration content to the knowledge level of visitors. Detailed surveys may even help inform the moving of demonstration elements, such as Station #9, to more easily visible or accessible locations.

Recommendations for PG&E Curriculum

Continue and Broaden ZNE Educational Efforts

Our customer surveys found that there was both a need for ZNE education, and a high level of interest in ZNE. Our baseline survey results indicated that less than half of ETC customers surveyed were aware of the goal for achieving ZNE in residential new construction by 2020, and that many respondents reported having none or little prior ZNE knowledge. In addition, the average interest in "ZNE in general" was high in the baseline survey (3.9 of 5) and increased slightly after customers visited the demonstration (4.0 of 5). PG&E could capitalize on this need for and interest in ZNE knowledge through other demonstrations, providing more ZNE related classes, and promoting the whole house approach for programs and code compliance pathways.

Evaluation Recommendations

Use Mid-Delivery Evaluations to Improve Demonstrations

Evaluations or assessments conducted after a demonstration is launched, but before it ends, can be useful. These can identify demonstration successes and shortcomings, which can guide demonstration improvements while they are still serving customers. These evaluations or assessments could be conducted directly by PG&E or a contractor, as was done here.

Compare Demonstration to Logic Model and Adjust Accordingly

Part of the evaluation should include a comparison of the demonstration with the program logic model. Logic models provide a roadmap for how a demonstration fits

into larger efforts, through expected activities, outputs, and outcomes. By comparing the actual demonstration with the logic model, PG&E can assess whether the demonstration is meeting its intended purpose.

Conduct Indirect Impact Evaluations Where Appropriate

To determine if energy savings have occurred as a result of ZNE educational activities, we recommend a methodology similar to that taken in the Indirect Impact Evaluation following the Standard Protocol in the California Energy Efficiency Evaluation Protocol, by estimating the energy or demand savings based on participant self-reported information. Steps include:

1. Document education activities employed
2. Administer pre- and post-tests to gauge participants' knowledge gain, and gather and measure implementation changes.
3. Administer a post-test to gather information for the post-training knowledge changes.
4. Administer a post-survey within six months after the training to collect further information of post-training direct activities, such as installation of specific equipment or strategies
5. If savings will be claimed, develop attribution methods to apportion energy savings among the particular educational activity evaluated, and other educational activities or programs

In this report, the first three steps were completed for the ZNE Home Demonstration. For the fourth step, email addresses were collected from Assessment Survey respondents. We advise PG&E to conduct follow-up survey with 3-6 months to determine if the knowledge gained by respondents from the ZNE Home Demonstration has led to future action, as completed by similar studies in our literature review. We note that tying indirect energy savings to the ZNE demonstration may be inappropriate -- energy savings estimates are most relevant when tied to efforts pushing specific technologies, while the demonstration objective is to educate ETC customers on broad ZNE topics.

Another possible methodology for future assessments is to conduct surveys of project teams that completed ZNE projects to determine if team members had visited PG&E ZNE demonstrations and whether the demonstrations had influenced their building practices.

Market actors are often influenced by various factors when making an energy efficient decision, which can include multiple PG&E programs. While this repetition can be useful in influencing the market actor, it makes it difficult for an evaluator to attribute these actions to a specific program, or apportion savings among them. However, it may not be necessary for PG&E to apportion savings to different programs, if educational programs continue to serve as non-resource programs. Instead, the finding that an educational program results in energy savings actions, even if these actions are attributable to multiple programs, should be presented as evidence of this educational program's success and contribution towards short term (energy savings) and long term (market transformation) goals.

APPENDICES

We present the following supporting documents as appendices:

- Appendix 1: Literature Review p. 51
- Appendix 2: Project Team Interviews p. 65
- Appendix 3: Customer Surveys p. 70
- Appendix 4: Raw Survey Results p. 77
- Appendix 5: ZNE Home Demonstration Exhibit p. 80

APPENDIX 1: LITERATURE REVIEW

As part of this evaluation, HMG has conducted a brief literature review for how demonstration sites, or other educational programs, have been evaluated in the past by other utilities. The findings of this literature review will inform our approach by identifying possible metrics, survey methods, or survey questions that we could use.

SOURCES AND INFORMATION REVIEWED

HMG reviewed publications from the following sources for the literature review, including resources inside and outside of California.

- California Measurement Advisory Council (CALMAC)
- American Council for an Energy-Efficient Economy (ACEEE)
- Emerging Technologies Coordinating Council (ETCC) for California
- Northwest Energy Efficiency Alliance (NEEA)
- Energy Center of Wisconsin (ECW)
- California Center for Sustainable Energy (CCSE)
- Market Assessment and Program Evaluation (MAPE) Clearinghouse
- Applied Public Policy Research Institute for Study and Evaluation (APPRISE)
- International Energy Program Evaluation Conference (IEPEC)
- Northeast Energy Efficiency Partnerships (NEEP)
- California Energy Efficiency Evaluation Protocols
- California Evaluation Framework

HMG focused on finding publications that evaluated educational, informational, or demonstrative energy efficiency programs where direct energy savings are not observed. We did not find publications that met these criteria in many of the sources listed above.

Within the publications that HMG identified, we specifically looked for the following information for each evaluation publication:

- Scope and goals
- Data collection methods and survey instruments
- Performance metrics (energy and non-energy)
- Energy savings estimates (if provided)
- Key findings

RESULTS

Below we provide results of the literature review.

CALIFORNIA ENERGY EFFICIENCY EVALUATION PROTOCOLS

These protocols, created in 2006 by TecMarket Works for the California Public Utilities Commission (CPUC), was created to guide policy makers, evaluators, and other stakeholders in structuring evaluations of energy efficiency programs and program portfolios. These protocols reference, and are heavily influenced by, the California Evaluation Framework.

The document includes an "indirect impact" evaluation protocol for programs that seek to change the behavior of consumers through energy efficiency information, education, marketing, promotion or outreach. The protocol states that these programs may not have stated energy savings goals, but are still expected to result in an energy impact within their target markets.

Indirect impact evaluations can range in rigor, and the protocols describe three levels: Basic, Standard, and Enhanced.

- In a "Basic" evaluation, the evaluator measures the net behavioral change. These evaluations must consider the target audience of the program, how the behavioral impacts will be measured, how the evaluation will establish a baseline, how long participants are exposed to the educational material, and the inherent self-selection bias of the evaluation.
- In a "Standard" evaluation, the evaluator builds on the results of the Basic, by estimating the energy and demand savings that will result from the behavioral changes. The overall approach is to research how the behavioral changes induced by the evaluated program will lead to energy savings, and then attribute savings to the evaluated program based on prior impact studies.
- In an "Enhanced" evaluation, the evaluator builds on the results of the Standard by verifying these energy and demand savings through field observations and testing.

All of the evaluation studies that we reviewed for this report used the Basic approach. In other words, all of these studies described or measured behavioral change. We did not find a study that estimated the energy or demand savings that could be attributed to this behavioral change.

California Evaluation Framework

This document, created in 2004 for the California Public Utilities Commission (CPUC), was designed to provide a consistent, systemized, and cyclical approach for planning and conducting evaluations of California's energy efficiency programs. It outlines an evaluation framework in which energy efficiency programs can be fairly compared, their energy savings can be verified in a standardized manner, and non-energy effects can be quantified. The framework was used a precedent for the California Energy Efficiency Evaluation Protocols.

For educational and informational programs, the framework outlines four possible evaluations, a process evaluation, market transformation evaluation, impact evaluation and information / educational effects evaluation. Of these, the impact evaluation and the informational / educational effects evaluation are most relevant to the evaluation of the ZNE demonstration sites.

Impact Evaluation

The impact evaluation is applicable when the informational / educational program that is evaluated directly refers participants into energy impact programs with procurement goals. When this is true, the evaluation of the informational / educational program should be done in coordination with the evaluations of the programs it advertises. In this way, the informational / educational program can be evaluated and savings can be attributed based on the program's ability to influence customers to participate in the impact program(s) it promotes.

Informational/Educational Effects Evaluation

This type of evaluation is applicable if the program's goal is to encourage customers or targeted market actors to take actions that reduce energy use, in the short or long term. The goal of this type of evaluation is to quantify the success of a program in achieving its educational goals. The following is a complete list from the California Evaluation Framework of possible measurements of success for an educational program:

- Number and percent of customers reached, or made aware
- Number and percent of customers reached that take recommended actions
- Number and type of actions taken as a result of the program
- Changes in awareness or knowledge by topic or subject area, by type of customer targeted
- Customer perception of the value of the information and/or education received
- Elapsed time between information exposure and action(s) taken by type of customer targeted
- Attribution of cause for actions taken when multiple causes may be associated with the actions taken
- Demographic, firmographic, or psychographic information as appropriate
- Influence of program on dealers, contractors, and trade allies
- Effects of program on manufacturers and distributors
- Identification of barriers experienced by program, and the development of recommendations for addressing those barriers.

The framework recommends that evaluators measure these indicators of program success using surveys, participant interviews, focus groups, site visits, pre and post testing for training initiatives, and long-term follow-ups to track changes in behaviors.

2006-08 SCE Energy Centers (AgTAC, CTAC) Process Evaluation Report

This 2008 process evaluation study conducted by M&E, Deborah Laurel and Associates, McLain ID Consulting/ASW and KVD Research Consulting examines the performance relative to the goals of SCE's Agricultural Technology Application Center (AgTAC) and Customer Technology Application Center (CTAC) in Irwindale. Below are the details of the goals, methodology, metrics and findings of the evaluation of the exhibits at the energy centers.

Evaluation Goals

The overall goal of a process evaluation is to assess the program, and provide recommendations for its improvement.

According to the report, this process evaluation answers the following questions regarding the energy center exhibits:

- How are the EC exhibits performing relative to key metrics associated with support of classes, energy efficiency programs, and customer segments?
- What does the current literature describe that can help guide future efforts to focus on the most appropriate "levers" for behavior change?

Data Collection Methods

For this report, evaluators developed a "yardstick" by which to measure the performance of each exhibit. The evaluators developed a short series of objective Yes/No questions that were used to determine how well an exhibit met the relevant goal. Each yes/no question is also given a point value. Evaluators then audited 17 exhibits at AgTAC and 15 exhibits at CTAC, and customers answered the yes/no questions. Summing up the points for a given category, evaluators could rate the exhibits based on their support of classes and programs, and their potential for sparking behavior change.

Exhibit Yardstick

The exhibit yardstick was developed based on responses in each of the following categories:

Support of classes

- Tie in To classes (3-point scale from "High tie-in" to "No tie-in")
- Use with Classes (5-point scale that ranges from "directly used in class" to "NOT used or referred to in class")
- Promotion of Classes (3-point scale ranging from "signage specifically mentions class" to "No mention of this class")

Support of Programs

- Tie in To Programs (3-point scale from "High tie-in" to "No tie-in" for each class)
- Direct support of programs, with program specific information (series of yes/no questions)

Support of Behavior change

- Conveying Technology Purpose, Use, and Benefits (series of yes/no questions)
- Supporting Hands-on Interaction (series of yes/no questions)
- Encouraging Action (series of yes/no questions)
- Helping Overcome market Barriers (series of yes/no questions)

Support of Customer Segments

- Tie-in to Customer Segments (series of yes/no questions)
- Segment-specific support (series of yes/no questions)
- Second-language support (series of yes/no questions)

Performance Metrics

The performance metrics for the exhibit were measured as follows:

- Support of classes and programs (determined using established yardstick)
- Support of behavior change (determined using established yardstick)
- Support of customer segments (determined using established yardstick)

Key Findings

Based on the data collected on the exhibits, the evaluators made the following findings. These descriptions were taken directly taken from the report:

Findings for Exhibits' Support of Classes:

- Excellent tie-in between exhibits and programs
- Excellent use of exhibits in classes
- Mixed results in promotion of classes at exhibits

Findings for Exhibits' Support of Programs:

- Excellent tie-in between exhibits and programs
- Poor support of programs through signage and collateral at exhibits

Findings for Exhibits' Support of Behavior Change:

- Excellent use of signage to convey purpose, use, and benefits of the technology; mixed results for collateral
- Excellent support of guided hands-on interaction; very good support of independent hands on
- Very poor at directly supporting and encouraging action

Findings for Exhibits' Support of Customer Segments:

- Excellent tie-in between exhibits and customer segments
- Very poor support of segment-specific needs
- Very little second-language support in signage and collateral

Thus, in general, the exhibits were well integrated with classes and provided good support of hands on interaction. But the exhibits provided poor support of directly encouraging action, segment-specific needs, or providing second-language support.

PY2006-2008 Indirect Impact Evaluation of the Statewide Education & Information Programs

This 2010 study conducted by Opinion Dynamics Corp., Summit Blue Consulting, and Jai J. Mitchell Analytics described nine separate evaluations of indirect energy savings for different educational or informational programs. Below we present the goals and key research questions for the evaluations, followed by a summary of the evaluation results for the programs most similar to the PG&E demonstration sites.

The evaluation was described as an "indirect impact" evaluation. Specifically, they intended to answer the following questions:

- What education or information is provided and what behaviors are encouraged?
- What is the reach of the program?
- How likely is the program to induce behavioral change?
- What are the changes in awareness of energy saving opportunities as a result of the program?
- What behavior change occurred as a result of the program?
- What are the net energy savings as a result of the program?
- What percentages of participants were fed into resource programs, and which resource-based programs were promoted?
- What is the value of the program versus the cost of the program?

PG&E 2044: Building Energy Code Training

According to the evaluation, the Building Energy Code Training (BECT) program targets contractors (builders), subcontractors and local code official and provides

classroom and on-site code training to the building industry with the goal of improving compliance with Title 24 energy codes for residential new construction.

Data Collection Methods

Evaluators observed a classroom training session and a construction site training session and conducted several depth interviews with course attendees while on-site. In addition, evaluators fielded a telephone survey of builders and code officials who attended a BECT course. Out of a sample of 736 BETC participants who attended a course between 2006 and 2008, 107 completed a phone survey sometime between October and December 2008, of which were 63 code officials and 44 builders.

Survey respondents were asked the following on a 7-point scale:

- Their prior knowledge of energy code (Title 24)
- How much they learned from the course
- If the program increased their familiarity of Title 24 regulations for a given end use
- If as a result of the program they feel better prepared to meet / enforce Title 24
- If as a result of the program they are more aware of utility sponsored EE programs

The evaluators estimated energy savings from the self-reported behavior changes of the builders, but not the code officials.

Performance Metrics

The evaluation of this program presented the following performance metrics averaged over the two participant types, code officials and builders:

- Percentage of participants hearing new information (yes/no)
- Usefulness of program information (7-point scale)
- Prior Title 24 knowledge and Title 24 knowledge increase (7-point scale)
- Overall amount of knowledge increase (7-point scale)
- Increased familiarity with specific Title 24 requirements (% that strongly agree, 6-7, on 7-point scale)
- Impact on ability to meet/enforce Title 24 (% that strongly agree, 6-7, on 7-point scale)
- Program impact on resource program awareness (7-point scale)

Key Findings

The evaluation found that this program is "particularly valuable because Title 24 code is continuously evolving and the building community needs to be informed and trained on code updates." Below are some key findings from the evaluation report:

- The program conducted a total of 167 trainings in the 06-08 program cycle, exceeding its goal, and trained a total of 1,978 builders and code officials.
- On average, a participating builder might construct up to 275 homes per year and a code official might inspect up to 300 homes per year.
- The course information may be more valuable to code officials than to builders

- Among builders, 70% applied the course concepts to their jobs and 55% recommended energy saving actions learned in the training.
- Among code officials, 87% applied the course concepts to their jobs and 73% identified energy code infractions that they learned in the training.
- Less than half of the participants strongly agreed that they were more aware of utility programs after attending the training.
- Overall, 58% of the builders reported making at least one change to a specific area in a home and 70% of the code officials say they now enforce certain code requirements for at least one specific area of the home
- Lighting, insulation, duct work, and HVAC are the places in the home that are most impacted by this program

PGE 2057: Build It Green Technical Support

According to the evaluation, the Green Building Technical Support Services -Build It Green program provides two key services:

- Supports the supply and demand sides of the market by providing both building professionals and consumers with the tools and technical expertise they need to build green homes
- Supports the regulation of green construction by providing local government officials information and forums to discuss and design green residential construction policy

Data Collection Methods

Evaluators collected observations, internet surveys and in depth interviews of Green Home Tour participants, policy makers, and professional consultants. On a 7-point scale, survey respondents were asked to rate their knowledge of energy efficiency before and after visiting the Green Home. The study conducted approximately 325 surveys.

Performance Metrics

The evaluation of this program presented the following survey results:

- Energy efficiency knowledge increase by level of prior knowledge (average of 7-point scale ratings over sample)
- Overall knowledge increase (7-point scale)
- Knowledge and awareness gains (7-point scale)
- Types of people with whom residents share information (check boxes)
- Percent that took action since attending a tour (yes/no)
- Measures installed by residents since attending a tour (yes/no, by measure type)
- Percent of Green Home Tours participants channeled into utility programs (yes/no)

Key Findings

The evaluation found that this program conducts many activities to connect consumers and building professionals with the tools and technical expertise they need to build quality green residential buildings. Below are some key findings from the evaluation report:

- The vast majority (93%) of residents describe themselves as already having at least "some" energy efficiency knowledge prior to attending the tour.
- Knowledge from the tour was useful and their levels of energy efficiency knowledge increased
- 95% of residents reported taking an energy-related action since attending a Green Home Tour
- 70% of council members recommended new building design principles they learned about at the meetings
- 41% of council members recommended energy modeling for equipment that uses significant of energy

SCE 2548: Southern California Home Performance

According to this study, the Southern California Home Performance program delivers classroom and field training to enable contractors to diagnose the energy efficiency of homes, recommend improvements, and, where possible, provide energy efficiency improvements.

Data Collection Methods

For this program, evaluators collected post training participant surveys, observed one field training, and conducted in-depth interviews as well as telephone surveys. From a list of 154 participants provided by the program, all were contacted and 52 were surveyed. Survey respondents were asked to rate their "awareness and knowledge of home performance techniques and [also] elicited information about behavioral changes stemming from the program, including recommendations to homeowners and follow-through."

Performance Metrics

The final evaluation of this program presented the following performance metrics by participant type:

- Energy efficiency knowledge increase (average of 7-point scale ratings over sample)
- Overall knowledge increase (7-point scale)
- Increased knowledge and awareness gains (7-point scale)
- Changes in certain behaviors (yes/no)
- Increased awareness of utility programs (7-point scale)

Key Findings

The evaluators found that this program teaches contractors to expand the services they provide and encourage homeowners to improve the energy efficiency of their entire home. Below are some key findings of the evaluation:

- All participants believed they learned a lot about energy efficiency as a result of this program.
- 92% of participants reported applying training concepts to the services provided to clients
- 81% believe that the changes they made resulted in significant or moderate energy savings in customers' homes

SCG 3531: PACE ENERGY EFFICIENT ETHNIC OUTREACH PROGRAM

According to this study, the PACE Energy Efficiency Ethnic Outreach program encourages customers to save energy through behavior changes, participate in utility programs such as Home Energy Efficiency Surveys and rebate programs, install free measures provided by the program, and, when applicable, attend an in-language food service seminar.

Data Collection Methods

Evaluators observed booths at community events, conducted intercept surveys at those events, and fielded a telephone survey to participants in PACE booths and recipients of direct business outreach and/or seminars.

The evaluation collected 55 intercept surveys and 88 phone surveys with participants at one of 123 community events in 2007 and 2008. Phone surveys were conducted in May 2009.

Performance Metrics

The final evaluation of this program presented the following:

- Residential and nonresidential participant information sharing by group (yes/no for different classifications of friends, relatives and acquaintances)
- Residential and nonresidential energy efficiency knowledge increase (average of 7-point scale over sample)
- Overall residential and nonresidential knowledge increase (7-point scale)
- Residential and nonresidential knowledge and awareness gains (7-point scale)
- Residential and nonresidential energy efficiency measures s installed since PACE event (yes/no, by measure type)
- Residential and nonresidential awareness of, and participation in, utility programs (yes/no)

Key Findings

According to the report, the evaluators found that the value of this program lies in its role in the marketplace: reaching out to non-English-speaking populations that otherwise would not have received as much energy efficiency information as the general population and in its ability to channel the individuals touched by the program into other utility programs. Below are some of the key findings of the evaluation directly taken from the report:

- PACE has been able to directly reach approximately 18,062 customers
- 21% of residential and 30% of nonresidential participants claim to have participated in a utility program since participating in PACE

- PACE participants believed they learned a lot about saving energy as a result of this program
- 85% of residential participants and 95% of nonresidential participants reported changing their behavior with respect to using energy
- 85% of residential and 61% of nonresidential participants reported installing CFLs or energy efficient lighting
- Approximately four in ten residential (37%) and nonresidential (41%) participants said they searched for additional information on energy efficiency equipment after participating with PACE

Translation to Energy Savings

This study7 also estimated net energy savings from actions taken by program participants. The authors that there are caveats to these estimates, but that they believe it is possible to determine the magnitude of annual energy savings from many education and information programs. In some programs, they extrapolated savings back to the population from which they sampled (e.g., participant population). In others, they based savings only on the participants that could be contacted.

They found a range of savings from 53 to 16,950 MWh per program. Compared to resource-based (e.g., rebate or incentive) programs, these savings are relatively small. However, the authors also note that the costs for these educational programs are also relatively small. Programs targeting mid-stream actors, including the Building Energy Code Training (BECT) program, achieved high savings, because of their potential multiplier effect. The authors note that, "We also found this type of multiplier effect in our evaluation of the Energy Centers". Their Energy Center assessment was based on a case study of ten market actors, which showed energy savings from 15 to 150 buildings per market actor.

Overall Findings

In general, the study found that education and information programs were effective at educating participants and increasing their energy efficiency knowledge, and motivating them to take an energy saving action. These actions could include installing CFLs (consumers), enforcing certain code requirements more (inspectors), or applying green building principles in home design (builders).

This study was also the one reference identified in our limited literature review that estimated energy savings from the behavior taken.

The Utah House: An effective education tool and catalyst for behavior change?

This 2009 peer-reviewed publication8 by Michael E. Dietz, Jayne Mulford and Kerry Case looked into the effectiveness of the Utah House in Kaysville, UT. The Utah House is a demonstration facility built and operated by Utah State University

[7] There are three volumes in this report. These citations are from Volume I.

[8] Publication is available at: http://theutahhouse.org/files/uploads/Dietz_etal.pdf

Cooperative Extension that is designed to showcase alternative building techniques. The focus is on sustainable use of resources, energy and water conservation, healthy indoor air, and universal design. The house is open to the public. This publication set out to determine if the house influenced customers' level of knowledge, or more importantly, their behavior.

Data Collection Methods

The authors received three-page surveys from 254 out of 1636 people who left their contact information at the Utah House. According to the publication, the survey asked how people felt about the key topics, if their visit to the Utah House changed their level of knowledge about each topic, and what they have actually done in response to their visit. The survey also asked for demographic information, how often the respondent visits the Utah House, and which activities the respondent participated in while at the Utah House. Each question was to be answered on a 5-point scale.

Results

By averaging scores over different subsets of the sample population, and then comparing the mean before and after scores using a t-test, the authors were able to draw the following conclusions regarding the effectiveness of the Utah House:

- There is a statistically significant increase in knowledge over the entire sample population for all five topic areas which are as follows: "sustainability", "energy efficiency", "water conservation", "healthy indoor air", and "universal design"
- In general, respondents felt that the Utah House staff did a good to a very good job of teaching the topic areas
- A substantial number of people reported implementing at least one of the actions as a result of a visit to the Utah House. The most common actions included installing one of the following: a CFL, water-efficient toilet or faucet, additional insulation, efficient irrigation system, or low-water landscaping plants. (Based on the survey questions, these actions could be taken by a homeowner or (in some cases) tenant. A contractor could also take these actions on behalf of the homeowner, but this survey was not geared for contractors.)

Thus, this study found that there was a statistically significant knowledge gain from the demonstration, including for energy efficiency. In addition, based on follow-up surveys, a substantial number of visitors (63%) implemented at least one action based on their visit to the demonstration; these actions were most commonly installing a CFL, water efficient toilet or faucet. The authors did not try to translate these actions into energy savings.

The authors also note that 83% of visitors reported that they had already conducted at least one pro-environmental behavior before visiting the demonstration, which indicates that the demonstration may be attracting an audience that is already inclined to make such changes. Thus, the demonstration may not need to adjust visitors' attitudes about the topics presented, but could be useful in providing further education to visitors.

LIGHTING DESIGN LAB: MARKET PROGRESS EVALUATION REPORT, NO. 4

This 2003 report, conducted by Energy Market Innovations Inc. and the Heschong Mahone Group, evaluates two market transformation initiatives, the Lighting Design Lab and the BetterBricks Daylighting Lab. According to the report, the Lighting Design Lab provides educational programs, technology displays, consultations, and facility-based evaluation tools to lighting professionals who make or influence decisions regarding commercial and industrial buildings. The BetterBricks Daylighting Lab provides a similar array of consultations and education, as well as daylighting simulation modeling services. The consultation services involved providing daylighting simulation and daylighting analysis for a given project.

DATA COLLECTION METHODS

According to the report, telephone surveys were completed with participants in 90 Daylighting Lab consultations. Among the stated objectives for these surveys, one was to explore participant attitudes and awareness toward daylighting. Interviews were conducted with 52 of the 90 Daylighting Lab consultation participants.

PROCESS EVALUATION METRICS

This report evaluated the BetterBricks Daylighting Lab using the following metrics:

- Significance of daylighting component within a project (5-point scale)
- Satisfaction ranking of daylighting lab services (5-point scale)
- Daylighting consultation influence ranking (5-point scale)
- Participant likelihood to use photocontrols in future building designs (7-point scale)

The study found that, in general, participants were satisfied with the services provided by both facilities (the LDL and the Daylighting Lab). Fifty-five percent of participants reported that the Daylighting Lab consultation was fairly or extremely influential for their projects. However, for 10 of 12 projects in which team members had received a consultation through the LBL, the recommendations had not yet been implemented. The evaluators also noted that there was no follow-up with the participants, and recommended that this be included.

CONCLUSIONS

Various studies have researched the impacts of educational, informational and demonstrative programs. These studies generally include findings on participant satisfaction, the relevance of the information presented to their broader curriculum (in the case of a demonstration) and/or their professional work, and if the participant plans to (or has) made changes in their behavior based on the program. One of the studies that we reviewed, the Opinion Dynamics Corporation Indirect Impact Evaluation of the Statewide Education and Information Programs, published 2010 (the "Indirect Impact Evaluation") estimated energy or demand savings from these programs. One finding from this study was that education or information programs targeting mid-stream market actors (e.g., contractors) resulted in more savings, because of the multiplier effect.

Thus, of the studies reviewed, most follow the Basic protocol for an indirect impact evaluation presented in the California Energy Efficiency Evaluation Protocol. The

Indirect Impact Evaluation followed the Standard protocol in the California Energy Efficiency Evaluation Protocol, by estimating the energy or demand savings based on participant self-reported information (Standard). None of the studies used the Enhanced protocol, of verifying energy savings through field testing or observation.

In addition, HMG did not find a detailed framework for attributing program savings to informational or educational programs. The California Energy Efficiency Evaluation Protocols provide a useful starting point: it recommends linking behavioral changes to energy or demand savings by using the deemed or calculated savings assumptions that are used in rebate or incentive type programs. However, it may not be appropriate to apply all of the same rebate or incentive program assumptions for actions taken because of the educational program. For example, free ridership values for these energy efficiency actions may not be the same. Also, if the educational program is encouraging participants to participate in a resource-based program, there must be a method to split savings between the educational program and resource-based program.

The evaluations identified in this literature review could be useful in establishing a framework for evaluating demonstration sites in the future. Below are some common themes from this literature review.

- Collect background information (e.g., profession) about customers
- Identify goals of the resource (demonstration, class, etc.) and ask customer survey questions specific to those goals
- Use scales (e.g., 3, 5, or 7-point) to quantify metrics, such as understanding, attitudes, or intentions
- Ask about intention for actions or behavior at the time the resource is delivered (e.g., when the customer visits the demonstration or takes the class).
- If possible, ask later if these intended actions were followed
- If possible, use statistical methods to understand differences in behavior due to the educational program, including differences in awareness, knowledge, attitudes, or actions that are planned or that have been taken.

We provide more detail on these themes below.

Collect Customer Data

In this literature review, we have gathered examples of how and what data to collect from participants / customers. In addition to collecting data on how a participant interacted and learned from an educational tool, each evaluation studied in this literature review included data collection on the participants and/or customers demographics. Detailed demographic information allows the evaluator to draw meaningful conclusions about subsets of their sample population. Also, this level of demographic detail has allowed some evaluations to project energy savings numbers based on rough estimations of where a respondent fits into the market, and how much influence that market actor could potentially have in a given year.

Identify Goals and Performance Metrics

For an evaluation that does not directly look at energy savings, it is imperative to clearly define the goals of the evaluation and the metrics on which the evaluated program will be judged upon. By establishing "performance metrics" that quantify

the typically abstract program goals of educational programs, it becomes possible to quantitatively compare programs and their effectiveness. To gather information on these metrics, participants are often asked to rank their initial, or their increase, in knowledge, attitudes, intentions, or other parameters on a numerical scale.

UNDERSTAND PARTICIPANTS' INTENTIONS OR BEHAVIOR

To understand how a non-resource program such as a demonstration or class could translate into energy savings, evaluations ask participants about their plans for changes in their behavior. This could include purchasing or installing a particular measure or using a strategy encouraged through the demonstration or class. If time allows, an evaluation will follow-up with participants to gather data on these types of actions.

TRANSLATE BEHAVIOR INTO ENERGY SAVINGS

The Indirect Impact Evaluation estimated net energy savings from actions taken by program participants. The authors that there are caveats to these estimates, but that they believe it is possible to determine the magnitude of annual energy savings from many education and information programs. In some programs, they extrapolated savings back to the population from which they sampled (e.g., participant population). In others, they based savings only on the participants that could be contacted.

They found a range of savings from 53 to 16,950 MWh per program. Compared to resource-based (e.g., rebate or incentive) programs, these savings are relatively small. However, the authors also note that the costs for these educational programs are also relatively small. Programs targeting mid-stream actors, including the Building Energy Code Training (BECT) program, achieved high savings, because of their potential multiplier effect. The authors note that, "We also found this type of multiplier effect in our evaluation of the Energy Centers". Their Energy Center assessment was based on a case study of ten market actors, which showed energy savings from 15 to 150 buildings per market actor.

APPENDIX 2: PROJECT TEAM INTERVIEWS

As part of the data collection, HMG interviewed the following project team members:

- PG&E project manager – oversees demonstration project and team
- Content designers (3 ZNE and energy efficiency experts) – created the content for the demonstration
- Exhibit designer – created the lay-out and flow of the demonstration, based on the content provided by the content designers
- ETC supervisor – provided input on the use of the demonstration and its integration into ETC curriculum, and manage the demonstration once installed

PG&E PROJECT MANAGER INTERVIEW

Agatha Vaaler, a PG&E Emerging Technologies (ET) project manager, is overseeing the design, installation and operation of the ZNE demonstrations. Her overall role at PG&E is to manage projects that receive Emerging Technologies funding, evaluate the commercial potential for new and under-utilized technology, and ultimately to fit help fit ET measures into incentive programs. HMG conducted a phone interview with Ms. Vaaler, on October 8, 2012, for both the ZNE home and ZNE classroom demonstrations. The following provides a summary of findings from that interview.

VISION FOR THE ZNE DEMONSTRATIONS

The project manager's vision for the ZNE demonstration is to leverage an existing, well utilized educational facility with a strong user base to educate market actors on the concepts and practical applications of ZNE construction. However, this project was constrained in that the demonstrations needed to be delivered by the end of 2012. Based on the limited time and budget, PG&E focused on conveying the message of defining ZNE and introducing people to the ZNE mindset. The project manager believes that both demonstrations have features that show the "guts" of ZNE construction. The intended audience are those involved in residential construction, including contractors, raters or auditors, and tradesman. The expectation is that those visiting the ETC make an ideal audience, because they have already shown some commitment and appreciation for new ideas in energy efficiency. Ms. Vaaler also hopes that ETC instructors incorporate the ZNE demonstrations into their courses.

PG&E sees the demonstrations as one strategy for the utility to support and push the market towards a ZNE approach. Ms. Vaaler indicated that, because these are some of the first ZNE demonstrations, the ETC ZNE demonstrations will lay the foundations for a more aggressive outreach effort to engage the marketplace, builders and other practitioners in understanding and practicing ZNE strategies.

GOALS AND MEASURES OF SUCCESS

The project manager has identified both demonstrations' overall goal as enabling customers to learn new techniques or gain an appreciation for a ZNE concept that they had not previously considered. As a whole, the goal is to present customers of all professions a holistic approach to construction that will make them consider ZNE

within the context of their profession. For example, a home energy rater educated on ZNE can communicate to customers the relevance of ZNE in residential construction in California, as well as the rater's role in the ZNE process, thus making the rater more marketable. Ms. Vaaler sees potential success metrics for the demonstrations including the number of customers, number of enrollments in ZNE classes, use of PG&E resources (including rebates, incentives, or educational tools), increased networking, as well as comments and feedback that indicate an increased demand for ZNE information.

CONTENT DESIGNERS' INTERVIEW

The content designers' role is to develop the demonstration content and text. HMG conducted a phone interview with this team on October 2, 2012. The following provides a summary of findings from that interview.

CONTENT DESIGNERS BACKGROUND

The interviewed content designers consist of Steve Easley, Ann Edminster, and Rick Chitwood. These three team members are all experts in residential building energy efficiency and zero net energy practices.

APPROACH AND METHODOLOGY

The content designers' overall approach and methodology for designing the demonstration was constrained mainly by time, budget and the available facilities at the Energy Training Center. The demonstration has been designed for any customer to the Energy Training Center with all levels of prior knowledge of ZNE construction. However, they expect most customers to have little existing knowledge on ZNE, or for some of this existing knowledge to be somewhat inaccurate. The expectation is that a customer to the demonstration will spend on average 15-20 minutes at the demonstration, perhaps before attending a class, during a class break, or during the lunch hour. As a result of this time constraint, the demonstration has been designed with a "random access" model. That is, while there is a numbering and natural flow to the panels, the content designers has built in a redundancy of high level information. The content designers finds this beneficial, because under limited time constraints, an HVAC technician that may jump straight to the HVAC panel will still obtain the high-level, key concepts the overall demonstration is meant to convey.

GOALS AND MEASURES OF SUCCESS

The content designers has identified the overall purpose of the demonstration is not to provide a step by step "how-to" guide, but rather to introduce market actors to the concept of ZNE homes, dispel any misconceptions they might have about ZNE construction and have them walk away with an idea of what ZNE can mean and why it is beneficial. The demonstration should provide a basic framework of ZNE knowledge that will allow policy makers, different tradespeople, and laborers alike to have an equal understanding and mindset in gearing up for ZNE residential construction. The content designers have identified overall traffic to the ZNE demonstration house, interest in ZNE, and overall knowledge of ZNE as a few performance measures.

Expected Outcomes and Actions

If the overall goals of the demonstration are met, the content designers expects there to be a greater demand for ZNE classes, greater penetration of ZNE subject material in the existing curriculum, and more class use of the ZNE demonstration home. In addition, the content designers is gearing up for a Phase II in which the demonstration will become more interactive, and the message will have a further reach than just those who visit the demonstration at the Energy Center. The idea is to reach all market actors, including end-use consumers, about ZNE construction. For example, later outreach could include PG&E kiosks at shopping centers, PG&E service centers, subdivision model homes, an interactive "virtual tour" website, or flyers attached to building permits.

Project Exhibit Designer Interview

Delphi, the exhibit designer, is responsible for designing the flow and lay-out of the demonstration, using the content developed by the ZNE home content designers. HMG conducted a phone interview with Delphi's account executive, Jacques Geoffrion, on October 4, 2012. The following provides a summary of findings from that interview.

Background

Delphi designs and fabricates demonstrations and demonstration models. Their projects are mainly for trade shows, retail, museums, and corporate events. Mr. Geoffrion is an account executive at Delphi. He sees projects through the entire process – he manages projects when they are acquired, facilitates the demonstration design, and ensures team members understand what the customer is trying to accomplish with the demonstration.

Approach and Methodology

Delphi is designing the demonstration to generate interest in ZNE, deliver broad messages regarding ZNE, and to show how various strategies (such as those that customers may learn about through ETC classes) could be part of a ZNE strategy. Mr. Geoffrion identifies the top tier messages for the demonstration as 1. ZNE is coming and here to stay, 2. ZNE is doable, and 3. The seven stations in the demonstration provide practical strategies to get to ZNE.

The demonstration is designed to capture a customer's attention immediately with a 2 minute video at the entrance. This should draw customers into the seven individual kiosks deeper in the demonstration. The kiosks are numbered to suggest an order, but the content of each is self-contained. Delphi has designed Phase 1 of this project to be a passive experience that is kiosk based. As a part of Phase 2, Delphi is looking to include more interactive exhibits. In the design process, Delphi has assumed an average of 30 minutes will be spent at the demonstration.

Goals and Measures of Success

Delphi has identified that the overall purpose of the demonstration is to relay to customers that ZNE residential construction is about to become a requirement and, so the customer should "start paying attention to it". PG&E is providing this

demonstration as a means to push ZNE to the forefront and introduce customers to ZNE strategies. Delphi would measure success by understanding if customers seek more information about ZNE, if they implement any of the knowledge they have gained at the demonstration, or if they spread their interest in ZNE construction to their colleagues and customers.

PG&E ETC Supervisor Interview

The Stockton Energy Training Center (ETC) staff's role in both ZNE demonstration projects include providing input on the best use of the demonstrations, integrating them into ETC curriculum, assisting with marketing the demonstrations, and managing the demonstrations once they are installed. HMG conducted an in-person interview with the ETC supervisor, Gary Girardi, on October 3, 2012, for both the ZNE home and ZNE classroom demonstrations. The following provides a summary of findings from that interview.

Vision for the Demonstrations

Mr. Girardi sees the demonstrations as a way to reach out to market actors, including energy auditors, contractors, trades people, and policy makers, and give them a basic knowledge of how systems come together in ZNE construction. He also sees the classroom demonstration as an opportunity to attract a new clientele to the ETC – namely, stakeholders that are associated with schools. Mr. Girardi expects that most customers will have little ZNE knowledge prior to visiting the demonstrations. Although the ETC provides a ZNE class series, it represents roughly 5% of the portfolio, and it has generally appealed to customers with a home performance interest. The overall message he would like to deliver is that ZNE construction will not just happen if we continue with "business as usual", and to provide better knowledge on the interrelationship of systems and project team members. The ETC classes are complementary to the demonstrations. Thus, ETC instructors will be encouraged to review the ZNE demonstrations, promote them in their classes, and, where possible, incorporate the demonstrations in their class. Mr. Girardi approximates that roughly 50 classes a year could make use of the demonstrations.

Background

Mr. Girardi's primary role is to provide oversight for the operations of the ETC. The ETC serves about 12,000 customers per year, and he estimate that this includes roughly 7,000 different students. (Some students attend more than one class.) The current ETC customers includes builders; tradespeople, including HVAC, electrician, and solar contractors; and home performance professionals, including contractors and auditors. While some trades serve both the residential and nonresidential sectors, they generally serve primarily one or the other.

Goals and Measures of Success

Mr. Girardi believes the goals of the demonstration should be not only to educate people on the concepts of ZNE, but also to incorporate them into their business practices. One way he sees this as occurring is through promoting PG&E programs

that incent technologies showcased at the demonstrations. Mr. Girardi also sees a large opportunity in bringing in the schools market sector.

APPENDIX 3: CUSTOMER SURVEYS

Please note that format of these surveys has changed slightly to fit onto the page. Original copies can be made available upon request.

PRETEST SURVEY

Stockton ETC Customer Baseline ZNE Survey

Thank you for completing this survey to gather baseline data for two Zero Net Energy (ZNE) demonstrations.

1. **Which of the following best describes your job title / position? Circle all that apply:**
   General contractor HVAC contractor Electrician Insulation contractor Energy auditor
   Solar installer Home Performance Contractor Other (specify): _____

2. **What is your primary reason for coming to the ETC today?**

   To attend a class Other (specify): _____

3. **On a scale of 1-5, what is your current knowledge of Zero Net Energy (ZNE) buildings? Circle one.**

   1: None
   2: A little – Have heard of ZNE, but unfamiliar with general concept
   3: Basic understanding – Understand general principles, but not details for achieving it
   4: Detailed understanding – Understand detailed ZNE strategies, but have not worked on a ZNE project
   5: Expert – Have worked on a ZNE project

4. **Please number the following strategies in the order that would most effectively achieve a ZNE new construction building. Label '1' for the first strategy taken and '4' for the final strategy.**

   ___Establishing a team with a ZNE mindset and meeting early and often
   ___Installing renewable energy (e.g., photovoltaic, solar hot water)
   ___Reducing energy loads (e.g., creating highly efficient envelope to reduce heating / cooling needs)
   ___Installing efficient equipment

5. **On a scale of 1-5, please rank your interest in the following:**

	No interest				*Very Interested*
Learning about ZNE in general	1	2	3	4	5
Visiting a ZNE demonstration home	1	2	3	4	5
Visiting a ZNE demonstration classroom	1	2	3	4	5
Building a network with others interested in ZNE	1	2	3	4	5

6. **If you answered > 1 to any of the above, please rank why you are interested in ZNE:**

	No interest				*Very Interested*
To incorporate ZNE into my business model or practices	1	2	3	4	5
To better understand ZNE practices in general	1	2	3	4	5
To better understand a particular measure or strategy Please specify: _____	1	2	3	4	5
To meet the needs of a current project	1	2	3	4	5

7. **The California Energy Efficiency Strategic Plan calls for all new residential construction to be ZNE by**

2020. Were you aware of this? (Circle one) Yes No

8. On a scale of 1-5, how feasible do you think it is to achieve ZNE in residential new construction?

Not Feasible				*Very Feasible*
1	2	3	4	5

9. What other training would you like ETC or PG&E to provide regarding ZNE or energy efficiency?

_____

Thank you for taking the time to provide us with your feedback!

BASELINE SURVEY

Stockton ETC Customer Baseline ZNE Survey

Thank you for completing this survey to gather baseline data for two Zero Net Energy (ZNE) demonstrations.

1. Which of the following best describes your job title / position? Circle all that apply:

General contractor HVAC contractor Electrician Insulation contractor Energy auditor
Home performance contractor Solar installer MEP designer Other (specify): _____

2. What is your primary reason for coming to the ETC today?

To attend a class (specify name):_____ Other (specify): _____

3. On a scale of 1-5, what is your current knowledge of Zero Net Energy (ZNE) buildings? Circle one.

1: None
2: A little – Have heard of ZNE, but unfamiliar with general concept
3: Basic understanding – Understand general principles, but not details for achieving it
4: Detailed understanding – Understand detailed ZNE strategies, but have not worked on a ZNE project
5: Expert – Have worked on a ZNE project

4. On a scale of 1-5, please rank your interest in the following:

	No interest				*Very Interested*
Learning about ZNE in general	1	2	3	4	5
Visiting a ZNE demonstration home	1	2	3	4	5
Visiting a ZNE demonstration classroom	1	2	3	4	5
Building a network with others interested in ZNE	1	2	3	4	5

5. Please rank why you are interested in ZNE:

	No interest				*Very Interested*
To incorporate ZNE into my business model or practices	1	2	3	4	5
To better understand ZNE practices in general	1	2	3	4	5
To better understand a particular measure or strategy	1	2	3	4	5
Please specify: _____					
To meet the needs of a current project	1	2	3	4	5

6. The California Energy Efficiency Strategic Plan calls for all new residential construction to be ZNE by 2020. Were you aware of this? (Circle one) Yes No

7. On a scale of 1-5, how feasible do you think it is to achieve ZNE in residential new construction?

Not Feasible				*Very Feasible*
1	2	3	4	5

8. Please order the following strategies to most effectively design a ZNE new construction building (1st = strategy best started first, 4th = strategy best started last).

Establishing a team with a ZNE mindset and meeting early and often	1st	2nd	3rd	4th
Sizing renewable energy (e.g., photovoltaic, solar hot water)	1st	2nd	3rd	4th
Reducing energy loads (e.g., envelope lowers conditioning/lighting needs)	1st	2nd	3rd	4th
Specifying efficient equipment	1st	2nd	3rd	4th

9. What other training would you like ETC or PG&E to provide regarding ZNE or energy efficiency?

Recommendation:_____

Thank you for taking the time to provide us with your feedback!

ASSESSMENT SURVEY

Stockton ETC Customer Assessment ZNE Survey

Thank you for completing this survey to assess the effectiveness of the Zero Net Energy (ZNE) demonstration. At the end, please write your email address to be included in a raffle for a $200 Home Depot gift card and ZNE book.

1. Which of the following best describes your job title / position? Circle all that apply:

General contractor HVAC contractor Electrician Insulation contractor Energy auditor
Home performance contractor Solar installer MEP designer Other (specify): _____

2. What is your primary reason for coming to the ETC today? Circle one.

To see this demonstration To attend a class (specify name):_____

3. On a scale of 1-5, how would you describe your knowledge of ZNE, *before* visiting the demonstration?

1. None
2. A little – Had heard of ZNE, but unfamiliar with general concept
3. Basic understanding –Understood general ZNE principles, but not details of how to achieve it
4. Detailed understanding – Understand detailed ZNE strategies, but have not worked on a ZNE project
5. Expert – Have worked on a ZNE project

4. **How feasible did / do you think it is to achieve ZNE in residential new construction**

	Not Feasible				Very Feasible
a. *Before* visiting the demonstration?	1	2	3	4	5
b. *After* visiting the demonstration?	1	2	3	4	5

5. Please order the following strategies to most effectively design a ZNE new construction building (1st = strategy best started first, 4th = strategy best started last).

Establishing a team with a ZNE mindset and meeting early and often	1st	2nd	3rd	4th
Sizing renewable energy (e.g., photovoltaic, solar hot water)	1st	2nd	3rd	4th
Reducing energy loads (e.g., envelope lowers conditioning/lighting needs)	1st	2nd	3rd	4th
Specifying efficient equipment	1st	2nd	3rd	4th

6. On a scale of 1-5, how has the following *changed* since you visited the demonstration?

	Much Less		*Same*		*Much More*
a. Your interest in ZNE	1	2	3	4	5
b. Your likelihood of researching ZNE or taking a ZNE class	1	2	3	4	5
c. Your understanding of ZNE benefits	1	2	3	4	5
d. Your understanding of the general ZNE approach	1	2	3	4	5
e. Your understanding of how your ETC class (if applicable) fits into a general ZNE approach	1	2	3	4	5
f. Your likelihood of purchasing an energy efficient product or using an energy efficient strategy	1	2	3	4	5
g. Your likelihood of using a PG&E rebate/ incentive for an					

energy efficient product or strategy	1	2	3	4	5
h. Your likelihood of developing a professional network with others interested in ZNE	1	2	3	4	5

7. Which station(s) did you find useful?

Station	Not Useful				Very Useful	
Video	1	2	3	4	5	Did Not Visit
Overview, Defining ZNE	1	2	3	4	5	Did Not Visit
Mindset & Design Principles	1	2	3	4	5	Did Not Visit
Load Distribution & Plug Loads	1	2	3	4	5	Did Not Visit
Teamwork & Goal-setting	1	2	3	4	5	Did Not Visit
Design Fundamentals (size, orientation)	1	2	3	4	5	Did Not Visit
Building Enclosure (sealing, insulation)	1	2	3	4	5	Did Not Visit
Systems (HVAC and photovoltaics)	1	2	3	4	5	Did Not Visit
Construction Quality (performance, tests)	1	2	3	4	5	Did Not Visit
Occupancy Considerations	1	2	3	4	5	Did Not Visit

8. The California Energy Efficiency Strategic Plan calls for all new residential construction to be ZNE by 2020.

a. Were you aware of this? (Circle one) Yes No

b. Did you learn this because of the demonstration? Yes No

9. What did you learn that you found most useful from the demonstration?

_____

10. On a scale of 1-5, what is your overall satisfaction with the demonstration?

Very Unsatisfied				*Very Satisfied*
1	2	3	4	5

If unsatisfied (1 or 2), please explain:

_____

11. What other information did you wish the demonstration had provided?

_____

12. What other training or information would you like ETC or PG&E to provide regarding ZNE or energy efficiency?

_____

Raffle Entry

Thank you for your feedback! To be entered in the raffle for a $200 Home Depot gift card and the book, "Energy Free: Homes for a Small Planet", please provide your email below.

Email:_____

Would you like to be added to the ETC email list? Y N Already on it

APPENDIX 4: RAW SURVEY RESULTS

PRETEST RESULTS

Date	Page	1a	1b	1c	1d	1e	1f	1g	1h	2a	2b	3	4a	4b	4c	4d	5a	5b	5c	5d	6a	6b	6c	6d	6e	7	8	9
10/17/2012	1		1			1		1		NATE	Further training	2	1	4	2	3	4	4	4	4	4	3	3		3	n	3	
10/17/2012	2									NATE		3	1	4	2	3	5	5	5	3						y	5	
10/17/2012	3	1	1							NATE	Get into program	3	1	1	4	4	3	3	3	3	3	3	3		3	n	3	
10/17/2012	4		1							NATE		3			1		5	5	5	5	5	5	5		5	n	5	
10/17/2012	5		1							NATE		2	1	4	2	3	5	5	4	3	3	4	4	Renewable energy	2	n	4	
10/17/2012	6		1							NATE		1			1		5	5	5	5						n	5	
10/17/2012	7		1							NATE		1					4	3	4	4	3	4	3		2	y	4	
10/17/2012	8		1							NATE		2	1	4	2	3	4	4	4	3	3	3	4	passive conditioning	4	y	2	
10/17/2012	9		1							NATE		3	1	4	3	2	3	3	4	4			5			y	3	commercial energy auditing
10/17/2012	10		1							NATE		1	4	3	2	1	3	4	4	3	3	4	4		3	n	4	
10/17/2012	11						1			NATE		5	7	3	2	4	4	4	4	4	3		1		1	y	4	
10/17/2012	12		1							NATE		1					3	4	4	1	4	4	3		1	y	4	solar sizing and install
10/17/2012	13		1							NATE		3														1	2	
10/17/2012	14		1							NATE		2					1	5	4	5	4	5	4		5	n	4	PLC control
10/17/2012	15		1							NATE		1	1	3	2	4	3	3	3	2	3	3	3	solar	1	n	2	general awareness
10/17/2012	16		1				1			NATE		3	4	1	2	3	3	3	3	2	3	3	3		1	n	4	
10/17/2012	17		1							NATE		3	4	3	2	1	3	4	4	2	3	3	1		1	n	3	
10/17/2012	19								warehouse/driver/helper	NATE							4	4	4	4	3	4	4		4	n	3	
10/17/2012	20		1							NATE		1	2	3	4	1	5		5	5	5	5				n	5	
10/17/2012	21		1							NATE		4	4	3	1	2	4	4	3	4	4	4	4		4	y	4	
10/17/2012	22	1	1							NATE		2	1	4	2	3	5	5	5	3	5	5	5		1	y	5	
10/17/2012	23		1							NATE		1					5	5	5	3	5	5	5	relate to hvac	1	n	3	
10/17/2012	24	1	1	1				1		NATE	to learn	1	1	4	3	2	4	4	4	4	5	4	4		2	n	5	informative, hands on training
10/17/2012	25								hvac service tech	NATE							5	5	5	5	5	5	5		1	n		
10/17/2012	26								service tech	NATE	education	1	1	4	2	3	5	5	5	5	5	5	5		5	n	5	everything
10/17/2012	27	1								NATE		4	1	4	2	3	4	4	4	4	4					y	3	
10/17/2012	28								hvac contractor apprentice	NATE	knowledge	1	1	4	2	3	3	3	3	3	3	3	3		3	n	2	
10/19/2012	1								consultant	T24 Res Quality		4	1	4	2	3	5	5	5	4						y	3	
10/19/2012	2								finance, real estate	T24 Res Quality		2	1	4	2	3	3	3	5	4	4	2	1		5	y	4	connecting contractors to RE community
10/19/2012	3								mortgage lender	T24 Res Quality		3					4	3	3							y	3	
10/19/2012	4				1					T24 Res Quality		1	4	3	1	2	5	5	5	5	3	3	3	home work as system	3	n	3	bpi certification
10/19/2012	5								thermography instructor	T24 Res Quality	home performance efficiency	1					5	1	1	1	1	5	1		1	n	3	
10/19/2012	6	1								T24 Res Quality	knowledge	1	1	4	2	3	5	4	5	4	4	4	5	efficient envelope	3	n	5	
10/19/2012	7								historic house restoration	T24 Res Quality	learn something new	3	1	4	2	3	5	5	5	4	4	5			1	y	5	
10/19/2012	8								mech engineer	T24 Res Quality		2	1	4	2	3	5	4	4	2	3	4	2		2	y	3	
10/19/2012	9								window installer	T24 Res Quality		2			1		3	3	3	3		4			2	n	3	
10/19/2012	10		1							T24 Res Quality		2	1				5								y			
10/19/2012	11								property mgmt	T24 Res Quality	get up to speed	3	1	3	2	4	4	4	5	4	4	4	5	radiant control	5	n	2	
10/19/2012	12	1								T24 Res Quality	learn	3	1	4	4	1	4	4	4	4	4	4	4		4		4	anything
10/19/2012	13	1	1				1	1		T24 Res Quality	continuing education	4	1	4	2	3	5	5	5	5	5	5	5		5	y	4	

BASELINE RESULTS

Date	Page	1a	1b	1c	1d	1e	1f	1g	1h	1i	2a	2b	3	4a	4b	4c	4d	5a	5b	5c	5d	5e	6	7	8a	8b	8c	8d	9
10/23/2012	1									WS/NGAT Tech	Duct Testing		2	5	5	5	5	5	5	5		5	n	5	1	1	1	1	
10/23/2012	2									weatherization specialist	Duct Testing		1	4	5	5	5	1	5	3		3	n	4	3	3	2	2	
10/23/2012	3									weatherization specialist	Duct Testing		2	4	5	5	4	3	4	4		2	n	5	4	3	3	4	
10/23/2012	4									weatherization specialist	Duct Testing		2	4	5	5	4	4	4	4		4	y	3	4	1	2	3	
10/23/2012	5									weatherization specialist	Duct Testing		1	4	5	5	4	3	3	1		3	n	4	1	4	3	2	
10/23/2012	6	1	1		1				1		Duct Testing		2	3	3	3	3	3	3	3		3	y	3	2	2	3	1	
10/23/2012	7	1									Duct Testing		1	3	3	3	3	3	3	3		3	y	4	3	3	3	3	
10/23/2012	8									subcontractor	Duct Testing		1	5	5	5	5	4	5	2		1	n	3	4	1	2	3	
10/23/2012	9				1						Duct Testing		3	3	3	3	3	3	2	3		2	n	3	3	2	2	3	
10/23/2012	10								1		Duct Testing		2	3	3	3	3	3	3	3		3	n	3	3	1	2	3	
10/23/2012	11								1		Duct Testing		2	4	3	4	3	2	4	3		1	n	4	3	1	2	4	
10/23/2012	12				1						Duct Testing		3	3	3	3	3	2	2	3		3	n	4	1	2	3	4	
10/23/2012	13									NGAT	Duct Testing		3	4	4	5	4	4	4	4		4	n	5	1	2	4	3	
10/23/2012	14	1									Duct Testing		3	4	4	4	4	3	4	4		3	n	4	2	3	2	2	basic understanding
10/23/2012	15									energy assistance program	Duct Testing		3	5	5	5	5	4	5	5		5	n	4	1	1	1	1	
10/23/2012	16						1				Duct Testing		5	5	5	5	5	5	5	5		5	y	5	1	1	1	1	
10/24/2012	1									consultant	Lghtng for Industrial+		4	4	4	4	4	4	4		enclosure design	2	y	3					more zne demos
10/24/2012	2					1					Lghtng for Industrial+		5	3	4	4	5	5	4	2		4	n	2	2	4	3	1	
10/24/2012	3							1			Lghtng for Industrial+		2	3	3	3		3	4	1		2	n	2	1	3	2	4	
10/24/2012	4					1				lighting sales	Lghtng for Industrial+		4	3	2	4	3	3	4	2		1	y	4	1	4	2	3	
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10/24/2012	7										eQuest		3	4	4	4	3	3	4				y	2	1	4	2	3	
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ASSESSMENT RESULTS

Date	Page	1a	1b	1c	1d	1e	1f	1g	1h	1i	2a	2b	3	4a	4b	5a	5b	5c	5d	6a	6b	6c	6d	6e	6f	6g	6h	7a	7b	7c	7d	7e	7f	7g	7h	7i	7j	8a	8b	9	10a	10b	11	12
10/31/2012	1									production mngr		Whole House	2	3	4	1	2	3	4	4	5	4	4	3	5	5	5	0	3	3	3	3	3	3	3	3	3	n	y	2020 plan	4	just read wall boards	no class, have pg&e set one up	
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10/31/2012	13					1						Whole House	2	1	4	1	4	2	3	5	4	5	3	5	5	5	4	0	5	4	3	5	3	5	5	5	5	n	y	lofty goal is realistic	4	did not see video		
10/31/2012	15	1					1			HERS rater		Whole House	3	4	5	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	y	n	home enclosure efficiency	5		none	bpi
10/31/2012	17	1					1					Whole House	2	3	5	1	4	2	3	4	4	4	4	3	4	4	3	0	4	3	3	4	4	3	3	4	3	y	y	proper insulation	4			
10/31/2012	19									interior design		Whole House	1	3	4	1	4	3	2	5	4	5	5	4	4	4	5	0	5	5	5	5	5	5	5	5	5	n	y		5			
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10/31/2012	23	1										Whole House	1	1	4	1	3	2	4	4	3	4	3	3	5	5	5	3	4	4	4	4	4	4	4	4	4	y	y	efficiency	4			
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11/1/2012	5									utility employee		Ind. Refrigeration	3	3	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	y	n	5				
11/2/2012	1					1						Advanced Package	4	5	5	1	4	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	y	n	basic info, nothing new	3	rather cont'd class, demo be "at will"		
11/2/2012	3									tile	1	Advanced Package	2	1	3	2	3		3	4	5	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	y	y	bpi	4			
11/2/2012	5					1						Advanced Package	3	4	5	1	4	2	3	5	5	5	5	5	5	5	5	4	4	5	5	5		4	4	4	5	y	n	getting all trades together	4		nothing	updates
11/2/2012	7									HERS rater		Advanced Package	3	4	4	1	2	3	4	4	4	4	4	5	5	5	4	4	4	4	4	4	4	4	4	4	4	y	y	information provided	4		none	none
11/2/2012	9		1		1				1			Advanced Package	3	4	4					4	4	4	4	4	4	4	4	0	4	4	4	4	4	4	4	4	4	y		measuring electrical usage	4			delivered btus
11/2/2012	11									electric motor		Advanced Package	3	3	4	3	3	3	3	3	2	4	4	2	4	4	3				3			4	4			y	n		4			
11/2/2012	1	1	1				1		1			T24 HVAC	4	4	4	1	4	2	3	3	3	3	3	3	3	3	3	0		4	0	4	4	4	3	4	4	n	y		3		none	continue class offerings
11/2/2012	3	1	1				1		1			T24 HVAC	4	5	5	1	4	2	3	3	3	3	3	3	3	3	3	0	4	4	4	4	4	4	4	4	4	y	n		5		n/a	take-home brochures
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11/2/2012	9		1									T24 HVAC	2			2	2	3	2	3	1	2	2	2	1	3	1											n	y		2			
11/2/2012	11		1									T24 HVAC	1	4	4	1	3	2	4	5	4	3	5	5	4	3	3	0	5	3								n	y	"oversizing less energy effective"	3		info on specific systems/strategies	
11/2/2012	13		1			1				hers rater		T24 HVAC	3	3	4	1	3	2	4	3	3	4	4	3	4	4	3	1	3	3	3	3	3	3	3	3	3	n	n		2			
11/2/2012	15		1									T24 HVAC	2	1	5	1	3	2	4	5	5	5	5	5	3	5	3	0	5	5		5						n	y	how to save energy cheapest way	4		brochures to take home	none
11/2/2012	17		1									T24 HVAC	1	2	5					4	4	5	5	4	4	4	4	0		4	4	4	4	4	4	4		n	y		4		brochures	more hands-on

APPENDIX 5: ZNE HOME DEMONSTRATION EXHIBIT PANELS

1

Zero net energy (ZNE) describes a home, connected to the power grid, which produces as much energy in a year as it consumes.

- California's Long-Term Energy Efficiency Strategic Plan establishes a goal for all new residential construction to be built to ZNE standards by 2020.

Although there are several definitions of zero net energy (see sidebar), the definition most commonly used by ZNE home builders is zero net site energy.* This means that the amount of renewable energy produced on the building site equals the amount of energy consumed on the building site.* The most common renewable energy source for ZNE homes is solar photovoltaics (PVs).

Predicting Energy Use in ZNE Homes

Computer modeling is used to help identify opportunities to minimize energy use and to estimate how much energy will be used and how much renewable energy the home will need to produce. The modeling needs to reflect as accurately as possible the way the home will be designed, built, and operated. This requires careful analysis by knowledgeable experts. Conventional modeling often does not account for real-life conditions.

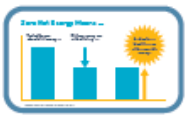
Factors That Affect Home Energy Use

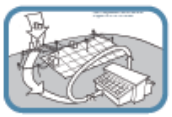
Each of these factors represents an opportunity to minimize the home's (and its occupants') energy needs.

- **Building geometry** - the home's size, shape, complexity, and orientation. See panel 5.
- **Enclosure** - air sealing, insulation (both quantity and quality), framing and windows. See panel 6.
- **Systems** - heating, cooling, ventilation, and renewable energy systems, including design, sizing, locations and layout. See panel 7.
- **Construction** - quality of installation. See panel 8.
- **Occupants** - their power-using devices ("plug loads") and their energy use behavior. See panel 9.

Common Mistakes

There's a clear relationship between the size of the PV array and the amount of west-facing glass on the home, which carries with it a very large cooling load.





In addition to zero net site energy, other definitions of ZNE include:

- Zero net **source** energy – the amount of energy consumed at the energy source (e.g., the power plant) equals the amount of energy produced on the building site.
- Zero net energy **emissions** – the home produces as much emissions-free renewable energy as it uses from emissions-producing energy sources.
- Zero net energy **cost** – the price the utility pays for the energy the building produces is at least equal to the price paid to the utility for the energy it supplies.

Different definitions drive larger or smaller renewable energy systems.

Homes don't use energy – people do!

ZNE refers to the energy used at the home site – both indoors and outdoors – and typically excludes transportation energy, the energy used for the production of food and goods used by the home occupants, and embodied energy. However, some ZNE pioneers are also including these other energy uses in their calculations.

2

The most effective path to ZNE starts with forethought and planning.

Mindset

Achieving high performance is an exercise in developing the team's professional and organizational capabilities. The end product is the result of effective groundwork.

▸ **Set goals.** Include specific, quantitative energy goals (including a project-specific definition of zero net energy, as described on panel 1), as well as design priorities. Establishing clear measures for success provides important navigational guidance throughout the project. See panel 4.

▸ **Build a team.** Develop solid relationships with well-qualified colleagues and vendors. Getting to zero will require a high level of commitment from all the players, and effective collaboration to get the most out of everyone's knowledge. See panel 4.

▸ **Research.** Gather concrete knowledge about efficient designs, systems, equipment, and installation. This will allow you to determine which technologies and approaches will produce the most efficient results. See panels 5-8.

▸ **Learn.** Enhance your team's knowledge by learning new skills, such as accurate energy modeling and effective insulation installation. Much of your success in building ZNE homes will hinge on high-quality execution of the un-glamorous basics. See panels 6-8.

Design Principles

Because it is generally much more cost-effective than home-scale renewable energy systems,[3] energy efficiency should be prioritized in targeting ZNE. As you begin your design process, focus on these key principles:

▸ **Minimize loads.** Use all available means to reduce the energy loads. For example, a home with less exterior surface area will have less heat loss and gain through the enclosure.

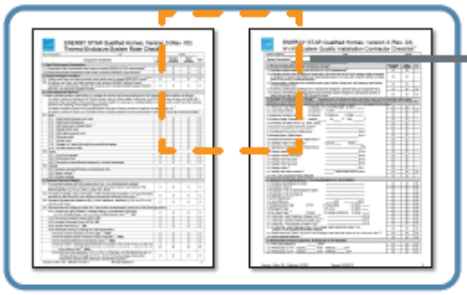
▸ **Simplify.** Eliminate complexity as much as possible. The simpler the building, the easier it is to heat, cool, keep comfortable, and avoid defects.

▸ **Optimize.** Orient the long axis toward the east/west when possible to optimize for passive design and solar electricity generation.

▸ **The envelope counts!** Pay attention to durability and building integrity. Make air, moisture, and thermal barriers continuous throughout the building enclosure.

▸ **Future-proof.** Minimize the effects of occupant choices as much as possible. Tomorrow's occupants will differ from today's ... and they'll probably have more stuff!

▸ **Choose "best-fit" technologies.** When selecting products and technologies, consider their life span, ease of use, and their cost compared to renewables. The newest high-tech options are not necessarily the best.



> "The most resource-efficient home you can build is one you don't have to rebuild."
>
> –Steve Easley,
> Easley & Associates

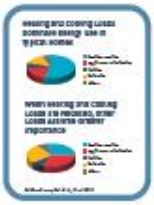
3

In a typical home, heating and cooling account for the largest fraction of energy costs.[5]

▸ In efficient homes, energy-savvy designers use many design strategies to reduce heating and cooling loads. As those loads get smaller, the other loads become more significant.[4]

These other loads – water heating (including swimming pools), lighting, appliances, and other "plug loads" – have traditionally gotten less attention from building professionals, but represent major energy-saving opportunities.

Occupant behaviors can make or break a ZNE home. ZNE demonstration projects have shown that occupants can use much more energy than predicted by the energy simulations – most frequently due to lighting, home electronics, and other occupant-driven factors.[7] A key challenge in creating ZNE homes is to figure out how to minimize occupant energy use through thoughtful design and quality construction.



Minimizing Lighting and Plug Loads

LIGHTING

The basic principle of efficient lighting is first to light the tasks, and then to light the room.

▸ Avoid standard ceiling can lights. They are a poor choice for most lighting applications, and therefore a poor energy investment.

▸ Compact fluorescent lights (CFL) in table lamps and wall sconces are more flexible, use lower wattage, and are more flattering to people's faces.

▸ For general illumination, wash ceilings with concealed light-emitting diode (LED) uplights or fluorescent or LED pendants.

▸ For kitchen downlights, consider LEDs with wide distributions. Under-cabinet fixtures, e.g., dimmable T2 fluorescents, provide good task lighting.

▸ Consider vacancy sensors to turn off lights when rooms are not in use.

APPLIANCES

Select appliances based on the features you are most likely to use; do not oversize appliances (particularly range hoods). Rebates are available for many efficient appliances.

ELECTRONICS

Provide user-friendly controls to enable home office areas, entertainment centers, and areas where gizmos accumulate to be switched off easily when power is not needed.

SWIMMING POOLS

Pools are often the second largest energy user in a home. To minimize energy demands of pools, first select a shape that will accommodate an insulating cover. Then, ensure that the design incorporates a variable-speed filtration pump, cartridge filters, and LED lights.

4

Teamwork and goal-setting are critical foundations for a ZNE project.

An integrated, collaborative approach to design and construction is crucial. The standard, sequential process of each specialist doing his or her work and then handing off to the next (e.g., architect to structural engineer to mechanical designer to landscape architect to general contractor, etc.) doesn't make the best use of your team's knowledge and experience – and you'll need all that to optimize your ZNE home!

Forming a ZNE team

A ZNE team should be made up of experienced, committed, and enthusiastic professionals. Think in terms of needed capabilities and knowledge, rather than traditional roles. Smaller projects generally have smaller teams; larger projects generally have larger teams.

ZNE team capabilities should include:

- **Deep energy-efficient design experience**, incorporating architecture, interiors, landscaping, lighting, and post-occupancy evaluation (showing that design strategies actually resulted in low energy use)
- **Energy analysis and modeling**
- **Building science knowledge** to ensure holistic integration of thermal performance, product selection, health, and durability
- **Mechanical systems knowledge**, particularly integrating heating and cooling with renewable energy systems
- **Construction/structural expertise** to ensure appropriate feedback on structure, cost, and constructability issues

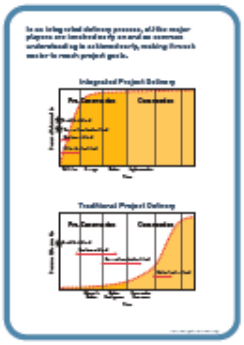
"No matter how good the design, nothing will come of it if the builders don't follow it closely throughout construction. Buildings are never built exactly according to design ... increased energy use will be the likely outcome, unless the builder has a complete understanding of the intent of the design, as well as its technical aspects."

–David Cohen,
Northwest Energy
Efficiency Alliance[1]

The Team Process

Form your team at the earliest possible time. Common understanding is the key to successfully achieving your ZNE goals.

- **Meet early and often** – spend as much time together as you can, pooling your brain power to resolve all the issues that any team member raises, until you arrive at the optimum solution.
- Kick-start your teamwork with a **workshop or charrette**, at least a full day. This may solve some design problems, will bring many issues to the team's collective attention, and will build collegial relationships that will set the tone for the entire process.
- **Agree on the basic parameters**: approximate size, style of architecture, budget, and functional needs the project must meet.
- At your first meeting, **set concrete goals and priorities**, including a ZNE definition and boundary condition.
- **Cultivate patience for revisiting issues.** Progress is iterative and cyclical.



5

Achieving ZNE requires rigorous attention to design fundamentals.

ZNE homes don't have to cost more if the project starts with thoughtful planning and a commitment to achieving the energy goal within the project's budget.

"Design thrice, measure twice, cut once."

–Ann Edminster
Energy Free Homes
for a Small Planet

To accomplish the ZNE goal, designers have many variables to work with, all of which need to be considered actively in the design process.

- **Size.** A plan can be efficient or inefficient; a well-crafted centralized design reduces the square footage dedicated to circulation.
- **Shape.** The most efficient form for a ZNE house is a straightforward rectangle with the simplest possible roof form (that provides adequate space for PVs).
- **Orientation.** The ideal house has its long direction oriented east-west; when that isn't feasible, more ingenuity is needed to prevent overheating living spaces that face west and to optimize the roof and windows for solar benefits.

Take advantage of site conditions.

- **Sun.** Get enough, not too much, heat, don't over-heat.
- **Shade.** Well-designed shading devices and intelligent landscaping can substantially reduce cooling energy requirements at very low cost, and can help address the energy challenges of a west-facing home.
- **Wind.** Ventilating breezes can help reduce cooling loads.
- **Shelter.** Excessive wind can increase heating loads.

Common Mistakes

Geometric complexity is the enemy of ZNE, leading to more surface area, more framing and less insulation, challenges to insulation installation, and a host of other compromises. Simpler is simply better. Curb appeal comes from elegant proportions and quality craftsmanship.

6

A ZNE home starts with a highly efficiently building enclosure.

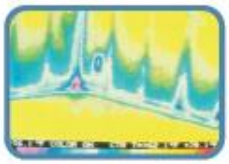
- A high-performance building enclosure is key to achieving the goal of a ZNE home. Space conditioning can easily be 50 to 60% of energy use in a typical home.[7]

Benefits of a High-Performance Building Enclosure:

- Substantially reduces the heating and cooling system size, energy use, and costs.
- Manages moisture problems and other durability risks.
- Simpler, smaller systems are more reliable and longer-lasting.
- Improves occupant comfort and air quality.

Key Elements of Cost-Effective Enclosures

- **Air sealing.** Air leakage can represent 30% of total heating and cooling costs.[8] Typical California homes experience 8 to 11 air changes per hour.[9] Air sealing also reduces wind washing – air passing through the insulation and scavenging away heat – which significantly reduces the insulation's effective R-value. Build a tight structure and use controlled ventilation to ensure good indoor air quality.
- **Insulation.** ZNE homes generally include much more insulation than is required by code in roof, walls, floors, and slab edges. How insulation is installed is just as important as how much insulation is installed.
- **Advanced Framing.** Framing materials conduct heat more easily than insulation, and about 20 to 25% of the walls in a typical American home consist of wood framing, reducing the insulation value of the wall accordingly.[10] Advanced framing techniques – for example, increasing stud spacing to 24" on center – can reduce the amount of framing and improve thermal performance.
- **Windows.** Careful window selection, sizing, placement, and installation are extremely important for ZNE homes, affecting both energy costs and comfort. Window selection should be based on climate. Without thoughtful design, solar heat gain through windows can account for 40% of total cooling costs.[11]
- **Roof.** In cooling-dominated climates, consider including a "cool" roof. (See www.coolroofs.org for more information.)
- **Water & Moisture Management.** A weatherization barrier, properly installed and integrated with flashing, is important to deflect and drain water away from building components, reducing the likelihood of leaks, mold, and decay.



7

Selecting ZNE systems is as much art as it is engineering.

▸ Choosing heating, ventilation, cooling, water heating, and renewable energy systems for ZNE homes requires balancing a long list of system criteria, including initial cost, ease of installation, ease of integration into the structure, appropriateness for the home design, fuel options, cost and ease of maintenance (by the available workforce), ease of replacement, and longevity.

Equipment Sizing and Selection

ZNE home enclosures are typically as energy-efficient, and most California climates are so mild, that it is challenging to find heating and cooling systems with small enough output capacities. Most systems (including all conventional gas furnaces) are too large. ZNE homes in California generally yield a heating/cooling system load between 5,000 and 10,000 BTUs for every 1,000 square feet of conditioned floor area.

"Right-sizing" equipment results in long run times at design conditions. This makes it possible to more easily deliver high levels of both comfort and efficiency. Although there are many possible choices, experience suggests that the systems described below are the first to consider for ZNE homes.*

▸ **Heating.** Because split-system heat pumps can provide both heating and cooling at low output capacities, they can be an ideal choice for ZNE homes. When properly installed and commissioned, they compete well with the operating cost and ease of installation of natural gas furnaces.

▸ **Ventilation.** Mechanical ventilation is important to providing good indoor air quality. Heat-recovery ventilators (HRVs) make sense in California's dry climate, providing controlled fresh-air ventilation that enhances indoor air quality without wasting energy.

▸ **Water Heating.** Heat pump water heaters can save a substantial amount of energy over conventional heaters. Because they do not require a combustion flue, they also eliminate any risk of back-drafting combustion by-products into the home.

Common Mistakes

In a well-designed ZNE home, where careful attention has been paid to the building enclosure and system design, the sizing of mechanical equipment reflects the reduced design loads. This large air conditioning system is a good clue that this is not an optimized ZNE home!

System Installation and Commissioning

Every ZNE system installation must include performance testing and commissioning. Residential installation practices generally have been driven by price rather than by high performance. The focus on high performance is new and requires using commissioning to ensure real system performance. Quality control is covered on panel 8.

▲ Proper system installation and commissioning is key to efficient performance.

8

Quality management is essential.

▸ Often homes look great "on paper" but do not perform as designed.

Computer models are helpful in designing ZNE homes, but they only estimate energy performance. There is often a huge difference between predicted performance and actual energy use. Homes are made of thousands of pieces put together by hundreds of people, with myriad opportunities for mistakes. Diligent attention to detail, follow-through, and measurement during construction are critical to a successful ZNE project.

Achieving Real ZNE Performance

▸ **Look Beyond Labels.** Programs, green labels, certifications, codes and standards such as GreenPoint Rated, LEED, Energy Star, or HERS II can be helpful guidelines, but by themselves do not assure success.

▸ **Skills, not Certifications.** While certifications are generally good, ZNE homes are completely new territory for the great majority of professionals. Relevant experience, creativity, and the ability to work collaboratively are key traits to look for to ensure a quality product.

▸ **Performance vs. Ratings.** It's a common but incorrect assumption that products and systems will perform as labeled or rated. Photovoltaic systems, for example, typically produce 15 to 20% less energy than their nameplate DC output rating, due to specifics of installation, such as location, orientation, and other factors. System sizing and analysis should be based on real operating conditions (e.g., weather at the site).

▸ **Whole Home Performance.** Achieving ZNE performance requires paying attention to the entire house, including plug loads and their companion, phantom loads. See panel 3.

Common Mistakes

The air flow through this duct is severely restricted, greatly impairing system performance. Proper installation is critical for efficient performance and comfort.

Tips for Success

▸ Develop a **comprehensive quality management plan** with input from the entire team. Have it in place at the start of the project.

▸ Create checklists for **intermediate and final testing** to verify the installed performance of every energy feature. Include air infiltration, duct leakage, infrared scan, system airflows, etc.

▸ **Assign one person responsibility** for assuring that the checklists are followed and performance is measured and documented.

▸ **Keep a daily construction log**, documenting the construction process with photographs and commentary. This helps ensure accountability.

▸ Consider basing contract payouts on **building or system performance.**

Air conditioners need to be properly charged to function correctly.

9

Achieving ZNE depends on the home's occupants.

After the designers and builders have finished their jobs, the occupants will determine the success in actually achieving ZNE. Occupants' behavior can vary energy use by 50% or more.[4] A variety of tools can help them succeed.

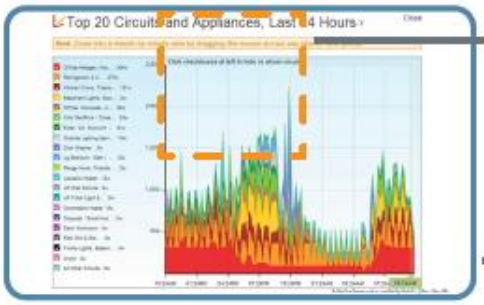
"There are no ZNE homes, only ZNE occupants."

Provide Control Options

Make it easy for occupants to rein in their electrical energy use by providing simple controls.

- Smart power strips
- Innovative electrical outlets
- "Green switches" - wall switches that control specific outlets or entire rooms

Many home automation systems which promise energy savings may actually use more energy than they save! Make sure that controls don't cancel the energy benefits they're supposed to provide.



Empower With Information

Targeted, well-designed information sources empower occupants to operate their homes to achieve zero net energy.

- **Operations and maintenance manuals** that are clear, concise, and accessible can help assure ZNE performance of household systems. They may need to be offered in multiple languages.
- **Photographs and video** or multimedia clips can provide important guidance to operating or maintaining specific types of equipment.
- **Performance "dashboards" or monitoring devices** may assist occupants in tracking their energy use and net consumption over time. Monitoring provides helpful feedback. People can't manage energy use if they don't know how and where they are using energy.

- Choose a monitoring system that is easy to understand and to operate.
- Install the monitoring interface in a location that is accessible and visible.
- Ensure the system allows for data collection over time.
- Gather and analyze the data – are the energy goals being met over time?
- Use lessons learned to inform the next project!