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FINAL REPORT
Volume I: Project Description and Results

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Pacific Gas and Electric Company
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Market Assessment & Evaluation Study in Support of Codes and Standards

Final Report
Volume I: Project Description and Results

A Joint Study by Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, Southern California Gas, and the California Energy Commission

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EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

Pacific Gas and Electric Company (PG&E) contracted with the Pacific Consulting Services team to develop recommendations on how to improve the new construction industry's effectiveness in installing energy efficiency products commonly used to demonstrate compliance with California's Title 24 energy efficiency standards. This study was initiated as part of the second phase California Board for Energy Efficiency (CBEE) studies for 1999. It was conducted as a statewide study, involving the four investor-owned California utilities—PG&E, Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and Southern California Gas (SCG)—and the California Energy Commission (CEC).

In proposing this study, the CBEE, the utilities, and the CEC recognized that energy standards and codes are central to capturing the public policy benefits of energy efficiency programs. Standards provide a means of energy performance measurement, allowing a fair basis for comparison between alternative products and practices. Codes also provide enforceable minimum levels of performance. The combination of standards and codes establishes baselines from which energy efficiency improvements can be evaluated. In California, the Title 24 energy efficiency building standards apply to new residential and nonresidential construction as well as most major building renovation projects.

STUDY PURPOSE

This study was designed to include: 1) characterization and development of ideas on how to improve the construction industry's effectiveness in installing key energy efficiency measures commonly used to demonstrate compliance with Title 24 standards, as well as 2) an assessment of the opportunities to use existing PGC-funded energy efficiency programs to identify and develop potential revisions to Title 24 and support effective infrastructure development and implementation of the Standards. The key aspects of the measure effectiveness and opportunities to use PGC funding assessments are captured in the overall project objectives that guided the study.

Objective 1. This study should assess strategies for improving the construction industry's effectiveness in installing energy efficiency measures commonly used to achieve compliance with

California's Title 24. It should focus particular attention on building commissioning (in the nonresidential sector), diagnostic testing (in the residential sector), third party inspections, and linkages between construction quality and liability insurance concerns.

Objective 2. This study should assess how utilities, either informally or through formal PGC-funded programs, can more effectively influence the standards development and implementation process by promoting consensus for incorporation of industry best practices in the standards. In doing so, this study should document how the codes and standards process can work synergistically with PGC-funded programs to achieve stated program objectives.

The results of the study are intended for use by the investor-owned utilities—including the Codes and Standards Statewide Committee, the CEC, and other interested parties who wish to initiate and/or refine PGC-funded activities to improve the effectiveness of energy efficiency measure installation and influence the development and implementation of the Title 24 energy efficiency building standards.

METHODOLOGY

This study largely consisted of data gathering followed by an assessment and synthesis of those data. No sophisticated quantitative analysis was required or appropriate for meeting the project objectives. The success of the project lay squarely with how thoroughly we examined information about activities related to quality installation of energy efficiency measures and development of building codes and standards, and how well we engaged the attention of key players in this market. To that end, we developed a systemic data collection procedure that allowed us to gather information and then use that information at each stage of the study to determine which areas to probe further, identify additional people to contact, and formulate recommendations to test.

The data collection effort started with an extensive review of the literature during which we also gained insight about key players in the building construction market and issues related to energy efficiency installation effectiveness and codes and standards in that market. The literature review comprises Volume III of this project report. It includes a detailed review of the issues that we identified and a bibliography of about 140 sources that we reviewed.

We followed this with in-depth interviews with 57 industry experts and utility representatives active in this area. The combination of these first two activities allowed us to formulate trial recommendations for improving energy efficiency measure effectiveness that we then tested in a series of five focus groups. We conducted two residential construction industry groups, two

nonresidential construction industry groups, and one insurance industry group, covering both Northern California and Southern California to capture potentially different market conditions and concerns. The interviews and focus groups are discussed in Volume I of this report, supplemented with information in the appendices that comprise Volume II of this report.

Ultimately, we synthesized the information gathered from all of these activities, as well as comments from utility representatives—including members of the Statewide Codes and Standards Committee and the CEC—to develop recommendations to improve the effectiveness of energy-efficient installations in residential and nonresidential buildings in California.

By using this multi-stage data-gathering approach, we ensured that we identified knowledgeable market actors and provided opportunities for these experts to share and comment on others' views regarding barriers and opportunities for improvement. Also, we were able to both formulate and test the sensibility and viability of quite a number of trial recommendations.

RECOMMENDATIONS

These recommendations were synthesized from 1) the results of the literature review, 2) the in-depth interviews that we conducted with industry experts, 3) trial recommendations that we tested and revised in the focus groups, and 4) reviewer comments. They therefore reflect the opinions of the people who participated in the focus groups and the comments received from reviewers of those results, including members of the Codes and Standards Statewide Committee and the CEC. A number of these recommendations are already being worked on by the utilities, the CEC and others.

Developing these recommendations in consultation with leading edge market actors with direct experience and insight into the building performance issues that we identified, rather than a random sample of actors, raised two concerns. First, these people are not completely representative of their respective groups. The majority of builders, inspectors, etc. are not yet sensitized to these issues or potential solutions. Using our "experienced" group, we could jump right into developing strategies to improve measure effectiveness and the code process, rather than spending time educating people and then obtaining their first thoughts about it. Second, the recommendations would reflect their biases rather than providing ideas that are truly valuable and viable to the community. We attempted to prevent this from happening by using the focus groups, which each consisted of different market actors, to develop consensus strategies. The recommendations here are only those that reflected collective thinking. Please note that there may be other viable options not identified here.

We recognize that there are challenges, in some cases considerable, to implementing the recommendations. The wording of these recommendations and the caveats noted address these challenges and capture the comments of the study participants and the reviewers. Several challenges noted apply to many of the recommendations in both the residential and nonresidential markets. These include:

- Increased building costs are always problematic to the construction industry. Nevertheless, many improvements in construction effectiveness promise to result in reduced building owning and operating costs, at least after the industry transitions to new practices. The utilities, the CEC, and organizations, such as CBIA, need to consider how to enact recommendations that achieve improved energy efficiency objectives in a manner that mitigates potential increased first costs.

- The recommendations may be more burdensome to smaller and custom builders. Larger builders have a larger base across which to spread the costs of training and testing.

- Procurement of long-term funding for some of the recommendations will be important. While PGC funds are recommended to 'kickstart" some of these actions, they are not expected to remain permanently available.

- A number of the recommendations cannot be implemented solely by the utilities. They will require non-utility proponents to champion them into practice.

Recommendations for Residential Construction

1. Require mechanical drawings as part of design documents for building permits.

The goal of this recommendation is to foster continuity from design through construction. We heard support for this in nearly every in-depth interview as well as in both the residential focus groups. Contractor completion of Manual J and D design for each house plan, when followed, has been shown to be especially helpful in reducing HVAC defects. There is activity underway at several utilities to encourage good design.

Caveats to Recommendation 1: While requiring mechanical drawings is widely expected to improve HVAC and duct performance, it does not guarantee quality workmanship. Designs can be disregarded or altered during construction. Thus, without field verification, this recommendation cannot ensure measure effectiveness.

2. Require certification of HVAC and insulation contractors and installers. Tie the certification to successful completion of training courses. Require an affidavit from contractors documenting satisfactory self-inspection results and performance testing reports as precondition for issuing occupancy permit.

In interviews and focus groups, certification was heralded as an important component of improving HVAC and insulation effectiveness. The importance of including both contractors and the actual installers in the certification was noted so that the certification would be more meaningful. Surprisingly, most participants in the focus groups supported the idea of self-inspection, and were, in general, much more trusting of each other than previous studies have shown.

Caveats to Recommendation 2: Several items clearly need to be addressed of implement this recommendation. One is to determine how certification relates to current contractor licensing. Another is procurement of long-term funding to cover the costs of the certification program. PGC funds may be used to partially or fully offset the cost of setting up the training and certification, but since that funding is not expected to last in perpetuity, other mechanisms need to be explored to sustain the activity. This recommendation will require that utilities and the CEC work with professional/industry associations to develop and perhaps take responsibility for certification.

3. Establish mechanisms to conduct random, third-party inspections for quality control.

Inspections would be conducted by people who are not local building inspectors and would cover a sample of homes constructed by each builder. CBIA strongly supports the concept of independent, third-party inspections and using a sampling approach to control costs. Some large builders said they are already doing this.

Caveats to Recommendation 3: It is clear that before this recommendation can be implemented, quite a number of issues need to be resolved. Questions that were raised by project participants include: To whom will the third-party inspectors report and how will the results be used? How will the sample homes be chosen? At what stage(s) of construction will the homes be inspected? Then there is the issue of cost. PGC funds may be used to establish the third-party inspections, train the inspectors, and initially pay for the inspections. At this time, it is unclear whether this could become a self-sustaining market-based change or whether a long-term funding mechanism will be necessary to ensure the sustainability of this practice.

4. Use PGC funds to conduct contractor and installer training on proper installation, proper testing, and recent changes to Title 24.

Support is widespread for using PGC funds to conduct contractor training on proper installation, testing, and recent changes to Title 24. Discussing concerns about how to effectively reach busy contractors, the focus group participants most favored the idea of on-site demonstrations of proper installation. Also, by going to the job site, one can target the installers, not just the contractors who employ them. Another suggestion was to create a special section on the CEC website that provides a quick overview of Title 24 changes.

Caveats to Recommendation 4: This recommendation is already a work-in-progress. The utilities have a number of training sessions available to members of the building industry—including Title 24 consultants, local building officials, HVAC contractors and installers, architects, mechanical engineers, equipment suppliers, developers, and Realtors. A list of these training sessions is included in Volume II, Appendix E of this report. Despite offering training at alternative locations and times, the utilities find they are not always successful at persuading the intended market actors to attend the training sessions. Conducting training sessions at the construction site may address this barrier.

5. Use PGC funds to augment and train local building inspectors on the "house as a system" approach.

Many of those interviewed felt that the local building inspectors are not up to date on the new energy-efficient technologies, and do not understand the interactive nature of a home's component systems and the implications of the poor performance of any one component on the others. Having inspectors trained at actual homes would be an effective way to deliver training on diagnostics and quality construction results. Comments on this recommendation were all favorable, both during the focus groups and in subsequent review. Reviewers thought that having building inspectors trained on the "house as a system" approach would enhance compliance. Most, but not all, agreed that having more trained inspectors would be beneficial in decreasing potential construction delays that could arise from inspectors being unfamiliar with the methods.

Caveats to Recommendation 5: Barriers go far beyond the need for training and are more related to lack of local government budget resources, low priority of energy efficiency relative to health and safety code requirements, and lack of educational and professional expertise. Implementing this recommendation will require the utilities to enlist the support of and collaborate with several parties. Partnerships with professionals who can provide the training will be necessary. Interactions to gain the support of local building officials will be necessary. Finally, this will likely need a non-utility champion to make it happen.

6. Conduct additional research to quantify potential non-energy benefits of a systems approach to home construction. Quantify the benefits from reduced callbacks and reduced exposure to litigation.

This is currently considered a "hot issue" at insurance industry conferences, suggesting that now would be a favorable time to initiate such a study.

Caveats to Recommendation 6: We need to emphasize that the litigation referred to is rarely, if ever, due to energy efficiency performance failures, and energy standards cannot be used to enforce construction quality. Nonetheless, we are already seeing a convergence of interests here that reinforce the value of conducting energy efficiency measure benefit assessments. The American Architectural Manufacturer's Association (AAMA) has been working with window manufacturers because of leakage litigation problems, offering an opportunity to also discuss improving energy efficiency through better construction and installation of window units. Also, the Building Industry Institute has been successful in associating improved quality in energy-efficient construction with reduced builder exposure to liability. Finally, it should be noted that quantifying non-energy benefits of building energy efficiency improvements in ways that are meaningful and actionable for the insurance industry may be difficult to accomplish.

7. Increase consumer education on energy efficiency by way of a mass media public awareness campaign.

There was quite a bit of debate during data collection efforts regarding the role of consumer demand in driving the marketplace toward higher efficiency and quality construction. By increasing consumer education and creating value for quality construction and energy efficiency, builders and contractors alike believe consumers will begin asking for more efficient homes.

Caveats to Recommendation 7: The utilities already have some energy efficiency consumer awareness programs in place. To help builders see the value of energy efficiency, these programs could be more focused on identifying and educating consumers about a few specific measures that they should look for in a new home.

8. Establish simple, standardized diagnostic testing procedures.

While nearly everyone agreed that diagnostic testing procedures should be required, the dilemma is how to define such procedures. By establishing common protocols in the standards, everyone will have access to information on how to conduct diagnostic testing.

Caveats to Recommendation 8: This has already been accomplished for duct testing. The standard is the Duct Blaster test. This type of standardization needs to be extended to other HVAC components and the building envelope. PGC funds could perhaps be used to facilitate this extension.

9. Simplify Title 24 while raising the standards (i.e., make them more stringent but easier to understand and apply).

Title 24 is considered by many, if not all, as far too complicated and hard to understand. Simplifying the standards would reduce confusion and improve the likelihood of compliance. These same respondents said that more stringent standards should be required, such as offering fewer credits for easy trade-offs; e.g., credits for installing interior window shading. Many complained that contractors and builders opt for the lowest cost credits, even if they doubt their effectiveness, and therefore sacrifice energy efficiency. This recommendation would help rectify this problem.

Caveats to Recommendation 9: There was considerable agreement on this recommendation, despite its potential restrictiveness. In the focus groups, (large) builder representatives said they expect there would be support among builders for simpler requirements even if they are more stringent. CBIA, which might be more widely representative of builder views, supports the mandate that any update to Title 24 must be cost-effective in its entirety when compared with historical practice. To implement this recommendation, it is evident that representatives from many groups will have to grapple with the trade-off between the increased compliance that simplicity would facilitate and the additional costs that increased stringency would likely impose.

10. Offer state tax credit for green and tested, energy-efficient buildings to both builders and consumers.

By offering a state tax credit for “green” (and tested) energy-efficient buildings, market actors are being encouraged to pursue field-verified energy efficiency. Respondents believed that this might be more successful if associated with construction of “green” buildings. By splitting the incentive, so that both owners and builders receive a portion of the tax credit, it would ideally create a symbiotic push-pull approach to market transformation. Obviously, the infrastructure would need to be in place to support the tax credit, as well as governmental buy-in. Everyone who reviewed this recommendation thought it would be helpful for promoting energy efficiency.

Caveats to Recommendation 10: This is clearly a recommendation that utilities cannot implement on their own. It will need a champion within the legislative process.

Recommendations for Nonresidential Construction

Most of the recommendations for the nonresidential market are analogous to the recommendations made for residential construction. There are, however, several differences worth pointing out. First is the recommendation of mandatory testing for nonresidential construction. Second is the no recommendation of third-party inspections. Third is a provision that could prove especially helpful to smaller building owner/developers or potential commissioning agents: an equipment lending library. Finally, there were no recommendations to simplify and increase the stringency of the standards.

1. Require commissioning of the HVAC system and lighting controls with the mechanical engineer of record responsible for the HVAC system and the architect responsible for the lighting.

The systems most at risk for construction defects in new nonresidential buildings are the HVAC and the lighting controls systems. While architects and builders alike might be reluctant to commission the whole building due to cost and time constraints, these two systems in particular should be addressed. Since the mechanical engineer is responsible for designing the HVAC system, it seems most appropriate assign responsibility to this party for ensuring that this system operates as designed. Architects or lighting designers should see that lighting and the control systems are installed and function as planned. In particular, since occupants can and do override controls when the lights do not perform as needed, the lighting designer needs to ensure that the controls are appropriately installed and calibrated. There is precedent for this recommendation in similar requirements, that were put into effect in Massachusetts in January 2000.

Caveats to Recommendation 1: The biggest problem with implementation of this recommendation may be how to overcome the cost burden that this will impose on builders. Full building commissioning costs can be 10-20% of the construction cost of a building. Also, a commissioning infrastructure needs to be developed in California, including training for lighting designers and mechanical engineers on commissioning procedures. Public electricity charge funding is being used in the Pacific Northwest, New York, and other northeast states to develop a commissioning infrastructure in those parts of the country. PGC funds could be used to develop this infrastructure in California.

2. Use PGC funds to offset costs of commissioning.

Building owners and developers often see commissioning as a discretionary cost that could lead to construction of the building going over the budget and eating up profits. Commissioning can be one

of the first things to go when construction budgets get over-extended. By using PGC funds to offset the costs of commissioning, the likelihood of having commissioning cut from the plans could be alleviated.

Caveats to Recommendation 2: It is not anticipated that PGC funds will be available to cover the entire cost of commissioning or that they will be available indefinitely. Since building commissioning includes drafting written plans, conducting testing, and fixing mistakes, its unclear whether PGC funds should be applied to all or only some components of commissioning.

3. Design simple and uniform testing protocols.

Commissioning implies many things to many people. Having simple and uniform testing protocols would alleviate confusion regarding what constitutes the commissioning process. Some headway has been made in addressing this: ASHRAE has a committee on testing protocols. PG&E is also developing testing guidelines.

Caveats to Recommendation 3: This recommendation will require collaboration between commissioning experts developing the guidelines and the professionals that will be trained to use them. Furthermore, while utilities can and are encouraging uniform protocols, they cannot impose them.

4. Use PGC funding to establish a standardized certification process to train and certify commissioning agents.

This recommendation directly addresses several of the commonly cited barriers to building commissioning: cost, lack of awareness of pervasive equipment performance problems, and lack of knowledge on how to perform testing. By requiring training and certification, professional commissioning agents would be able to see the benefits that commissioning offers, understand commissioning practices, and demonstrate their competency in applying the procedures.

Caveats to Recommendation 4: We realize the CEC does not currently have the authority to "certify" commissioning agents. Teaming with or encouraging professional organizations such as ASHRAE or the Building Commissioning Association to certify them was seen by project participants as viable and highly recommended. Developing and sustaining this infrastructure component will likely require continued funding over the medium to long term.

5. Use PGC funds to create a library of testing equipment for builders and their commissioning agents to borrow.

This recommendation stems from feedback we received about the lack of ownership of equipment for testing building systems. Such equipment is often too expensive for a building owner/developer or potential commissioning agent to acquire for infrequent use. Activity is already underway on this recommendation. The Pacific Energy Center has started an equipment lending library. Increased access to testing equipment is part of the infrastructure needed for some of the other recommendations to be effective.

Caveats to Recommendation 5: The issues that need to be addressed for this recommendation include identifying which equipment to make available, and establishing the locations from which the equipment might be obtained.

6. Use PGC funds to conduct additional studies on costs and benefits of building commissioning, including a quantitative cost-benefit analysis of commissioning relative to energy and non-energy benefits, such as improved air quality and better work environment resulting in higher productivity.

Suggestions for additional studies of the nonresidential sector primarily focus on generating and communicating findings from successful building commissioning demonstration projects. Many builders said that having such studies available would help them sell commissioning to building owners and justify allocating part of the project's budget to commissioning.

Caveats to Recommendation 6: This recommendation is similar to that made for residential construction and faces the same challenges.

7. Offer state tax credits to builders and building owners for commissioning energy-efficient and "green" buildings.

As in the residential market, by offering a state tax credit for "green" (and tested) energy-efficient buildings, market actors are being encouraged to pursue field-verified energy efficiency.

Caveats to Recommendation 7: This recommendation is similar to that made for residential construction and faces the same implementation challenges.

Recommendations for Future Research

Implementation of some of the recommendations made here will require or would greatly benefit from additional research. These items include:

- Conduct studies that assess and document the energy as well as non-energy benefits of diagnostic testing and/or building commissioning to market actors, including insurers, builders, and owners/buyers. These should be actuarial quality studies that would afford insurers confidence to reduce builders' premiums for performance tested and commissioned buildings.
- Actively foster partnerships with professional associations in the construction industry to facilitate development and implementation of training and certification for diagnostic testing and building commissioning.
- Determine exactly how requirements of Title 24 (current and proposed) overlap with activities that comprise building commissioning. This may involve revisiting and/or revising the working definition of building commissioning for best use in California.
- Track how building commissioning in Massachusetts is working to gauge the likely practicability and benefit of the first nonresidential recommendation above.
- Since there is still some controversy regarding the use of third-party inspections in residential construction, conduct a study to investigate their need/acceptance and develop practical strategies for using them.
- The residential and nonresidential recommendations above are somewhat general. Further investigation needs to be made into which submarkets of the construction industry will be the best hosts for these recommendations. Utility/PGC-funded programs should be directed at implementing the recommendations in these markets first.

1 INTRODUCTION

A. INTRODUCTION AND BACKGROUND

Pacific Gas and Electric Company (PG&E) contracted with the Pacific Consulting Services team to characterize the new construction market relative to the construction industry's effectiveness in installing energy efficiency products commonly used to demonstrate compliance with California's Title 24 energy efficiency standards. This study was initiated as part of the second phase California Board for Energy Efficiency (CBEE) studies for 1999. It was conducted as a statewide study, involving the four investor-owned California utilities (PG&E, Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and Southern California Gas (SCG)) and the California Energy Commission (CEC).

In proposing this study, the utilities and the CEC recognized that energy standards and codes are central to capturing the public policy benefits of energy efficiency programs. Standards provide a means of energy performance measurement, allowing a fair basis for comparison between alternative products and practices. Codes also provide enforceable minimum levels of performance. The combination of standards and codes establishes baselines from which energy efficiency improvements can be evaluated. In California, the Title 24 energy efficiency building standards apply to new residential and nonresidential construction as well as most major building renovation projects. However, market transformation gains in design practices, building shells, or appliances are not permanently captured until they are reflected in improvements to standards, codes, and building energy budgets.

B. RESEARCH OBJECTIVES

This study was designed to include: a market characterization of the construction industry's effectiveness in installing key energy efficiency measures commonly used to demonstrate compliance with California's Title 24 energy efficiency standards, and an assessment of the opportunities to use existing Public Goods Charge (PGC)-funded energy efficiency programs to identify and develop potential revisions to California's Title 24 energy efficiency standards and to

support effective infrastructure development and implementation of the standards. This study focused on assessing:

- the barriers to achieving quality in the construction and installation of energy efficiency features,
- the barriers to using diagnostic testing (residential construction) and building commissioning (nonresidential construction) as means of ensuring that building energy performance expected to result from compliance with Title 24 is actually achieved, and
- the potential for using third parties as special inspectors to increase construction quality and ensure building energy performance.

Discussion at the kick-off meeting and informal conversations with PG&E and the CEC provided the opportunity to refine the objectives that ultimately guided the study.

- **Objective 1** This study should assess strategies for improving the construction industry's effectiveness in installing energy efficiency measures commonly used to achieve compliance with California's Title 24. It should focus particular attention on building commissioning (in the nonresidential sector), diagnostic testing (in the residential sector), third party inspections, and linkages between construction quality and insurance liability concerns.
- **Objective 2** This study should assess how utilities, either informally or through formal PGC-funded programs, can more effectively influence the standards development and implementation process by promoting consensus for incorporation of industry best practices in the standards. In doing so, this study should document how the codes and standards process can work synergistically with PGC-funded programs to achieve stated program objectives.

i. Objective 1: Improve Effectiveness of Measure Installation

The approved research plan called for meeting the first objective by performing the following tasks:

1. Develop a list of residential and nonresidential measures that are either required for standards compliance using the prescriptive approach or are commonly relied on to achieve compliance using the performance approach.

2. Evaluate the effectiveness with which these measures are currently installed, focusing on actual building performance rather than paper compliance. For subsequent steps, focus on measures for which there is evidence of performance problems.

3. Identify the market actors with important decision making roles in the installation of measures with performance problems.

4. Assess the incentives and disincentives each market actor has to make decisions that lead to effective installation and function of targeted measures versus circumventing the intent of the standards.

5. Summarize the barriers to effective installation and function of targeted measures.

6. Assess the opportunities to use building commissioning, diagnostic testing and third-party inspections, and linkages between construction quality and both liability insurance concerns and financing considerations as strategies to improve the effectiveness of measure installation. Draw lessons from other energy-efficient building programs and pay particular attention to the compatibility between the proposed strategies and the identified interests of various stakeholders.

7. For those strategies considered viable, develop recommendations for how they might be promoted, either through PGC-funded programs or through modifications to the standards development and implementation process.

ii. Objective 2: Assess Utility Opportunities to Influence Standards Process

The approved research plan called for meeting the first objective by performing the following tasks:

1. Describe the process by which California's energy standards are developed, modified, and implemented.

2. Assess opportunities for using the standards process as a tool for PGC-funded programs to meet their program objectives. Assess whether utility PGC program planning processes should be modified to establish closer links between the standards process and PGC program objectives.

3. Review utility involvement in the standards process and explore factors contributing to the success or failure of those interventions.

4. Develop recommendations for ways utilities and PGC-funded programs can effectively influence the standards process.

C. Report Organization

The remainder of this report discusses the research approach, study findings, and our recommendations for future activities and research. This volume of the report is supplemented by two additional volumes. Volume II contains five appendices: lists of industry experts and utility staff we interviewed and/or who participated in the focus groups, data collection instruments, summaries of interviews that we used to develop the interim and final recommendations presented in this report, and listings of utility-sponsored activities in 2000 that are related to Codes and Standards. Volume III contains the results of the literature review that we conducted at the outset of the project that helped shape the issues we examined.

2 METHODOLOGY

A. OVERVIEW

This study largely consisted of data gathering followed by an assessment and synthesis of those data. No sophisticated quantitative analysis was required or appropriate for meeting the project objectives. The success of the project lay squarely with how thoroughly we examined information about past and ongoing activities related to quality installation of energy efficiency measures and development of building codes and standards and engaged the attention of key players in this market. To that end, we developed a systemic data collection procedure that allowed us to gather information and then use that information at each stage to determine which areas to probe further, identify additional people to contact, and formulate recommendations to ultimately test.

The data collection effort started with an extensive review of the literature during which we gained insight about key players in the building construction market and issues related to energy efficiency installation effectiveness and codes and standards in that market. We followed this with a number of in-depth interviews with identified industry experts and utility representatives active in this area. The combination of these two activities allowed us to formulate straw-man recommendations for improving energy efficiency measure effectiveness that we then tested in a series of focus groups. These focus groups consisted of residential and nonresidential market actors and were conducted across the state to capture a diversity of views. Ultimately, we synthesized the information gathered from all of these activities, as well as comments from utility representatives—including members of the Statewide Codes and Standards Committee-to develop recommendations to improve the effectiveness of energy-efficient installations in residential and nonresidential buildings in California.

Some of the experts we interviewed had contributed to the body of literature we reviewed. And most of the focus group participants had been among the people we had interviewed. By using this multi-stage data-gathering approach, we ensured that we identified knowledgeable market actors and provided opportunities for these experts to share and comment on others' views regarding barriers and opportunities for improvement. Also, we were able to both formulate and test the sensibility and viability of quite a number of trial recommendations for recipients of this report.

The remainder of this section describes what we did in performing each of these activities.

B. LITERATURE REVIEW

To maximize the effectiveness of our data collection and analysis efforts, we wanted to avoid duplicating previous research efforts and make full use of published literature and data sources. Thus we conducted an extensive review of literature and other secondary sources that provided inputs into other key tasks. The review was targeted at literature and other data sources that contained information most critical to the study. Types of literature we reviewed included:

- **California Energy Commission Documents and Data.** We started our review with the Title 24 Standards and associated manuals, newsletters, and other tools the CEC has developed to promote code compliance. In addition, we reviewed several studies the CEC has conducted or sponsored that investigate Title 24 compliance.

- **Utility Documents.** We focused on utility PGC-funded programs since 1997, and our review looked at program design documents and evaluation results since that year.

- **Other Energy Program Documents.** Organizations outside of California have quite a bit of experience in building commissioning, diagnostic testing, energy-efficient building programs, energy code development, energy-efficient financing, and insurance issues. We explored information from a number of organizations.

- **Conference Proceedings.** We reviewed recent proceedings from conferences organized around building commissioning and energy code issues, including the proceedings for the 7th National Conference on Building Commissioning and Affordable Comfort conferences.

- **Other Consultant Studies.** We reviewed a number of studies that specifically investigate the current issues surrounding Title 24 and building commission protocols, such as Portland Energy Conservation, Inc.'s *National Strategy for Building Commissioning* (for the US Department of Energy), National Institute for Building Science reports on total building commissioning guidelines development, ConSol/LBNL duct and building envelope protocol projects, LBNL's residential building commissioning project, and various field studies on duct leakage and the need for whole house diagnostics.

- **Industry Periodicals.** Publications from building industry and commissioning associations were looked at to gain their insights into guidelines for successful commissioning and Title 24

compliance strategies. Examples include *Architectural Record* (published by AIA), *Building Operating Management*, *Home Energy* and *Energy Design Update*.

- **State Building and Energy Codes**. We also looked at other codes from states likely to be progressive in their code development and enforcement.

- **Related Studies.** Finally, we researched numerous available reports that address the linkage between building performance and issues such as occupant productivity and health, liability exposure, and financing.

This extensive literature review is available under separate cover as part of the documentation for this project.

C. In-depth Interviews

Our primary data collection efforts were initiated with a series of in-depth interviews with industry experts and utility staff. We compiled a database of more than 110 relevant industry contacts and completed 57 in-depth interviews. Most interviews were conducted by phone, however, whenever time and budget allowed, we were able to conduct in-person interviews (e.g., utility and CEC staff).

These interviews were a critical mechanism for assembling important contextual information, scoping out key issues related to the study research questions, isolating areas of agreement and disagreement, and helping to formulate recommendations we would later test in the focus groups. The interviews were exploratory in nature. For each interview we had a battery of issues we wanted to probe. We organized these issues and the interviews in nine modules. The interview guides are included as Appendix B. The modules are:

Module A. Construction practices in building quality and call backs

Module B. Diagnostic testing and performance testing for residential buildings

Module C. Building commissioning and performance testing for nonresidential buildings

Module D. Energy efficiency financing (energy-efficient mortgages, performance contracting, building appraisals, etc.)

Module E. Insurance/liability issues related to construction quality

Module F. Energy-efficient building and "green" building initiatives

Module G. Title 24 revision process

Module H. Using Title 24 to promote energy efficiency program objectives

Module I. Utility involvement in the Title 24 process

D. Focus Groups

Complementing our in-depth interviews, we used focus groups to explore potential recommendations that resulted from the interviews. There were three outstanding areas for which further exploration was necessary and recommendations were developed: residential diagnostic testing, nonresidential building commissioning, and insurance liability issues. We held five groups total, representing both Northern and Southern California.[1]

Focus group participant names were largely assembled from referrals of experts we had interviewed earlier in the project. Candidates were selected who seemed best suited to discuss the issues we wanted to address in each group. Locations were similarly chosen. We held the groups in places that could be most easily reached by the people we wanted to attend. For example, the insurance focus group was held in San Diego because of the high level of litigation concern indicated in that area. We included market actors in each group who represented different segments of the industry, gaining a multitude of perspectives. These included builders, contractors, architects/designers, engineers, inspectors and program staff. The focus groups were sprinkled with industry experts we had previously interviewed individually. The list of focus group participants is included in Appendix A of this report. Copies of the focus group discussion guides can be found in the Appendix C.

[1] We had initially scheduled six focus groups, however one of the Northern California focus groups was cancelled due to participant cancellations. Follow-up calls were placed to elicit opinions of those intended participants.

E. Analysis

The bulk of the effort in this project was directed toward qualitative data collection strategies—in-depth interviews and focus groups. The analysis associated with these efforts focused on summarizing results and reviewing them for patterns or trends. We also compared primary data collection results with findings from our review of secondary sources and documented experiences in other regions. Summaries of these findings are included as Appendix D.

Our analysis of interview and focus group results culminated in the formulation of findings and recommendations for future PGC-funded intervention strategies to influence the standards process. Recommendations that emerged from our analysis were tested for their ability to contribute to sustainable market effects. In keeping with the CEC's desire to more closely align the standards process with market forces, we conducted this test by subjecting each potential recommendation to the following series of questions:

- Would the recommended intervention lead to changes in standard practice in the construction industry?
- Would the recommended intervention produce steady growth in the market share of energy-efficient building designs and practices?
- Are construction market actors requesting or demanding this intervention?
- Would the recommended intervention reduce or remove risks that construction market actors experience (e.g., customer dissatisfaction, callbacks, and liability)?
- Would the recommended intervention reduce or remove split incentives that construction market actors experience?
- Would the recommended intervention "level the playing field," making it more possible for quality, energy-efficient construction to compete with lower-quality construction?

3 FINDINGS

A. STATUS OF MEASURE INSTALLATION EFFECTIVENESS

i. Key Measures Reviewed

From our literature review, we identified those residential and nonresidential measures that are either required for Title 24 standards compliance using the prescriptive approach or are commonly relied on to achieve compliance using the performance approach. These are noted in Table 1.

Table 1. Energy Efficiency Measures Typically Used for Title 24 Standards Compliance

	Nonresidential	Residential
Lighting	Lighting power density	Kitchen lighting
	Occupancy sensor control	Bathroom lighting
	Other controls	
HVAC	Equipment efficiency	Equipment efficiency
	Equipment part load performance	Duct design and airflow
	Variable speed fan control	Duct insulation
	Variable speed pump control	Duct sealing
	Economizer	Fireplace outdoor air source
	Fan system efficiency	Installation (refrigerant charge, airflow)
	Equipment sizing	
	Zone control	
	Supply air temperature control	
Envelope	High performance windows	Envelope sealing and air barrier
		High performance windows
		Interior window shades
		Insulation
Water Heating		Water heater efficiency
		Pipe insulation

This list of measures served as the basis for our review of measure installation effectiveness. Note that this table does not represent a comprehensive list of all technologies covered by the standards nor does it cover systems not within the scope of the standards (e.g., process systems, elevators, etc.).

For the purposes of this study, a measure is effective if it achieves the energy savings according to the requirements of the standard and/or the system design intent. For example, if a variable speed fan actually slows down as much as it should when air flow drops, then the measure is effective. If, however, due to problems such as improper duct pressure sensor installation, the fan speed does not drop as far as optimal, then the measure is not completely effective. Therefore, a reasonable measure of effectiveness is the fraction of potential savings actually achieved.

Verification of some measures used to achieve compliance can be visually inspected, such as whether or not a required device has been installed. Other measures cannot be qualitatively verified and require diagnostic testing. Examples of quantitative performance testing include measuring whether indoor coil air flow exceeds 350 cfm/ton and if duck leakage is less than 6% of system fan flow.

In order to determine the current effectiveness of the measures and identify which might be worth focusing on in revising the standards and/or in PGC -funded programs, we addressed the following questions by consulting the literature and interviewing industry experts:

- What types of performance problems occur for each measure?
- What are the causes of the problems? Are they related to specification, installation, operation or maintenance? Who is responsible?
- What is the frequency of these performance problems in the state?
- What is the effect of energy standards on measure specification, installation, operation or maintenance?
- Which problems can be addressed through commissioning, third party inspection or diagnostic testing?
- What role might energy standards play in improving measure performance?
- Are other non-energy standards interventions likely to be effective?

a. Residential Measures with Noteworthy Performance Issues

In the residential sector, we found abundant evidence of building performance issues associated with HVAC system design and installation. Building envelopes are also prone to numerous construction defects, although the energy efficiency implications may not be substantial, at least in

California. HVAC and envelope issues are discussed in more detail below. Residential lighting systems offer numerous opportunities for improved energy efficiency through more stringent technology requirements but do not appear to be particularly prone to construction defects.

Residential HVAC Issues

There are many factors that degrade HVAC system operating efficiency below nominal manufacturer-tested equipment performance. According to Neal (1998), four key factors affect performance: incorrect refrigerant charge, inadequate system airflow, duct leakage, and system oversizing.

- Incorrect refrigerant charge has been identified as a problem in over 70% of installations nationally (Neme, Proctor, and Nadel 1999). Correct refrigerant charge for installed systems requires improved HVAC contractor training and attention to detail in the final system tune-up process.

- Inadequate airflow over the indoor coil, which is typically due to reliance on rule-of-thumb duct sizing procedures, results in undersized and overly restrictive duct systems. Industry experts identified the need for mechanical system design as part of the overall house plan as a primary solution to this problem. The lack of system design often constrains the HVAC contractor to sub-optimal solutions for routing the duct system through the existing framing. The consequences include undersized ducts to get through framing pinch points, reliance on building cavities in lieu of return air-supply ducts, and sharp bends in the ducts, which increase air turbulence and are vulnerable to leaks.

- Duct leakage affects system performance in several ways. Return leakage causes unconditioned attic air to be pulled through the air handler unit, resulting in an increased cooling load on the evaporator coil. Supply-side leaks to unconditioned space reduce effective system capacity. A 4-ton cooling system with 11% supply leakage is effectively operating as a 3 1/2-ton system. Duct blaster tests have been developed to diagnose leaky ducts. For maximum utility, these tests should be conducted at the time ducts are installed while the contractor can still access the ducts to fix any leaks.

- The practice of oversizing cooling equipment has been projected to be as high as 47% over Manual J[2] prescribed sizing (Neme, Proctor, and Nadel 1999). Oversizing increases cooling

[2] Air Conditioning Contractors of America. 1986. *Residential Load Calculation—Manual J.* Air Conditioning Contractors of America

energy use and peak demand and requires the homeowner to pay for additional capacity that is not required. From the contractor perspective, oversizing of air conditioning systems has been the easiest way to minimize homeowner comfort complaints, which in reality are due to a myriad of problems including shortcomings in duct design, excessive duct leakage, inadequate airflow, and improper refrigerant charge. A comprehensive strategy of mechanical system design, duct testing and inspections, and HVAC system tune-up can reduce the impetus to oversize cooling systems.

Residential Envelope Issues

Much of California's climate is sufficiently mild that imperfections in the building envelope do not have catastrophic comfort or energy implications. Nevertheless, improperly constructed building envelopes appear to be common. A comprehensive builder training program completed during 1995-1998 found nearly a third of the houses tested had under-insulated ceilings (or other significant problems) and nearly half of the houses had walls with inadequate insulation, significant insulation compression, or other problems (BII and Consol 1998). The most viable solutions for improving the quality of insulation installation appear to be more regular training of installers and more routine inspections of insulation installation. Training efforts in California are hampered by widespread reliance on unskilled immigrant labor. Inspections are complicated by the short window of opportunity to inspect the insulation before it is covered over with wall sheathing.

While envelope issues may be less important than HVAC issues from an energy efficiency perspective (at least in California), it tops the list of risk management concerns. According to industry experts, residential building envelope problems associated with water infiltration are the most common sources of occupant discomfort and litigation. Water often infiltrates from below grade due to problems with the foundation. Water infiltration can also occur due to improper construction techniques in the building envelope. It is reportedly common to find double-glazed windows with bad seals in older homes. Poor roof and wall waterproofing, small roof overhangs, roof failures, and inadequate caulking and flashing all contribute to water infiltration. Moisture problems can also be traced to improperly operating HVAC systems that generate negative air pressure in the house, which can cause moisture to be drawn in and cause rot and deterioration of the insulation.

Based on our literature review of measure installation effectiveness, we concluded that quite a few HVAC and building envelope measures deserve further scrutiny as candidates for significant performance improvements and several others do not, either because there are no significant

performance issues or because the identified performance issues do not translate into significant energy impacts. These are summarized in Table 2.

Table 2. Assessment of Residential Measure Effectiveness

	Performance improvements worth pursuing	Insignificant performance issues or effects
Lighting	Bathroom lighting	Kitchen lighting
HVAC	Equipment efficiency	Fireplace outdoor air source
	Duct design and airflow	
	Duct insulation	
	Duct sealing	
	Installation (refrigerant charge, airflow)	
Envelope	Envelope sealing and air barrier	Interior window shades
	High performance windows	
	Insulation	
Water Heating	Water heater efficiency	
	Pipe insulation	

b. Nonresidential Measures with Noteworthy Performance Issues

Nonresidential HVAC Issues

Many of the HVAC issues described for the residential sector also apply to the nonresidential sector. In particular, equipment sizing and duct sizing, layout, and exposure were all described as problems across the board.

For chilled water plants, problems are associated with temperature controls on the condenser water, variable speed pump controls, and component interactions. For air distribution systems, problems are associated with variable speed fan controls and zone temperature controls.

Several performance issues were raised with respect to packaged air conditioners. Informants pointed out that these systems do not perform efficiently under part-load conditions. Cycling on and off is not an efficient operating mode and energy standards do not require economizers for these systems. There are also performance issues with the automatic scheduling and shutoff controls for

packaged units. Thermostats often control both the compressor and the fan. When the cooling set point has been reached, both systems shut off at the same time, leaving the building with no ventilation system.

Nonresidential Lighting Issues

Occupancy sensor controls, daylighting controls, and other lighting controls are the most frequently cited sources of lighting performance problems in the nonresidential sector. "The number of occupancy sensors being installed has decreased significantly from 1994 [to 1998]. Occupancy sensors have become somewhat unpopular because of their potential to turn off lights while the space is occupied. In the field we found a great majority of people removing and or over-riding the sensor due to poor functionality." (RLW Analytics 1999). Calibration issues are the most common problem. Users get disgusted and override the systems. It is very uncommon to find a working system that has not been tampered with.

Based on our literature review of measure installation effectiveness, we concluded that several measures deserve further scrutiny as candidates for significant performance improvements and a few others do not, either because there are no significant performance issues or the identified performance issues do not translate into significant energy impacts. These are summarized in Table 3.

Table 3. Assessment on Nonresidential Measure Effectiveness

	Performance improvements worth pursuing	Insignificant performance issues or effects
Lighting	Occupancy sensor control	Lighting power density
	Other lighting controls	
HVAC	Equipment part load performance	Equipment efficiency
	Variable speed fan control	
	Variable speed pump control	
	Economizer	
	Fan system efficiency	
	Equipment sizing	
	Zone control	
	Supply air temperature control	
Envelope		High performance windows

ii. Roles and Attitudes of Key Market Actors in Measure Effectiveness

a. Residential Owners and Home Buyers

The roles and attitudes of homeowners and buyers are well described in Barakat and Chamberlin (1997). According to this study, home purchases involve purchases of a package of desirable housing characteristics, including location, number of bedrooms and bathrooms, square footage, lot size, style, energy efficiency, etc.

In principle, homeowners have multiple incentives to purchase energy-efficient homes, including lower energy bills, increased comfort, and greater control of the indoor environment. However, they also face a number of barriers to purchasing energy-efficient homes. An important barrier is lack of information. Many home owners and buyers lack even basic information about the existence of energy-efficient measures. They also lack the information and technical expertise to weigh trade-offs in long-term costs and benefits, assess risks, gauge the credibility of energy efficiency claims, etc. Another serious barrier is the inseparability of home features. Simply put, energy efficiency may not be packaged together with other home features that rank higher on the buyer's list of purchase criteria.

b. Residential Home Builders

According to RER (1999), production builders are typically large corporations with internal departments and managers who handle a variety of functions including subdivision design and planning, home design, construction, marketing, and sales.

According to Barakat and Chamberlin (1997), home builders (including general contractors and developers) are motivated primarily by economic decision criteria. Their business priorities focus on minimizing construction costs, maximizing home sale values, minimizing construction project time, and minimizing performance problems for which they may be liable after the sale. The same study developed quantitative estimates of the importance builders place on various attributes that contribute to a home's marketability. They found that "[a]s a group, builders perceived location to be the most important criterion, followed by floor plan, sales price, square footage, style, and finally, energy efficiency." Builders' perceptions appear to be generally consistent with study findings regarding homeowners. Cost was repeatedly mentioned, as either a key driver or one of the key drivers for builder decisions, in the interviews we conducted during this project. Costs stemming from performance testing itself and from delays associated with inspections were cited as barriers to increased used of diagnostic testing.

Builders face several barriers to incorporating energy efficiency into their products. For example, builders do not directly benefit from the bill reductions that result from adopting energy efficiency. Builders are somewhat limited in their ability to analyze the trade-offs among alternative energy efficiency measures. This stems from their reliance on Title 24 consultants, who report energy impacts only as achieving or not achieving code compliance. Finally, builders are limited in their ability to specify energy efficiency to bidding contractors.

c. Residential Designers

Production builders develop design concepts internally, typically by a team that includes designers, architects, marketing and sales personnel, and senior management (RER, 1999). Factors that go into the design decisions include target buyer demographics and home features known to be popular among the target group. Characteristics such as square footage and number of rooms are designated and passed on to an in-house or contracted architect, who then prepares floor plans and building elevations. Title 24 compliance documents are prepared by a contracted Title 24 consultant, who recommends any needed design changes to the architect.

d. Residential Contractors

According to Barakat and Chamberlin (1997), contractors are motivated by the need to succeed in competitive bidding processes. Builders evaluate bids on three criteria: cost, ability to meet the construction schedule, and the ability to work without causing the builder undue hassle (e.g., call backs). Thus contractors have an incentive to adopt changes in construction practices that reduce their costs, streamline the construction process, and improve their work product.

HVAC contractors are responsible for determining the specific HVAC equipment and insulated ductwork that will meet the bid specifications. Selection of energy-efficient equipment tends to increase project costs. HVAC contractors are also responsible for determining ductwork sizing, register placement and size, and how the system is balanced. Their decisions are often limited by the need to install ductwork in whatever space is left by the builders, resulting in undersized ducts and numerous corners. HVAC contractors do not generally understand air flows.

Insulation contractors are responsible for determining the specific insulation that will meet the bid specifications. Their decisions are often limited by prior construction decisions. For example, fiberglass batt insulation beyond R-15 typically requires 2"x6" framing instead of 2"x4".

e. Secondary Market Actors in the Residential Sector

According to Barakat and Chamberlin (1997), Realtors play important roles in the home purchase process because "[t]hey are often homeowners' only source of information regarding the characteristics of the homes they are considering and the value of those characteristics. They also often control the sample of homes from which the homeowner chooses to purchase." The report cites Realtors' motivations being to enhance their sales commissions, minimize the time it takes to sell a home, and protect their business reputations. Sales commissions are tied to sale prices and sales volume.

The same study also cites mortgage lenders as important sources of influence. Lenders control the amount of money a homeowner can borrow. Unless the lender understands the connection between energy efficiency and the buyer's ability to make mortgage payments, the buyer may have to make trade-offs between energy efficiency and other factors that drive sales price (e.g., size and location). Lender motivations focus on avoiding risk, maintaining the ability to resell mortgages, and earning commissions through up-front points and fees, which generally are tied to mortgage value. As of 1997 there was only a weak secondary market for energy efficiency mortgages in California, consisting of a FHA program and the lenders Country Wide and Norwest.

f. Nonresidential Building Owners

According to RLW Analytics (1999), owners originate the project but may or may not be the ultimate users of the building. Because owners provide the financing for the work, they have responsibility for final approval of construction details (including any energy efficiency options) and project budgets. The study research findings support the general conclusions that building owner priorities focus on minimizing construction costs, maximizing the value of the finished building, minimizing construction project time, and minimizing performance problems for which they may be liable after project completion.

g. Nonresidential Designers

According to TecMRKT Works (1998), the role of architects and other design professionals in the nonresidential sector depends on the decision-making model adopted. The report describes three such models: (1) a traditional architect-driven plan/design/build model; (2) the design/build model; and (3) the collaborative model.

In the traditional architect-driven plan/design/build model, design precedes construction. The owner engages an architect, usually through a solicitation or competition, who then develops the schematic and manages development of detailed plans and specifications. Design specialists (typically mechanical, structural, and electrical engineers) are often involved in developing the detailed designs and specifications for the HVAC systems, electrical systems, safety and security systems, etc. With drawings in hand, the owner then solicits bids from contractors to construct the building. In principle, this model makes the owner, architect, and supporting designers the key decision makers in the design process and provides for fully integrated design solutions. In practice, full integration does not always occur.

Design/build models offer the advantage of speed. Design and construction are completed on parallel tracks. This model gives the general contractor an important role in developing design solutions. As a consequence, design tends to be formula driven and the level of analysis and integration may not be very high.

The collaborative model has been developed to address integration and quality issues. In this model, the owner hires an interdisciplinary team of architects, design consultants, and contractors. This approach stresses collaboration and coordination to achieve an optimal combination of cost, quality, function, scope, and time to meet the clients' needs. TecMRKT Works (1998) notes that the commissioning literature discusses the need for integration but does not address how such

integration should occur. The report suggests that the collaborative model addresses the need for greater integration in the design/construction process.

h. General Contractors

As previously indicated, the role of the general contractor depends on the construction model the owner adopts for the project (TecMRKT Works, 1998). Under the plan/design/build model, the contractor has little design responsibility but is exclusively responsible for carrying out the design in the construction phase. In the design/build model, the contractor, the design and construction process occur on parallel tracks. Many decisions that the architect's design team would make in the plan/design/build model are made in the course of construction by the contractor in the design/build model. In the collaborative model, design issues are fully resolved before construction starts but the contractor has a role in the design process, just as the architects and designers have a role in the construction phase.

B. OPPORTUNITIES TO IMPROVE MEASURE INSTALLATION EFFECTIVENESS

In the early stages of this project, several interventions were identified as possible candidates for improving the construction industry's effectiveness in installing targeted energy efficiency measures. During the literature and industry expert interviews we conducted, we probed these and identified other candidates to help formulate a set of intervention recommendations we could make as the final product of this study. These candidate strategies were:

- Diagnostic testing and third-party inspections (in the residential sector)
- Building commissioning (in the nonresidential sector)
- Linkages between construction quality and liability insurance concerns
- Linkages between construction quality and financing considerations
- Linkages between construction quality and other energy-efficient building initiatives

In this section, we discuss our findings about the candidate opportunities, barriers to their implementation, possible solutions to these obstacles, and, ultimately, which ones seemed worth presenting and evaluating at the focus groups.

i. Diagnostic Testing and Third Party Inspections

For the purposes of this project, the opportunity to improve measure installation effectiveness through diagnostic testing is focused on insulation installation and HVAC design and installation. For insulation installation and other envelope sealing steps, industry experts have advocated expanded training for the installers and a quality control mechanism capable of intervening before any problems are covered over and hidden. For HVAC systems, industry experts have advocated adoption of a systems approach to design and construction, which includes a mechanical design of the HVAC and ducts as part of the initial blueprints; making sure designs are followed; and performance testing of the ducts and HVAC system. For convenience in the following discussion, we refer to a comprehensive system of design, inspection, and performance testing, covering both HVAC systems and envelope construction, as "diagnostic testing."

There is some difference of opinion within the industry whether efforts to promote performance testing should focus on standard production homes or on large custom homes. On the one hand, one can argue that the potential for large energy savings and the complexity of large custom home construction makes these projects the preferred candidates for testing. On the other hand, the sheer volume of production houses amplifies the energy impacts of even minor construction defects, if repeated on a broad scale.

a. Trends in Diagnostic Testing and Third Party Inspections

The most recent changes to Title 24, adopted in July of 1999, incorporate duct design and testing and building envelope sealing as optional compliance approaches. The full impacts of those changes have yet to be seen. Builders pulled large numbers of permits prior to the adoption date. Many of those homes are still under construction. As more builders gain experience and confidence with these new compliance credits, one may expect to see an increase in duct design testing and envelope sealing.

The EPA/DOE ENERGY STAR® Homes Program incorporates diagnostic testing as a requirement for home certification. The labeling program appears to be gaining momentum as a common platform for designing utility programs. Every major utility in California is instituting programs that promote ENERGY STAR buildings.

The preponderance of diagnostic testing and third-party inspections currently being conducted on residential construction is done in association with energy efficiency programs administered by a utility or governmental agency. However, in the private sector, a few builders test ducts simply to

promote quality homes. ConSol's ComfortWise Program stands out as a user-funded initiative that adopts a systems approach, including performance testing, to deliver high-quality, comfortable homes. This program does also receive some utility funding. ConSol reports that diagnostic testing is a growing business. ComfortWise claims to have 6,000 homes in pipeline[3]. Over time, ConSol hopes to secure 20-30% of the new home construction market. ConSol also reports that on-site training in diagnostic testing completed between 1995 and 1998 in California and Nevada was very popular with builders and their subcontractors. Contractors who thought that they were installing tight ducts could see where and how much leakage was occurring (Buildings Industry Institute and ConSol 1998).

b. Impediments to Diagnostic Testing and Third Party Inspections

Despite the apparent benefits of performance testing, the practice has not been adopted on a wide scale to date. There appears to be broad consensus among industry experts on the reasons contributing to its limited appeal.

- Lack of awareness of the extent of construction defects on the part of builders. Performance testing sells what the builder thinks he already gets.
- Lack of awareness of the potential to avoid liability, callbacks, and litigation. Particularly lacking is an understanding of performance testing impacts on indoor air quality, moisture control, health and safety. More research in these areas is needed. According to some reports, indoor air quality may not be an important issue in California due to the relatively dry climate.
- Additional costs, not just first costs, but the costs of marketing. Also, if builders have to include the cost of testing in their bid, it makes them less competitive with other builders who don't use it and have lower costs.
- Unwillingness of home buyers to pay for performance testing. They assume the home purchase price should already cover correct installation. Consumers expect the systems to work, so offering energy efficiency and functional systems as an upgrade has limited appeal.
- Lack of knowledge, skill, and ability on the part of contractors. This barrier may be mitigated by contractor certification, which is gaining momentum through Air Conditioning Contractors of America (ACCA).

[3] Confirmed in discussion with Rob Hammon, August 2000.

- Potential for project delays due to a lack of performance testing infrastructure. Particularly in Southern California, the list of qualified raters is small (except in San Diego County). Builders cannot be certain of existing raters' ability to inspect construction projects without interrupting the work flow.

- Lack of awareness of who the service providers are.

- Lack of standardized methodology and testing procedures that would make the process of diagnostics more efficient, cost effective, and accessible. Also need more uniform standards relating to air pressure balancing (safety issues) and airflow and refrigerant charge. CEE is assembling "national" standards on installation. PG&E is working on uniform standards for installation quality.

Numerous suggestions were also made about how some of these obstacles to increased building commissioning can be removed. These include:

- Educate builders on the value of diagnostic testing. They need training on how to market benefits of higher quality homes and documentation showing increases in sale value, and reductions in liability.

- Compile data on the effects of diagnostic testing on the speed of home sales and their sale value.

- Offset or eliminate testing costs. Selling diagnostics as an energy efficiency program just doesn't work. The cost is seen as too high even though it is relatively low. To get it off the ground, testing should be free and emphasis should be placed on showing that building quality issues are prime concern. Perhaps offer tax credits for diagnostic testing to offset costs.

- Include Title 24 specialists in the building process from start to finish. Structural observation should be required of Title 24 specialists so that they ensure the project adheres to their original plan.

- Simplify the Title 24 codes so that builders can easily understand and comply with them.

- Utility support is important at first. Conditions for withdrawing utility support: established testing infrastructure, mechanism for continuing education, demonstrable benefits, and lower cost of tests.

- Mandate tight ducts in Title 24. Home builders resist changing construction mandates in the middle of projects but could incorporate testing in new projects.

- Third-party inspections may not be essential. Could have HVAC contractor or builder do testing as long as there is the potential for audit/QC inspections. While overall compliance was found to be low in California, there may be regional variation. SCG's past QC inspections have found good compliance with Title 24

- Provide testing equipment, tool lending program, field training, feedback loops from diagnostic tests to designers.

c. Opportunities to Improve Measure Installation Effectiveness Through Diagnostic Testing and Third Party Inspections

Significant benefits to construction market actors.

Builders are expected to benefit from diagnostic testing significantly. First, reduced litigation is potentially a big benefit because 60% of litigants win. Sources report construction defect cases valued in the $100 millions have been lost in San Diego County. Second is improved customer satisfaction. Customers have tangible evidence of high-quality construction which in turn improves the builder's reputation. Finally, builders that are known for performing testing distinguish themselves from the pack; their products can be perceived as better.

HVAC contractors are expected to benefit from performance tests. By identifying problems immediately, contractors can reduce callbacks. From the buyer perspective, performance testing improves home quality, particularly if it is done as part of a systems approach to construction. Without testing the mechanical systems, consumers do not know whether those systems work properly.

Provides tangible evidence of measure installation effectiveness.

One of the prerequisites for the successful implementation of a program that promotes greater energy efficiency in houses is a perception of fairness. This is true whether the program is related to code enforcement or incentives for greater energy efficiency. For example, some governmental jurisdictions have experimented with varying electric utility connection fees with the measured energy efficiency of the house. A program such as this requires a precise measurement of energy efficiency for its implementation. Some in the industry are not convinced that a HERS rating alone is a precise enough measuring device on which to base the size or determination of incentive payments. It is felt that when a blower door test is combined with a HERS rating, however, the necessary precision can be attained (Wirtshafter and Hildebrandt 1992). In this way, diagnostic testing could have noticeable impact on measure installation effectiveness.

Directly addresses the systems that promise most cost-effective energy efficiency.

Perhaps the strongest opportunity offered by the use of diagnostic testing is that the most widely discussed tests measure the effectiveness of systems that promise the most cost effective energy efficiency. Simulation results indicate that the most cost-effective energy efficiency measure is the reduction of outside air infiltration. A number of varying steps can be taken to reduce outside air infiltration, however, the effectiveness of all of them can be measured using a blower door test (Wirtshafter and Hildebrandt 1992). Another study indicates that 30% to 40% of residential HVAC energy consumption is lost through leaks in the ducting system due to poor installation. Seventy-five percent of the air loss was from the supply ducts and 25% of air loss was attributed to the return ducts (Syphers, Lekov et al 1998). Duct tests are also among the most widely discussed in the literature. The need for diagnostic testing of ducts is underscored by the wide variation observed in duct system efficiency and envelope leakage levels in different houses (Wray, Piette et al 1999).

Increased compliance with Title 24.

Another way that third-party inspections and diagnostic testing can improve measure installation effectiveness is in increasing Title 24 compliance. Title 24 compliance studies completed in the mid-1990s found that the compliance rate in California houses is the generally low. For example, a 1994 study of 133 buildings found that every building had at least one Title 24 discrepancy, 35 of the 93 residential buildings monitored did not meet overall energy standards (Valley Energy Consultants 1994) Although this may also reflect the complexity of Title 24 and/or the lack of enforcement on the part of building code officials, it still would indicate a need for further testing or inspection of buildings to enhance energy efficiency. A similar study showed homes participating in the Comfort Home Program, which has a third-party inspection and testing component to it, were more energy efficient as measured by Title 24 compliance and duct efficiencies. Participating homes had twice the compliance margin of non-participating homes (Eley Associates 1994).

We concluded that diagnostic testing and third-party inspections warranted additional consideration and testing in the focus groups.

ii. Building Commissioning

As we learned when we initiated this project, there are many different definitions of what commissioning implies. For the purposes of this project, we used the definition offered by Bjornskov, et al. (ACEEE 1996) “Commissioning is a systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all building facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owners operational needs, including preparation of operation personnel.” We consider building commissioning to include the following seven elements:

1. Commissioning plan at the predesign phase

2. Independent commissioning agent from outset
3. Customized test plan as part of project design documents
4. Review systems installation throughout and oversee functional testing
5. Operation and maintenance manuals and plans
6. Training plans
7. Final commissioning report for building owner

Commissioning has historically been done for buildings that have complex energy systems, high energy use, or for owners who value a high quality of indoor environment. Examples of such building types include government buildings and complexes, hospital and healthcare facilities, large commercial buildings, universities and owners who are responsible for establishing on-going building programs. (Dodds, Dasher et al 1998). Big companies, like Genentech, for whom system performance is critical, now practice system-level design and commissioning on a routine basis.

a. Trends in Building Commissioning

While building commissioning has made significant inroads in selected industries, it has yet to become "business as usual." Estimates suggest that less than 5% of all new construction and less than 0.03% of existing buildings are commissioned each year (Dodds, Dasher et al. 1998). Nevertheless there is a significant surge of interest in commissioning and recommissioning of buildings, which is being driven by energy efficiency and indoor-air quality (Claridge, Haberl et al. 1994). Expert informants cited a number of qualitative observations that indicate growing interest:

> "There seems to be more and more instances of case studies and success stories. At the National Commissioning Building Conference every year there are more participants. It's not just a small group."

> "It's finally growing because technology is improving. Some systems now you have to commission just to make sure they work, not just whether they are installed properly or to function most efficiently."

> "People are beginning to understand how and what it means to commission a building. People are learning about it through utility workshops, trade journals, ASHRAE, commissioning conferences, and indoor air quality forums."

"There is an opportunity for improved energy efficiency in the retrofit market. Property management firms and real estate holding companies have an interest in reducing operating expenses and can often be interested in improving their buildings."

b. Impediments to Building Commissioning

Despite the growing interest, there remain a number of significant market barriers to widespread adoption of building commissioning. Many studies list barriers to successful commissioning such as

- No one wants to take responsibility for building performance problems. In the current construction process, there is handoff among many players and accountability is lost.
- Additional project costs associated with commissioning, in the form of extra time and paperwork. Builders don't budget for it; they don't see commissioning as part of the construction process. Marketing it is expensive.
- Lack of awareness of the energy benefits and long-term economic savings benefits of commissioning. Building owners do not see the value of commissioning and they think they should not have to pay extra for something that should be included in the initial purchase (the assurance that the systems are installed properly). Owners do not see the value of asking for it and builders do not push it because they do not realize the value.
- Lack of a clear understanding of what building commissioning implies. The market actors do not all realize that buildings have become far more sophisticated and old practices are not enough. There is no commonly agreed definition of commissioning.
- Lack of commissioning expertise. Those conducting the commissioning lack knowledge of what to test and how to test it.
- Lack of a standardized methodology and testing procedures that would make the process of commissioning more efficient, cost effective and accessible. The IPM&V Protocol is an overly expensive standard for testing. Simpler protocols would address majority of problems with minimal effort. Commissioning advocates want expensive M&V (measurement and verification) to avoid risk. But the industry needs simpler M&V tools and procedures to make commissioning affordable.

- Skepticism on part of building owners and managers that a proposed Energy Conservation Measure (ECM) is going to work. People feel like they would be paying for something they should already be getting.

Numerous suggestions were also made about how some of these obstacles to increased building commissioning can be removed. These include:

- Make additional commissioning information more readily available (guide specifications, commissioning plans, guidelines, test procedures). Common training material developed by the Association of State Energy Research and Technology transfer institute with funding from U. S. DOE was successfully used in the Northwest and Wisconsin (Dodds, Haasl et al 1994). Perhaps develop a handbook that tells exactly when/where/how commissioning should be within the construction process. Perhaps develop metric for measuring the benefits of commissioning as part of DOE's International Performance Measurement and Verification Protocol.

- Facilitate training/certification for building commissioners by state. Maybe let private sector and/or universities handle this but maybe have the code define what is expected by commissioning. Ideas are: design an internship program or introduce commissioning into the standard curriculum for architecture and engineering programs; develop one-day lesson plan materials for commissioning to increase the likelihood that faculty would include commissioning in their course work.

- Initiate studies on costs and benefits of building commissioning, including a quantitative cost-benefit analysis of commissioning relative to 'non-energy' benefits, such as improved air-quality, better work environment resulting in higher productivity. (Dodds, Dasher et al 1998).

- Involve the federal government to promote commissioning through marketing efforts, provide funding for commissioning, demonstration projects, cost-effectiveness studies, develop a commissioning curriculum for engineering and architecture programs, requiring commissioning of all government performance contracts-especially for military bases.

- Incorporate commissioning into current energy programs, such as EPA's ENERGY STAR Building and Labels programs and Green Buildings program. Third-party initiative program gives smaller contractors and independent firms a chance to learn about better marketing skills and about building "tune-ups" or recommissioning.

- Tax incentives or other financial incentives were identified as an important strategy that the federal government could use to encourage building commissioning (Kunkle, York 1999).

- Encourage mechanical engineer involvement throughout building process. Start at the design phase and look for opportunities to optimize performance through the installation process. The key intervention often involves getting the mechanical engineer on the right track to design an energy-efficient system.

- Leave commissioning to private market actors. If we let "quality performers" do the commissioning themselves, they will do it, and they will do a good job. Many of the quality contractor firms will learn how to commission simply to carve out their own niche and make a name for themselves as quality builders. They will use it as a selling feature for their services.

- Educate all market actors. Educate the owners and architects and engineers and standardize the commissioning process in general.

- Offer small incentives for testing rooftop units.

- Simplify the protocols. Simpler protocols would allow the industry to capture 80% of the benefits with only 20% of the effort. Develop simpler monitoring equipment and software for analysis. Need to automate monitoring activities.

- Air quality and productivity issues provide particular opportunities to link building commissioning with insurance liability issues. Quantifying those links will be difficult but worth it. Insurance industry executives have already shown interest in funding additional research, though they may not yet be ready or willing to lower rates for commissioning.

c. Opportunities to Improve Measure Installation Effectiveness Through Building Commissioning

Benefits for builders.

If buildings are commissioned they have proof of being better buildings. They should have lower insurance/liability. The quality of the building is better. Customer complaints will be reduced. Many of the quality contractor firms will learn how to commission simply to carve out their own niche and make a name for themselves as quality builders. They will use it as a selling feature for their services.

Increased understanding of the value to market actors.

Making building commissioning a requirement will focus attention on the need for both consumer and builder/contractor/inspector education. These resources will become more readily available, perhaps through PGC funds at first and then by trainers/providers seeing an opportunity to sell their services. Making information and training more readily available increases the likelihood of use.

Encourage building design to address energy efficiency and achieve it.

Commissioning allows accountability and documents design intent so the end result mirrors the initial design. Provides feedback too for construction team so they know where the problems exist; documents the front-end information and reconciles it at the end.

Focus on major factors in energy use in buildings.

Effective commissioning of building HVAC and control systems has been increasingly identified as a major factor in ensuring the energy effectiveness of the building. Proper commissioning reduces energy consumption, increases occupant comfort, improves indoor air quality, and lengthens the life of equipment. Significant amounts of energy are wasted each year in commercial buildings due to inefficient operation of HVAC equipment. Increased energy consumption of 10–35% is not uncommon due to what appear to be minor adjustments to equipment and controls. Commissioning on buildings at Texas A&M found that they saved 28-50% on average in some situations.

We concluded that, using the suggestions for improving the acceptance of building commissioning, this intervention candidate warranted additional consideration and testing in the focus groups.

iii. Links to Liability Concerns

While there are many aspects to construction liability, many of them are not related to energy efficiency. Our review of liability concerns covered both residential and nonresidential construction. We focused on the key measures identified earlier: building envelope (residential), lighting control systems (nonresidential), and HVAC installation and design (both).

Types of liability insurance related to energy efficiency include:

- *Completed operations liability:* This insurance provides coverage for bodily injury and property damage arising from completed or abandoned operations, provided the incident occurs away from premises owned or rented by the insured. The best way of avoiding these problems is making sure the equipment is designed and installed properly, the focus of building code development and compliance, as well as standard measurement and verification protocols. In

addition, because indoor air quality illnesses can result in large insurance losses, reducing the strength of indoor pollutant sources is commonly the best method to reduce indoor air pollution.

- *Comprehensive general liability:* This insurance means that the insurance company will pay all sums the insured becomes legally obligated to pay as damages due to bodily injury and property damage.

- *Contractors liability:* Contractors are liable for damages resulting from bodily injury and/or property damage caused by an insured peril and arising out of the ownership, maintenance, or use of premises and operations in progress. Building code development and compliance, measurement and verification protocols, energy management and control systems, building commissioning, as well as reduction of indoor air pollution and radon resistant housing are all examples of how this insurance loss can be avoided.

- *Product liability:* Product liability is the liability for bodily injury or property damage incurred by a merchant or manufacturer as a consequence of some defect in the product sold or manufactured, or the liability incurred by a contractor after he has completed a job as a result of improperly performed work. Building commissioning is a process that can reduce product liability claims by making sure that equipment (and the building) is operating as designed.

a. Trends in Linking Effective Measure Installation to Liability Concerns

Builders are starting to see the benefits of improved measure installation in terms of reductions in liability and insurance premiums.

- Improved construction reduces callbacks and litigation costs for both builder and contractor. More and more, builders are looking for ways to cut costs and the high-quality builders see that these reductions can help do that.

- Virtually every category of insurance (from property and liability, to health and life) benefits from better construction practices. In particular, lower claims in professional liability for builders is significant.

b. Impediments to Linking Energy Efficiency to Liability Concerns

- There is a consumer perception that energy efficiency “improvements” can go awry and lead to fire, sick building syndrome, etc. While not entirely true, this is not entirely false either.

- It is important for people in the energy efficiency arena to be aware of the potential risks involved with being more energy efficient. For example, vinyl windows are heavily promoted in the energy efficiency arena but they melt and can cause fires. Tighter sealing can result in air-quality issues.

- Insurance premiums are differentiated to support loss control, to reward low-risk customers. Need data to justify reductions in premiums.

- DOE Building America program claims to have reduced callbacks but offers no data.

- Insurance carriers interested in actuarial data to justify reducing premiums for builders who use improved construction methods.

- Costs are tangible but benefits are fuzzy. Extra costs include tight ducts, Low-e glass (for low heat gain), installation protocols for insulation, diagnostics.

Suggestions were made about how to promote higher quality construction as a means of reducing insurance premiums and losses and managing risk. These include:

- Provide long-term warrantees on new homes.

- Document benefits. Data should be actuarial quality and should document benefits from reduced litigation exposure. The insurance regulators need to be convinced that this is a good thing. There is not much quantitative data on this yet.

c. Opportunities to Improve Measure Installation Effectiveness Through Links to Liability Concerns

Insurance carriers interested in actuarial data to justify reducing premiums for builders who use improved construction methods. This creates the potential for improved measure installation to reduce insurance.

Provides ongoing benefits to builders.

Linking premiums to quality and efficiency would give a much stronger signal than utility rebates. Unlike rebates, insurance credits are recurring so they would repeatedly incent.

Helps builders meet their own business objectives.

Building codes in particular can "join forces" with the insurance community and it's really a natural link. The issues that are faced by the energy and insurance industry are not unlike those faced by this community. For example, if you have missing insulation, it is not only an energy efficiency issue, but an insurance issue as well.

We concluded that linking quality construction with liability concerns warranted additional consideration and testing in the focus groups.

iv. Links to Financing

Energy efficient mortgages (EEMs) provide mortgage insurance to purchase or refinance a principal residence and incorporate the cost of energy efficient improvements into the mortgage. All buyers who qualify for a home loan qualify for the EEM. The EEM is intended to give the buyer additional benefits on top of their usual mortgage deal. The lender will use the energy efficiency of the house, as determined by a HERS rating, to determine what these benefits will be. Energy efficient mortgages can be done on most homes, and availability is not limited by location, home price or utility company.

Homeowners and home buyers generally have two sources of loan options to improve their homes: through federally-sponsored programs or through private loaning institutions (including utility programs). These options are discussed in the Literature Review appendix to this report.

a. Trends in Linking Effective Measure Installation to Financing

Interest in providing consumer financing for energy efficiency improvements began back in the 1970s during the energy crises. When energy efficiency financing was first introduced in the early 1980s, it exhibited very little success. Most of the literature reviewed attributes this not to lack of interest, but rather to several other factors, including perception of increased risk to the lender and lack of consistent energy rating systems or trained raters.

Since about 1992, there has been another push in the marketplace for energy efficiency financing programs. More market actors are getting involved, and lenders and consumers alike are beginning to see the value of owning a more efficient home, however participation in such programs continues to be low. The following sections describe the latest types of energy efficiency

financing that currently exist in the market place, as well as the barriers that continue to impede the programs.

Strides have been made in reducing resistance to EEMs. First, there have been numerous industry-based groups established, dedicated to removing market barriers, promoting energy financing, helping to create other rating organizations, and promoting energy ratings at national and local levels. Also, federal agencies seem to have shifted their focus from being regulators in the 1970s to facilitators in the 1990s. With the establishment of the ENERGY STAR Homes program, for example, EPA is working to promote efficiency and increase market demand, rather than simply regulate what efficiency guidelines and standards should be. Nonetheless, EEMs have not really taken off.

b. Impediments to Linking Energy Efficiency to Liability Concerns

There are apparently considerable obstacles to linking improving construction practices to financing. Reasons why lenders might not offer EEMs include:

Real estate professionals are not very informed about the availability of EEMs and how to use them in marketing real estate.

- Most builders are not aware of the benefits of EEMs. Resnet.com did a survey where they hypothesized that 100% of those applying for home mortgages would have received $5000 more through an EEM.

- Lack of adequate funding to successfully market EEMs to consumers and small profit potential. Lenders do not view energy efficiency financing as a profitable lending area due to overall weak consumer demand.

- Energy efficiency documentation creates additional paperwork and can slow a loan process already overburdened. There is a perception that EEMs require a lot more paperwork than they actually do.

- Commonly used lender and real estate forms do not convert readily to include financing of energy-efficiency products.

- Perceived risk--the secondary mortgage lenders have little enthusiasm for energy efficiency loans because of the increased potential for loss if the loan defaults (Verdict 1996)

- Appraisers don't consider energy efficiency improvements in assessing home.

- Need cooperation from both lenders and Realtors. Realtors are not interested because auditors come in and have to deal with disclosure issues which can jeopardize the sale.

- Most lenders don't really care about energy efficiency. Their bonuses are tied to the bottom line ($$). That is why a lot of energy efficiency projects don't go through. Energy efficiency is not valued as important.

- With respect to lenders, barriers can not be overcome with the types of programs we've seen in California. Must convince lenders that there is value in commissioning; that it makes sense from a financial point of view.

- In some cases, lenders have said they need simple tools that simply measure and then they need to be able to compare their building against other buildings. There needs to be a baseline and a way to compare that baseline to make sure it if meaningful.

Suggestions were made about how to encourage the availability of EEMs. These include:

- Certifications for products they install (e.g., HVAC contractors), making them test for and receive a certification at the federal level. This would also ensure common best practices.

- Policy intervention at the level of the national appraisal foundation. They are working with them already to put in uniform appraisal factors. If energy is introduced, it would overcome some of these barriers. One policy option under consideration is that of the Wall Street Initiative. This would be to standardize the way appraisers report line items. Appraisers, unlike other market actors, operate under standard rules, forms, etc. There is a lot of leverage there to introduce such things as energy into policy options.

c. Opportunities to Improve Measure Installation Effectiveness Through Links to Financing

According to one author, significant marketplace changes and removal of institutional barriers are causing renewed interest and guarded optimism about the future of energy efficiency financing (Verdict 1996).

There certainly are potential benefits to lenders. But, as one industry expert put it, "The benefits are not that great, and certainly not that obvious." Lenders can use EEMs as a sales tool to differentiate themselves from others. The projects are much larger, so profits are likely to be greater.

We concluded that linking quality construction with financing was not promising enough to warrant additional consideration and testing in the focus groups.

v. Links to Other Building Energy Efficiency Programs

Efforts to improve building construction and the standards process might be linked with other energy-efficient building and "green" building initiatives. We reviewed several programs in or near operation. These were:

- CHEERS
- City of San Jose Green Buildings (program under development)
- City of La Quinta
- City of Irvine IQ+ Construction Quality Building Program
- City of Santa Monica Green Building Program
- County of Santa Barbara's Innovative Building Review Program (provides incentives for buildings that exceed Title 24 by 20%, 30% and 40%)
- ComfortWise (Consol's privately run, residential new construction DSM)
- State of Minnesota Department of Public Services (state energy code which includes diagnostic testing requirements for residences)
- Sacramento Municipal Utility District (residential and nonresidential new construction program)

- Texas Lone Star Program
- Local Energy Assistance Program
- Certified Plus Home Program in Fresno
- PG&E programs:

    Comfort Home (Central Valley)

    ENERGY STAR (CHEERS raters inspect ENERGY STAR homes)

    Savings by Design

    Local Government Initiatives Program

    Codes & Standards Program

Our literature review and interviews also revealed a number of other programs underway or under development throughout California, including: programs in Anaheim, Chula Vista, Carlsbad, Santa Clarita, and Riverside County. A further development in creating links with the standards process is the increased coordination in efforts among utilities, the CEC, and Building Industry Institute (BII). Additional programs operated by the California IOUs are described in Appendix E.

a. Program Goals and Incentives to Builders and Developers

- Simple program application process (1 sheet, 2-sided). Sets three targets for increasing green building construction. Rewards each with increasing benefits. Targets reached by exceeding Title 24 and scoring energy points, as defined on the application sheet. Target 1: 20% beyond Title 24 and 4 energy points. Target 2: 30% beyond Title 24 and 12 energy points. Target 3 40% beyond Title 24 and 30 energy points.
- Nonresidential projects can get credits for low-emission paints and solvents, water conservation measures, and construction waste management plan.
- Key benefit is quicker approval process which can save several weeks. Note that the building permit process is expedited but not the planning review process.
- Goal for city's Green Building Program is to achieve efficiencies that exceed Title 24 by 25%. The program is for multi-family housing and commercial new construction.

- Examined possibility of incenting developers to exceed Title 24 but learned that it would be far too expensive (incentives totaling at least 3% of total project costs). Wanted to avoid developing a program that simply offered a prescriptive process by which builders could just barely meet the minimum requirements.

- The Green Building Program has very few rules and is not based on Title 24. It simply states that the resulting building must achieve performance levels that are 25% above Title 24. The Program results in an Energy Performance Ordinance. Specific equipment types and/or materials are not specified (as in Title 24). The city has developed a "cookbook" of green building practices that was peer reviewed by green building experts.

- San Jose Green Building program includes all players in the construction market; architects, engineers, Realtors, builders, building owners, homeowners, educators, loan agent, etc. Incentives are not yet finalized but all players are being asked how they might best benefit from a "green" building program.

- Program has a review committee that reviews plans, assigns points. Program encourages preliminary review before serious design. Committee has a Title 24 consultant. Once project plans are scored, building inspector can check that scored items actually implemented.

b. Problems and Challenges Implementing Programs

- Project needs to identify more incentives to participate. Eventually improvement in marketability of buildings should add partial incentive to participate.

- Program needs to develop better-documented relationships between point assignments and measure benefits. Need lifecycle call back analysis of measures. Currently, point structure based on expert judgement.

- Any statewide program should offer flexibility to address local land use, water issues. Program would need education component for builders/developers. Need case studies by climate zone, demonstration projects, monitoring studies.

- CEC can facilitate but not mandate non-energy benefits. California needs a state ombudsman for all resource conservation who can review all kinds of technologies and construction practices for range of resource conservation benefits. (e.g., low-flow showers, toilets, composting toilets).

- Architects and builders have great flexibility with program but the implication is that they must understand energy issues and the impact of design and system changes. To help, city has developed a software program that will be made available free of charge. The software assists users in testing their projects and is also capable of suggestion changes. Software is available free of charge.

- The city will require that all proposed projects be modeled at the permitting stage so that their compliance with the Energy Performance Ordinance can be determined.

- In recognition of the difficulty of executing the program, the city plans to invest in training and educating their own building inspectors.

We concluded that linking quality construction with other energy efficiency programs was not promising enough to warrant additional consideration and testing in the focus groups.

C. Opportunities to Influence Standards

i. Overview of Standards Development and Implementation Processes

The CEC as well as other government agencies, utilities, and third parties all contribute to the development and implementation, including enforcement, of the California building standards.

a. CEC Role in Standards Implementation and Development

The CEC contributes to the standards implementation process in two key ways—by offering training courses for energy consultants, building officials, HERS raters, contractors and other building industry market actors; and through the following technical assistance and implementation support mechanisms:

- Preparation of residential and nonresidential manuals: The *Nonresidential Manual for Compliance with the 1998 Energy Efficiency Standards* is provided to meet the requirement of this section. The Manual includes compliance method descriptions, calculation procedures, technical data, examples, and sample compliance forms for meeting the standards for nonresidential buildings, high-rise residential buildings, and hotels/motels.

- Development of an alternative calculation method and associated software: The Nonresidential Alternative Calculation Method (ACM) Approval Manual is intended strictly for those persons who want to design a calculation computer program for use with the energy standards.

- Compilation of a list of approved computer programs for determining building compliance with codes

- Maintenance of an information hotline: The Energy Hotline is run by the California Energy Commission's Efficiency Division, and provides callers with comprehensive and timely technical information on how to comply with the Title 24 Building Energy Efficiency Standards and information on appliances certified for sale in California. It is used daily by hundreds of utility, building and energy professionals.

- Publication of a regular newsletter, *Blueprint*, for building professionals.

- Publication of the *Home Energy Guide*, which provides energy efficiency tips for homeowners.

- Publication of *Six Steps to an Energy Efficient Addition*, which provides guidance to homeowners for completing energy compliance forms: This step-by-step guide aimed at helping homeowners correctly fill out detailed forms. It is currently under construction at the CEC website.

- Certification of home energy rating services: These services are to also include field verification and diagnostic testing available through Commission-certified providers and their raters when duct efficiency and envelope leakage measures are installed for complying with the new 1998 building efficiency standards (effective July 1, 1999).

- Establishment of protocols for "Quality Homes" technique to verify quality residential construction with diagnostic tools This online resource provides techniques to verify quality construction with diagnostic tools, and includes: protocols for energy-efficient residential building envelopes, procedures for HVAC system design and installation.

- Compilation of a roster of certified energy plan examiners for residential and nonresidential buildings: This online roster contains the names of individuals who have satisfactorily completed a voluntary certification program in which they have demonstrated a broad understanding of how to prepare and review building plans.

- Publication of a directory of certified equipment for residential space conditioning and water heating: This is an online directory that allows users to access listings of appliances which exceed California and federal appliance efficiency standards.

In addition to ongoing standards implementation activities, the CEC manages a standards development process that produces revisions to the standards every three years. Activities

associated with this process are cyclical in nature. A partial listing of CEC activities associated with the process includes

- Sponsorship of public workshops and hearings to address building energy research findings, compliance option development, public domain and approved calculation methods, HERS rating program regulations, and standards updates and
- Research and development related to building energy problems (e.g., the PIER program) and possible solutions to those problems through, among other things, standards changes.

Interested parties may submit proposals for changes to the standards to the CEC at any time. Proposals are reviewed by CEC staff, discussed in public hearings, and voted on by commissioners. Typically, hearings are attended by interested parties in the building industry such as manufacturers and professional associations for builders, contractors, and Title 24 consultants.

b. Other Government Agency and Market Actor Roles in Standards Implementation and Development

In addition to CEC-sponsored support activities, a number of other agencies and market actors play a role in the standards implementation process. Local government building officials play a primary role in enforcing the standards through plan checks and field inspections. BII, various utility programs, and the CHEERS program all engage in training energy consultants, building officials, HERS raters, contractors and other building industry market actors. Various utility programs also include compliance checking, diagnostic testing, HERS rating, and builder promotion assistance to market homes that meet and exceed the standards.

Enforcement is primarily the purview of local planning departments. The Warren-Alquist Act, chapter 5, section 25402.1, subdivision (g), states that "[n]o building permit for any residential or nonresidential building shall be issued by a local building department, unless a review by the building department of the plans for the proposed residential or nonresidential building contains detailed energy system specifications and confirms that the building satisfies the minimum standards established pursuant to subdivision (a) or (b) of Section 25402 and this section applicable to the building."

California utilities have had and continue to have a role in the development and implementation of building standards. We examined this role in greater depth in both our literature review and industry expert interviews, paying particular attention to the potential for expanding and increasing

the effectiveness of their role. The role of utilities in the standards process is discussed below in the section on opportunities to influence the standards.

When polled about their top priorities for future changes in the standards, representatives from California utilities, local government agencies, and third-party providers offered the following suggestions:

- Have the standards include Time Dependent Valuation (TVD), which opens the door to load shifting measures. During the last round of T-24 revisions, PG&E's T&D staff apparently pushed for inclusion of demand issues in Title 24. The cost of generating electricity varies by time of day and by season. These variations should be reflected in cost-benefit calculations that determine whether measures are cost effective for inclusion in Title 24.

- Model true performance of residential HVAC (nonresidential modeling just needs fine tuning). Avoid relying on bulk seasonal efficiency metrics such as SEER, AFUE, energy factor).

- Reduce nonresidential lighting power density

- Residential windows

- Residential insulation quality

- Shift tight ducts from ACM to mandatory measure

- Require commissioning and third-party inspections (but do not bypass local jurisdictions)

c. Barriers to Effective Implementation and Development of Standards

Despite the apparent benefits standards offer to energy efficiency, a number of barriers exist to their effective implementation. From the literature and our interviews, several problems were commonly cited, including:

- Complexity of the standards.
- Lack of understanding about the standards by builders, contractors, and designers.
- Low public support stemming from lack of understanding about benefits the standards provide.

- Irregular or inconsistent enforcement of the standards by local government, due to lack of interest or insufficient personnel.

- Infrastructure that does not encourage involvement of various stakeholders in suggesting changes to the standards. It was said that the CEC develops proposed changes and particularly wants to avoid new issues being raised at the hearings or Order Instituting Rulemaking (OIR) proceedings.

- Lack of availability of or consensus on computer software appropriate for calculating the impacts of proposed changes. It was suggested that this thwarts stakeholders' involvement in proposing changes to standards.

ii. The Relationship Between Standards and Energy Efficiency Programs

a. Expected Influence of Program Elements on the Standards Process

Tables 4 through 6 summarize key PG&E programs and program elements expected to have an influence, either direct or indirect, on the code process. The assessment of expected influence is based on a review of PG&E's 1999 Advice Filing. We elected to focus on 1999 because the program changes between 1998, 1999, and 2000 are relatively minor and because 1999 was the first advice filing following CBEE's October 16, 1998 Advice Letter, making it a reasonable representative of the planning efforts in other years since the shift toward market transformation.

We chose to focus on PG&E programs because PG&E programs are, for the most part, representative of the program plans for both PG&E and SCE in PY1999 and PY2000. The advice filings from the two largest utilities show abundant evidence of close collaboration and a distinct shift toward statewide programs. SDG&E program designs are generally consistent in design but relatively narrower in the scope of their activities. SCG program designs were less well developed at the time this assessment was performed though we have learned that SCG has committed to making some substantial changes in their 2000 program.

Influence can take a number of forms, including commercialization of an emerging technology, developing widespread acceptance of a technology or practice that is a candidate for coverage in the codes, educating practitioners and code enforcement officials, or otherwise facilitating proper code application and good design practice. The tables include only nine of the fourteen programs called for in the CBEE Advice Letter. The remaining programs were judged to be unrelated to the scope of the Codes and Standards MA&E Project. For similar reasons, individual program

elements were excluded if they were judged to be unrelated to the project scope. Excluded programs were Nonresidential Motor Turnover, Nonresidential Process Overhaul, Residential Lighting, Residential Appliances, and Industrial and Agricultural New Construction.

Along with CBEE programs and program elements, the tables show PG&E's proposed program interventions for PY1999. Again, only selected interventions have been included, based on their expected ability to influence the code process. As noted above, the interventions shown are, for the most part, representative of the program plans for both PG&E and SCE in PY1999 and PY2000.

A summary of utility programs and training offered is in Appendix E. They also regularly participate in Title 24 workshops, provide regulatory testimony and product and conduct additional activities to directly influence the development code, especially through the activities of the Codes and Standards Statewide Committee.

Table 4. Nonresidential Program Area Intervention Strategies Expected to Influence the Code Process

Program	Program Elements	1999 PG&E Intervention Strategy
Large Nonresidential Comprehensive Retrofit	Integrated C&I HVAC and Lighting Comprehensive C&I Lighting Retrofit Energy efficiency Centers	Pacific Energy Center Design and analysis tools, including Lighting Exchange and Cool Tools Project
Small Nonresidential Comprehensive Retrofit	Integrated C&I HVAC and Lighting Comprehensive C&I Lighting Retrofit Energy efficiency Centers	Pacific Energy Center Design and analysis tools, including Lighting Exchange, Cool Tools Project, Daylighting Initiative, Natural Cooling, and Commissioning and Performance Evaluation Tools
Nonresidential HVAC Turnover	High-Efficiency Equipment Sizing, Controls, and O&M	Design and analysis tools
Commercial Remodeling / Renovation	High-Efficiency (Lighting) Equipment High-Efficiency Design	Pacific Energy Center Design and analysis tools, including Daylighting Initiative

Table 5. Residential Program Area Intervention Strategies Expected to Influence the Code Process

Program	Program Elements	1999 PG&E Intervention Strategy
Heating and Cooling	Efficient Residential Equipment Information and Education	Targeted information to HVAC market actors
		ENERGY STAR brand promotion to consumers
	Improved HVAC Sizing and Installation Practices	Training, certification and/or inspection for HVAC market actors
	Linked HVAC Financial Incentives	Technical assistance and sales tools
	Regional and National Initiatives	Regional/national strategies for HVAC
Retrofit and Renovation	Promotion and Facilitation of Comprehensive, Discretionary Retrofit Service	Targeted information to consumers planning home purchase, sale, renovation
		Third party contract for institutionalization of HERS, EEMs
	Facilitation of Efficiency Retrofit at Time of Sale or Renovation	Third party contract to work with home improvement centers
	Energy Efficiency Centers	Stockton training center contractor training
		Building official training on codes and standards
		Third party contract with California Window Initiative

Table 6. New Construction Program Area Intervention Strategies Expected to Influence the Code Process

Program	Program Elements	1999 PG&E Intervention Strategy
Residential New Construction	Targeted Consumer Promotion and Information	Targeted information to consumers in market for new home
	Infrastructure and Product Development	Promotion of ENERGY STAR Homes label
	Integrated New Home Product	Incentives to third party builder allies
	Capability Development	CHEERS
	Market Leader Incentives	ENERGY STAR builder sales agent training and tool
		Training and technical assistance to builders and HVAC subcontractors
		Builder resource guide
CommercialNew Construction	Large Comprehensive	Savings by Design technical and design assistance
	Small Comprehensive	Targeted information and design incentives
	Prescriptive	Design and analysis tools, including Cool Tools Project and Commissioning and Performance Evaluation Tools
	Energy-Efficiency Center	
Codes and Standards	New Construction Codes and Standards Support	Code training and public education
	Local Government Initiatives	Develop voluntary design guidelines that exceed current requirements
		Information, assistance, incentives during local government planning and development process
		Links to third party financing for building retrofits

b. Opportunities for Standards to Help Meet Program Objectives

The literature supports the general conclusion that energy standards offer significant opportunities for advancing the market transformation objectives of PGC-funded programs. Nadel (1992) argues for a symbiotic relationship in which regulators weave strong energy saving options into codes and utility/MT programs then use these optional measures as the basis for incentive programs.

Northeast Energy Efficiency Partnerships (1998) notes that "code activities are not a substitute for new construction/renovation energy efficiency programs, but they can reduce the scale of such programs, make them more cost-effective, and provide an exit strategy for continuing incentive obligations for accepted technologies. Effective and universal code enforcement raises program

baselines and reduces freeridership." According to NEEP, energy standards offer at least three specific benefits to energy efficiency programs:

- Financial: When programs have largely succeeded in changing standard practice, continued program efforts may experience reduced effectiveness in stimulating new builders and developers to adopt measures. Standards can "lock in" past program accomplishments and permit the program to shift resources toward new energy efficiency opportunities.

- Equity: Program efforts tend to influence the largest, most aware, or most progressive market actors. Energy standards can extend program achievements to include rank-and-file market actors who tend to build to the minimum standards.

- Level playing field: In competitive bid situations, designers are reluctant to add measures that may save energy but have a higher first cost for fear of losing the bid. When high efficiency measures are required by code, these pressures are diminished.

This conclusion was supported by Nadel (1996) and Harris and Mahone (1998) and by many of the industry experts we interviewed. In particular, the interviewees noted

- Standards serve to set a baseline that programs can use to set higher energy-efficiency goals. It was mentioned that using codes started as early as 1979 with solar energy programs striving to exceed the code. The County of Santa Barbara's innovative building review committee provides incentives for buildings that exceed Title 24 by 20%, 30%, and 40%. EPA ENERGY STAR homes are required to exceed Title 24 requirements by 20% to 25%. The City of San Diego's green building policy requires all municipal buildings that are built or retrofit to perform 50% above Title 24. The standard provides important benchmarks that programs can use to push practices to higher energy efficiency.

- Standards support utility programs by serving as an exit strategy.

- Standards have had the effect of encouraging the use of newer technologies, the same thing that programs were trying to do. People might not use them unless required to do so and standards provided the push.

- Without codes and standards, one market actor mentioned, energy efficiency would never "take off." Standards have been important in moving consumers and the building industry toward energy-efficient practices.

- The alternative compliance methods allowed in Title 24 help achieve higher energy efficiency. One interviewee gave the example of window shading. Window covers never gained acceptance but flexibility in the compliance measures allowed builders to do something else to attain the same energy efficiency.

- Another interviewee suggested that the standards define the terrain and the programs find niches to satisfy the standards.

Finally, NEEP notes that "the appropriate relationship between building energy codes and utility programs is for the code to require all energy efficiency measures that are now cost-effective for building owners and are common practice in the market, and for utilities to offer incentives only for those measure which exceed code, are cost-effective for society, and which need a 'market push' to lower unit costs and gain recognition and acceptance in the marketplace."

iii. Opportunities for Programs to Influence the Standards Process

The literature review and our interviews with industry expert yielded a number of suggestions and examples of how PGC-funded programs can influence the development and implementation of standards in California. These suggestions provided the basis for some of the recommendations we ultimately tested in the focus groups, described in Section 4.

Both Northeast Energy Efficiency Partnerships (1998) and Heschong Mahone Group (1998) argue in favor of energy efficiency program interventions to support standards activities. NEEP identified six strategies for northeast utilities to pursue in support of energy standards, five of which seem applicable to California's utilities and PGC-funded programs.

- Participate in standards upgrade efforts. Programs can provide data on baseline new construction standards, make technical and program staff available to aid in the upgrade process, and provide testimony or letters of support for standards upgrades.

- Target program activities toward emerging technologies or design techniques that are not yet standards requirements.

- Raise public awareness of standards requirements.

- Assist in trade ally training programs.

- Assist in standards administration and enforcement. Utilities can require certification of standards compliance as a precondition to electrical service hook-up. They can also fund a technical consultant to work with developers and building inspectors to help projects meet standards requirements. Finally, they can contract with government to perform standards compliance services such as plan reviews and site inspections.

Similarly, Nadel (1992) identifies a number of options for improving coordination between energy codes and utility/market transformation programs, including

- Utility advocacy of code enhancements by proposing code changes, providing analysis of the costs and benefits of proposed code changes, and providing testimony at regulatory hearings
- Utility/MT promotion of new, stricter codes after they are promulgated but before they become mandatory
- Use of MT funds to offset code adoption costs, offer code official training, offset increased inspection costs, provide technical support, and offer incentives to cover increased building costs for the transition period
- Utility/MT promotion of Reach codes on a trial basis
- Use of sliding scale hook-up requirements and fees based upon level of code compliance

Additional opportunities suggested by the industry experts we interviewed include

- Utilities can provide support for future revisions to standards by helping CEC work around its contracting problems and augmenting CEC research activities (e.g., residential quality assurance project).
- Utilities can help day-to-day implementation of the standards by supporting local jurisdictions and the building community. For example, the City of Irvine has developed a program which refunds energy plan check and energy inspection fees to builders who participate in their program. This is an example of how a program supports compliance with the standard.
- Utilities can effectively assist in trade ally training programs. Field experience in North Carolina and Florida shows that HVAC contractors, after completing program-sponsored duct installation training, continued installing tight duct systems without any utility incentive.

- Ongoing educational services are needed to account for turnover within the building design and construction community and to cover changing in the code. Utilities can help implementation by assisting with that education process.

- Members of the public may not see or understand the public benefits standards provide. As a consequence, they may perceive energy standards as social engineering or unnecessary government intervention. Programs that educate the public regarding the benefits of energy efficiency can help further the standards development and compliance process by improving receptivity to the standards.

- Code simplification is critically important. Most of the jurisdictions studied are looking for simplification of the energy standards (Valley Energy Consultants 1993). The less complex the code or standard, the greater it appears that it will be used and/or enforced (Crowder and Foster 1998). It is clear from both the building and enforcement communities that the energy code needs to be simplified. This includes the code itself, compliance forms and enforcement techniques. Experience in Oregon documented by the latter indicates that the effectiveness of the code is improved when it is simpler to understand and apply. To the extent that programs can be used to develop better working relationships the governmental agencies that determine the codes and builders and contractors who use the codes, programs can establish the infrastructure needed to forge simplifications to the codes that can satisfy both the code setters and code users.

- Programs can provide data on baseline new construction standards, make technical and program staff available to aid in the upgrade process, and provide testimony or letters of support for standards upgrades. R&D has produced useful input to DOE standards. For example, a lab was built in San Ramon to simulate temperatures and compared SEER 10 to SEER 12 air conditioning units. Results showed that SEER 10 can out-perform SEER 12 at higher outdoor temperatures. This suggested that the Title 24 standard should be based on tests at high temperatures (e.g., minimum standard-SEER 10 and EER = x @ 95 degrees). CEC, NRDC, Oregon State Energy Commission, ACEEE all support the use of programs and R&D to support standards development.

4 DEVELOPMENT AND TESTING OF CANDIDATE RECOMMENDATIONS

A. Concept Design and Testing

Throughout our study we acknowledged that energy efficiency is strongly influenced by three main factors: design, choice of materials and technologies, and construction practices. The main focus for this study was on construction practices because in our view those are the hardest issues to regulate in Title 24 language. We were interested in design elements as well, but only to the extent they play a role in energy efficiency. We focused less attention on materials-not that they are not important, but we were informed early on of other studies with that focus. That said, we developed a list of concepts or potential recommendations to test on various market actors. These were based on the results of the literature review and in-depth interviews as discussed in Section 3.

The conceptual recommendations focused on three distinct areas: residential diagnostic testing, nonresidential building commissioning, and insurance liability. Most of the recommendations would require development of infrastructure to be implemented effectively, so we identified whether we considered the recommendation to be a short-term, medium-term, or long-term solution. In testing each concept we told the focus group participants the rationale for each recommendation, as well as any preconditions or assumptions that were made in developing the recommendation.

We conducted five focus groups throughout California: three in Southern California, and two in Northern California. In order to gain optimal feedback from different industry perspectives, our focus groups were made up of a variety of market actors. Table 7 shows a disposition of focus group participants. The people who participated in the groups were largely recommended by industry experts we interviewed and also included some of the interviewees. Details on the people who participated in the groups is included in Appendix A.

Table 7. Focus Group Disposition

Group	Market Actors	Participants
Northern California Residential Diagnostic Testing Group	Builders	2
	Contractors (HVAC, lighting)	2
	Researchers	1
	Utility Program Staff	0 (1 no-show)
	Other Program Staff (non-utility)	1
	Title 24 Consultant	1
Northern California Nonresidential Building Commissioning Group	Builders	2
	Contractors (HVAC, controls)	1
	Researchers (LBL)	2
	Architects/Designers	3
	Utility Program Staff	1
Southern California Residential Diagnostic Testing Group	Builders	1
	Contractors (HVAC, lighting)	2
	Engineer	1
	Consultant	1
	City Building Officials	2
Southern California Nonresidential Building Commissioning Group	Builders	1
	Contractors (HVAC, controls)	2
	Researchers	1
	Architects/Designers	2
	Utility Program Staff	2
Insurance/Liability Group[4]	Private InspectorsConsultants	3 2
	Builders	1
	Insurance Rep	1

[4] We had initially planned on having two insurance/liability groups – one in Northern and one in Southern California; however on the day of the group in San Francisco, half of the participants cancelled their participation, resulting in the cancellation of the entire group. One-on-one interviews were then scheduled with those willing to participate.

B. CONCEPTS TESTED

The following discussion presents specific findings from each of the three focus groups: residential, nonresidential, and insurance/liability.

i. Residential Diagnostic Testing

Based on our literature review and in depth interviews with industry experts, we concluded that there are two main building performance issues that exist from an energy efficiency perspective in the residential new construction arena. While we certainly recognize that these issues may not be the issues that get the most call backs, and they may not be the issues that end up going to court for defects, they are the areas that seem to have the highest energy efficiency implications. These areas are: HVAC installation and design problems and building envelope.

Also, from this background research we concluded that significant gains in energy efficiency can be achieved by improving overall building construction quality and mitigating construction defects through a systems approach to home construction. By "systems approach" we mean a construction process that includes

- A mechanical design of the HVAC system and ducts as part of the initial blueprints, considering house orientation, windows, lighting, and insulation on HVAC loads
- Performance testing of the ducts and HVAC system
- One or more envelope inspections to verify quality of the insulation installation and air and moisture sealing
- Verification and documentation that all building systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs

It is this “systems approach” that led to the development of concepts that were tested in the residential focus groups. Table 5 shows the conceptual recommendations that we tested during the residential diagnostic focus groups, along with the rationale behind the formulation of each recommendation, any preconditions or assumptions that must be in place for the recommendation, and whether we viewed the recommendation as a long-, medium-, or short-term solution.

Table 8. Residential Diagnostic Testing Recommendations Tested

Concept/Recommendation	Rationale	Long, medium, short term solution
Require "house as system" approach for all homes built in California. Require mechanical drawings as part of design documents necessary for building permit approval. Require satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit.	Requirement applies uniformly to all projects, maximizes energy efficiency gains if properly enforced.	**SHORT/MEDIUM TERM**
Alternative A**:** Require all builders to hire third party inspectors, at their own expense, to inspect, test, and certify envelope and HVAC systems for **all** homes they build.	This approach provides the most rigorous quality control.	**LONG TERM**
Alternative B**:** Require all builders to hire third party inspectors, at their own expense, to inspect, test, and certify envelope and HVAC systems for a sample of the homes they build.	This approach most closely resembles current Title 24 mechanism.	**LONG TERM**
Alternative C**:** Require certification of HVAC and insulation contractors. Tie the certification to successful completion of training courses. Allow contractors to inspect and test their own installations. Require affidavit from contractors documenting satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit. Establish random third-party inspection mechanism for quality control, with multiple deficiencies being grounds for revoking business license.	This will minimize the costs associated with third party testing and inspections. It will also improve knowledge, skill and ability on the part of contractors. Finally, it will address the concern for project delays due to a lack of performance testing infrastructure. However, it requires significant changes in the enforcement authority of the CEC, the state licensing board, or other agency.	**LONG TERM**
Alternative D**:** Allow contractors to inspect and test their own installations. Require affidavit from contractors documenting satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit.	By relying on the honor system, this eliminates the costs associated with third party testing and inspections and minimizes the concern for project delays. However, it does not assure adequate knowledge, skill and ability on	**LONG TERM**

	the part of contractors. This approach provides the least rigorous quality control.	
Use public goods charge funds to offset costs of contractor and installer training regarding diagnostic testing and revisions to Title 24.	This will improve overall knowledge, skill and ability on the part of contractors	**SHORT/ MEDIUM TERM**
Conduct additional research to quantify potential non-energy benefits of a systems approach to home construction. Quantify the benefits from reduced callbacks and reduced exposure to litigation.	Addresses potential benefits to builders and subcontractors to avoid liability, callbacks and litigation. Additional research may convince insurers to lower insurance premiums for builders and contractors who are diligent in adopting "house as a system" construction practices	**SHORT/ MEDIUM TERM**
Step up consumer education efforts around construction quality issues, particularly in association with ENERGY STAR.	Addresses lack of consumer awareness of the extent of construction defects; addresses potential unwillingness of home buyers to pay for a systems approach to home construction.	**SHORT/ MEDIUM TERM**
Simplify Title 24. Include substantive input from builders and contractors starting in the initial states of revision of the standards	This will encourage wider acceptance of the procedures and reduce the costs associated with the systems approach to home construction.	**SHORT/ MEDIUM TERM**
Offer a state tax credit for Green Buildings.	Addresses added cost issues for building and diagnostic testing.	**MEDIUM/LONG TERM**

a. *Discussion and Results of Residential Conceptual Recommendations*

The following provides feedback heard from the focus groups on each recommendation. This feedback led directly into the formulation of our final recommendations, presented in the Section 5.

Recommendation: Require "house as a system" approach for all homes built in California. Require mechanical drawings as part of design documents required for building permit. Require

satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit.

For the most part, participants in both residential groups did not have any problem with the "house as a system" approach. There was particularly overwhelming support for the requirement that mechanical drawings be included from projects' onset. Participants all agreed that the absence of well-laid mechanical plans prior to construction was the cause of most HVAC construction defect issues (e.g., compromised duct runs and equipment placement).

Alternative A: Require all builders to hire third party inspectors, at their own expense, to inspect, test, and certify envelope and HVAC systems for **all** homes they build.

Recommendation number one, coupled with alternative A, was the least preferred option among participants. They said that no other trades are required to have independent third party inspections and this would be unfair. Experts from the groups felt that requiring all homes to be inspected was unreasonable, and unlikely, given the lack of inspection infrastructure. In addition, requiring all homes to be inspected would only cause project delays. If defects are uncovered, the contractor must be called back to fix the problem, the tester must be called back to reinspect the job, and the process could potentially repeat each time until the problem was resolved. Each call-back represents a time delay and cost.

Alternative B: Require all builders to hire third party inspectors, at their own expense, to inspect, test, and certify envelope and HVAC systems for a sample of the homes they build.

While participants felt having a sample of homes tested was more reasonable than requiring all homes be tested, they were still reluctant to fully support third party inspectors. Again, the lack of available resources (e.g., enough qualified third party inspectors) was cited as the biggest deterrent for outside inspections.

Alternative C: Require certification of HVAC and insulation contractors. Tie the certification to successful completion of training courses. Allow contractors to inspect and test their own installations. Require affidavit from contractors documenting satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit. Establish random third-party inspection mechanism for quality control, with multiple deficiencies being grounds for revoking business license.

For the most part, participants in both residential groups felt this alternative was the best option. Specifically, they felt that the process of becoming a contractor should include a "certification." They claimed that "it's just too easy to become a contractor after a two day seminars-resulting in under-prepared but licensed contractors."

Alternative D: Allow contractors to inspect and test their own installations. Require affidavit from contractors documenting satisfactory inspection results and performance testing reports as precondition for issuing occupancy permit.

This alternative was well-received among participants, however only for the large builders. Several said that they supported a peer review process, where they invite their colleagues to review and/or inspect each other's work. Most were skeptical that the smaller builders could be trusted to check their own work accurately due to lack of personnel and time pressures. There was additional concern that having such an honor system approach to verification was not an effective method of consistent verification and that the process would fall by the wayside once timelines and budgets were tight. Of course it should be noted that those participants who were builders felt that they should be able to be responsible for their own work, likening the process to plumbers, "plumbers don't have to have their work inspected, why should we?"

Recommendation: Use public goods charge funds to offset costs of contractor training regarding diagnostic testing and revisions to Title 24.

This recommendation was very well received by most participants. In fact, using public goods charge funds for training numerous market actor groups was agreed upon unanimously. Participants felt that if diagnostic testing was to be required, using these funds would be a good way to ensure contractors were "all on the same page." In addition, contractors might be more accepting of diagnostic testing as long as they did not have to carry the added burden of cost for training their staff.

In addition to contractor training efforts, there was wide agreement that building inspectors should be brought up to speed with the latest technologies. Too often, according to experts, building inspectors do not understand what they are looking at when it comes to complex mechanical systems. Including them in training efforts would help to ensure that inspections are carried out effectively.

Recommendation: Conduct additional research to quantify potential energy and non-energy benefits of a systems approach to home construction. Quantify the benefits from reduced callbacks and reduced exposure to litigation.

Additional research was supported by all participants, however the definition of what that research should be sparked debate. For the most part, participants felt that more research was needed on issues *not solely* related to energy efficiency or diagnostic testing (such as air quality). In addition, more research was thought to be needed in the area of litigation and quantifying actual losses that result from construction defect litigation. To satisfy the needs and concerns of the insurance providers, these studies should quantify the benefits to actuarial standards so that insurance companies can base premium reductions on the resulting data. This will be difficult, if valuable. Finally, contractors and builders alike mentioned the need for additional research on new materials and installation processes.

Recommendation: Step up consumer education efforts around construction quality issues, particularly in association with ENERGY STAR.

Consumer education was considered to be very important to participants in both of the residential focus groups. As one participant said, "…there is no perceived value with ENERGY STAR …consumers don't ask for it." Participants also felt that in order for them to fully participate in existing ENERGY STAR options, they would need to know that consumers valued it to justify the additional costs. Others pointed out that consumers are not aware of what makes a system "good" or "bad." When a consumer is purchasing a brand new home, they expect they are paying for a "good" system–concern for testing to make sure their systems are working is not considered necessary. Educating consumers on ENERGY STAR and home ratings was seen as a good way to inform them.

Another area of interest among participants was the education of not just consumers, but the industry as a whole. Specifically, inspectors needed some education tools so that they are aware of changes in building practices and materials.

Recommendation: Simplify Title 24. Include substantive input from builders and contractors starting in the initial states of revision of the standards.

This recommendation was considered by all to be the most important. Nearly everyone felt that Title 24 was far too complicated, with too many exceptions, and too many options. In addition, the

way Title 24 is worded is confusing and hard to follow, resulting in builders not fully understanding the implications of trade-offs and changes they might make during the construction process (e.g., changing a window size or location). And, while most felt that the code needed to be simplified, they agreed the bar also needs to be raised. Complicated forms, tedious detail, and indecipherable documentation requirements were also cited as rationales for simplifying Title 24.

Recommendation: Offer a state tax credit for Green Buildings.

This recommendation was also favorably regarded. Many thought that the incentive (e.g., tax credit) should be "split" among builders and homeowners, creating the "push-pull" demand mechanism.

ii. Nonresidential Building Commissioning

Based on our literature review and in-depth interviews with industry experts, we concluded that there are two main building performance issues that exist from an energy efficiency perspective in the nonresidential new construction arena, and they are HVAC and lighting controls systems. These seem to be the biggest issues because they are the most complex. They include

1. HVAC installation and design problems

- Equipment sizing and duct sizing--Routinely oversized to compensate for other deficiencies
- Chilled water plants–Performance issues such as interaction of temperature controls on the condenser water, variable speed pump controls, and other components. Systems do not operate efficiently under part-load conditions due to "Delta T Syndrome" when chilled water flow doesn't drop in response to reduction in load.
- Air distribution systems–Biggest source of nonresidential HVAC energy-related issues. Performance issues with variable speed fan controls. Zone temperature controls is an issue because few dual temperature setpoints are properly installed even though they are required. Cooling coils undersized. Sensors on economizers get set improperly.
- Packaged air conditioners–they don't perform efficiently under partial-load conditions. Dampers stick on economizers due to manufacturer defect. Cycling on and off is not an efficient operating mode and energy standards do not require economizers for these systems.

Automatic scheduling and shutoff controls were also mentioned as resulting in performance issues.

2. Lighting Control Systems

- Occupancy sensor controls–lights shut off when space is occupied. Control systems set improperly or are over-ridden by facility managers or occupants who do not understand how to program them.

- Daylighting controls and other lighting controls

We concluded that significant gains in energy efficiency can be achieved by improving overall building construction quality and mitigating construction defects through building commissioning. As there are many definitions of what commissioning implies, we used the following definition of building commissioning.

"Commissioning is a systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all building facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owners operational needs, including preparation of operation personnel." [Bjornskov, et al. ACEEE 1996].

In addition, we consider building commissioning to include the following seven elements:

1. Commissioning plan at the predesign phase
2. Independent commissioning agent from outset
3. Customized test plan as part of project design documents
4. Review systems installation throughout and oversee functional testing
5. Operation and maintenance manuals and plans
6. Training plans
7. Final commissioning report for building owner

This commissioning approach led to the development of concepts that were tested in the nonresidential focus groups. Table 9 shows the conceptual recommendations that were tested during these focus groups, along with the rationale behind the formulation of each recommendation, any preconditions or assumptions that must be in place for the recommendation, and whether we viewed the recommendation as a long-, medium-, or short-term solution.

Table 9. Nonresidential Building Commissioning

Concept/ Recommendation	Rationale	Preconditions/Assumptions, if any	Long, medium, short term solution
Require commissioning for all nonresidential buildings built in California.	Requirement applies uniformly to all projects. Maximizes energy efficiency gains, minimizes construction defects, and thoroughly documents construction process in the event parties involved are subject to a legal challenge	That there is a common and accepted definition of commissioning. There is accepted testing/inspection protocols (whatever is cost-effective). Cost effectiveness has been thoroughly documented; and there is a fully developed infrastructure (qualified agents, adequate training, any/all software that's needed is in place).	**LONG TERM**
Alternative A: Include all seven commissioning elements.	Maximizes energy efficiency gains if uniformly applied		**LONG TERM**
Alternative B: Relax requirement for independent commissioning agent.	Minimizes commissioning costs		**LONG TERM**
Alternative C: Require commissioning only of HVAC and lighting control systems.	Minimizes commissioning costs by focusing attention on systems with greatest performance issues. However, it may not provide necessary quality control to address insurance and litigation issues (fire, sprinklers, elevators, envelope).		**MEDIUM TERM**
Alternative D: Offer compliance credits for commissioning as optional method for complying with Title 24.	Makes commissioning voluntary rather than mandatory.		**SHORT TERM**

Use public goods charge funds to offset costs of commissioning agent training and revisions to Title 24.	This will improve overall knowledge, skill and ability on the part of contractors. It will also improve commissioning infrastructure and expertise, and provide a clear understanding of what building commissioning implies and who the service providers are.		**SHORT/ MEDIUM TERM**
Develop simple and uniform testing protocols.	This will reduce additional project costs, as well as provide standardized methodology and testing procedures that would make the process of commissioning more efficient, cost effective and accessible. It will also minimize extra time and paperwork associated with the commissioning process.		**SHORT/ MEDIUM TERM**

Establish certification process for commissioning agents to make them more reputable and add standardization.	This will create standardized methodology and testing procedures that would make the process of commissioning more efficient, cost effective, and accessible. It will also clear up any misunderstanding about what building commissioning implies and who the service providers are.	That we've been able to come up with a certification process that adds credibility and standardization without becoming over onerous.	**MEDIUM TERM**
Conduct additional studies on costs and benefits for building commissioning, including a quantitative cost-benefit analysis of commissioning relative to energy and "non-energy" benefits, such as improved air quality better work environment resulting in higher productivity.	This will improve awareness of the energy benefits and long term economic savings benefits of commissioning. It will also improve skepticism on the part of building owners and managers that a proposed Energy Conservation Measure is going to work. Provide justification for reduced insurance rates.		**SHORT/ MEDIUM TERM**
Offer a state tax credit for Green Buildings.	Addresses added cost issues for commissioning. Addresses spectrum of owner/occupant concerns (health, safety, productivity, etc)	That we have gained buy-in from a wide range of political interests.	**MEDIUM/LONG TERM**

a. Discussion and Results of Nonresidential Conceptual Recommendations

The following provides feedback heard from the focus groups on each recommendation. This feedback led directly into the formulation of our final recommendations, presented in the following section.

Recommendation: Require commissioning for all nonresidential buildings built in California.

For the most part, participants agreed that commissioning a building was a critical element in good construction practices. However, most agreed that the difficulty with commissioning was that by the time the commissioning agent actually commissions the building (usually at the end of the project), systems are in place, as are "mistakes," and it is then too costly and inefficient to change. Many complained that building owners only ask for minimum code requirements, and thus the only way to get them to pay for or support commissioning is if it is required in the code. In addition, many felt the challenge for commissioning is simply that, "no one wants to hear their building is not working – who would pay for that?"

Another important issue that arose was the awareness that there really is no common or standard definition of what commissioning entails. During the course of these focus groups there was extended debate on the definition of commissioning.

Lastly, participants brought up the point that currently there are no repercussions for buildings that do not pass commissioning. So, from their perspective, commissioning is costly and ineffective if nothing will result from it. That said, most supported the idea that commissioning be required, but also noted the importance of needing a mechanism to ensure the building passed commissioning that problems were addressed.

Alternative A: Include all seven commissioning elements.

While most agreed that all seven elements were important in defining a good commissioning plan, they learned that the end result would be to create an infrastructure of unqualified commissioning agents who "are great at filling out paper, but they won't really understand the complexity of the building and its systems." Those who supported this approach felt that it was "just the stick that was needed to get things moving to build a commissioning infrastructure." However, time associated with completing commissioning that included all seven elements was again raised as an important drawback to requiring commissioning.

Alternative B: Relax requirement for independent commissioning agent

This alternative was more positively regarded among participants since it places responsibility for ensuring proper building operation back on the initial design engineer. There was some concern that, many design engineers are not sufficiently aware of system capabilities. But assuming they could be trained, experts said it should be designers' job to commission their own work.

Alternative C: Require commissioning only of HVAC and lighting control systems

Most agreed that HVAC and lighting controls were the critical areas that needed to have commissioning–-especially considering the complexity of recent systems and technologies. In addition, many said that when a project budget is in jeopardy, HVAC systems are the first to be compromised. That said, overall support still fell on the recommendation to commission the whole building–-but at a minimum, the HVAC and lighting control systems.

Alternative D: Offer compliance credits for commissioning as an optional method for complying with Title 24.

Not one person in either of the nonresidential commissioning groups liked this recommendation. They felt, again, that without repercussions for buildings that do not pass commissioning, "what's the point?"

Recommendation: Use public goods charge funds to offset costs of commissioning agent training and revisions to Title 24.

In general, the recommendation to use public goods charge funds as a means to offset elements of commission was well-regarded. However, most were less concerned with commissioning agent training and more focused on the overall added costs of building commissioning (sometimes as much as 10% of the entire cost of the building). Using the funds to offset commissioning was seen as a better use of those funds. Those who liked the idea of using PGC funds for training felt that architects and designers should also be included since that is generally where the problems arise that result in less-efficient buildings (according to participants). Another potential use of these funds is to sponsor demonstration projects that show the benefits of commissioning, with one participant claiming that "this has worked well in the Northwest."

Recommendation: Develop simple and uniform testing protocols.

Most participants recognized the need for simple and, more importantly, uniform testing protocols. Like the ambiguity expressed as to what commissioning is, testing protocols are likewise seen as inconsistent and lacking in standardization. The best approach to simplification was to address the building by each system. Several pointed out that "simple and uniform" were too vague, especially for the more complex systems. For example, some lighting systems might only require a page of simple protocol, whereas an HVAC system may require more.

Recommendation: Establish certification process for commissioning agents to make them more reputable and add standardization.

This recommendation was thought to be one of the better ones in the nonresidential commissioning groups. While several reminded us that the California Energy Commission does not have the authority to certify contractors, per se, other organizations, such as ASHRAE do. In addition, it is important to ensure that the certification, regardless of what it ultimately becomes, has a level of value to the contractor or energy engineer. It has to be considered to be worthwhile for them to pursue certification. Most agreed that part of the certification process would need to focus on training, especially for highly technical systems, so that commissioners did not simply become "paper pushers."

Recommendation: Conduct additional studies on costs and benefits for building commissioning, including a quantitative cost-benefit analysis of commissioning relative to energy and "non-energy" benefits, such as improved air quality and better work environment resulting in higher productivity.

Like the residential participants, most agreed that conducting additional analysis on costs/benefits of commissioning was an important step in learning which systems are most likely to require testing and which offer the most potential savings. In addition, other studies that present successful cases of commissioning were seen as a useful tool for builders to share with building owners, illustrating to them why commissioning is important.

Recommendation: Offer a state tax credit for Green Buildings.

This recommendation was generally thought of as a good idea among focus group participants. Several thought that labeling a building "green" carried value for building owners and tenants. Moreover, like the residential recommendation, participants felt that splitting the incentive between builders and owners might incent the owner to care more about energy efficiency, even though traditionally they are not the direct beneficiaries of such measures.

iii. Insurance and Liability Discussion

Our approach to the insurance and liability focus group was much more exploratory in nature. Throughout the literature review and in-depth interviews it became increasing clear that not much information exists regarding the insurance industry, construction defects, and the implications on energy efficiency. As such, we spent most of the time during the focus group trying to identify the links between better construction quality and insurance liability. Much of what was heard supports the recommendations tested in both the residential and nonresidential groups. The following presents highlights from the focus group.

Participants were first asked to describe the role of construction defect litigation in driving insurance rates. Not surprisingly, everyone agreed that poor construction led to higher insurance rates. And, those who worked with residential builders said that obtaining insurance policies was a "real headache." Several likened the process to applying for a job–-they have to jump through all kinds of hoops to get insurance. Others noted that many companies have been formed as a direct result of construction litigation (e.g., Pacific Property Consultants) in order to reduce the likelihood that developers will be sued.

For the most part, participants agreed that condominiums posed the largest problems for defect litigation, especially in San Diego. All agreed that San Diego was the "hot bed" for construction litigation–mostly as a result of water intrusion. Several said that because of this, developers are staying away from building condominiums, and instead are focusing on single-family detached homes, claiming that, "as a builder, single-family homes are much safer to build due to the reduced likelihood of litigation."

Everyone in this group said that the relationship between the builder and the insurance company was a critical component in avoiding litigation. Paper trails must be thorough and everything must be documented in order to prevent law suits. In addition, having the paperwork to back up and justify construction practices seems to alleviate some risk from the perspective of the insurer.

The next part of the discussion focused more on what insurance companies were doing about litigation issues. Overall, participants felt that insurance companies were becoming much more involved in the process–-hiring their own inspectors to conduct diagnostic testing. Some said that insurance agents are actually coming out to the job site and monitoring what is being done so that they have a paper trail to document quality. Many of the larger builders seem to be using third party inspectors primarily, as a result of being sued frequently.

One problem participants mentioned was that formerly only the builder would be sued. Now, however, everyone who is involved in a project is sued (e.g., all subcontractors). In addition, if a suit is initiated because of water intrusion and an inspector is sent out to document the damage, they then explore the entire house. Many other problems that may not have caused the occupant any distress may then be added to the suit. It is believed that most cases never make it to court because it costs more for a trial then it does to settle. As a result, participants believed that litigation was on the rise because it is "so easy to sue someone these days."

For the most part, design deficiencies and substandard or poor workmanship were cited as the top two causes of sparking construction defect litigation Water intrusion is the single defect that leads to most litigation.

Participants were then asked how feasible they thought it was to develop a standardized testing program that could catch most construction defects. Everyone in the group thought that this was a great idea, and quite feasible. However, they noted the difficulty in reaching consensus on what "standardized" should mean. Most also felt that insurers would have a vested interest in helping develop these standards and should therefore be part of the process.

5 RECOMMENDATIONS

Based on the results of the literature review, the interviews, and the focus groups we developed a refined list of recommendations. The recommendations presented here reflect the opinions of the people who participated in the focus groups and the comments received from reviewers of those results, including members of the Codes and Standards Statewide Committee and the CEC. A number of these recommendations are already being worked on by the utilities, the CEC and others.

Developing these recommendations in consultation with leading edge market actors with direct experience and insight into the building performance issues that we identified, rather than a random sample of actors, raised two concerns. First, these people are not completely representative of their respective groups. The majority of builders, inspectors, etc. are not yet sensitized to these issues or potential solutions. Using our "experienced" group, we could jump right into developing strategies to improve measure effectiveness and the code process, rather than spending time educating people and then obtaining their first thoughts about it. Second, the recommendations would reflect their biases rather than providing ideas that are truly valuable and viable to the community. We attempted to prevent this from happening by using the focus groups, which each consisted of different market actors, to develop consensus strategies. The recommendations here are only those that reflected collective thinking. Please note that there may be other viable options not identified here.

We recognize that there are still challenges, in some cases considerable challenges, to implementing the recommendations. The wording of these recommendations and the caveats noted address these challenges and capture the comments of the participants and the reviewers. Several challenges noted apply to many of the recommendations in both the residential and nonresidential markets. These include:

Increased building costs are always problematic to the construction industry. Nevertheless, many improvements in construction effectiveness promise to result in reduced building owning and operating costs, at least after the industry transitions to new practices. The utilities, the CEC, and

organizations such as CBIA, need to consider how to enact recommendations that achieve improved energy efficiency objectives in a manner that mitigates potential increased first costs.

The recommendations may be more burdensome to smaller and custom builders. Larger builders have a larger base across which to spread the costs of training and testing.

Procurement of long-term funding for some of the recommendations will be important. While PGC funds are recommended to "kickstart" some of these actions, they are not expected to remain permanently available. To become sustainable, the activities will either need another funding source, be government-mandated with the cost borne by builders or owners, or the market place will encourage their inclusion into the standard building process.

A number of the recommendations cannot be implemented solely by the utilities. They will require non-utility proponents to champion them into practice.

A. Residential Recommendations

The following final recommendations stem from results of the literature review, interviews, residential diagnostic focus groups, and subsequent reviewer comments.

1. Require mechanical drawings as part of design documents for building permits.

Clearly there is a need to include mechanical drawings early on in the construction process. We heard this in nearly every in-person interview as well as in both the residential focus groups. The underlying issue is that without including them, changes in the overall blue prints are made without consideration for mechanical systems, thus jeopardizing the quality of installation. Often when mechanical designs are not included early in the process, the quality of duct installations in particular suffers. Due to lack of space, ducts are often sized smaller than necessary to fit in tight spaces thus constricting air flow, and sometimes completely cutting it off. Furthermore, in the hyper cost-conscious construction industry, the last systems to be installed are often compromised, substituting lower quality materials, resulting in a system that does not perform as designed. The impact of such issues on efficiency and performance can be decreased by requiring mechanical drawings—indicated equipment placement, duct runs, and duct sizing from the onset. Requiring design drawings is an important step toward having contractors complete Manual J and D for each house plan.

Caveats to Recommendation 1: The goal of this recommendation is to foster continuity from design through construction. While requiring mechanical drawings is widely expected to improve HVAC and duct performance, it is no guarantee of quality workmanship. Thus, without field verification, it cannot increase measure effectiveness. It is also recognized that drawings reflect pre-construction thinking. Design elements are often modified during construction to minimize cost or to handle the unexpected site glitches. Title 24 already encourages this, in a way. Bill Pennington of the CEC alerted us that field verification to demonstrate implementation as designed is already included in Title 24 compliance credits. It is also part of Building Industry Institute (BII) training, and the ComfortWise program, showing that there is a precedent for implementing this recommendation. Still, prior to implementing this recommendation, a decision must be made as to whether this would be mandated at the state or at the local level. If at the state level, we were told that a new statute to give the CEC this authority would be required. Finally, an undercurrent to almost all of these recommendations is that they might prove especially burdensome to smaller builders. Drawings generally cost about $500 per design.

2. Require certification of HVAC and insulation contractors and installers. Tie the certification to successful completion of training courses. Require an affidavit from contractors documenting satisfactory self-inspection results and performance testing reports as precondition for issuing occupancy permit.

Certification was heralded as an important component of improving HVAC and insulation effectiveness. The importance of including both contractors and the actual installers in the certification was noted so that the certification would be more meaningful. While we realize the CEC does not have the authority to "certify" HVAC and insulation contractors, teaming with or encouraging professional organizations such as ASHRAE to certify them is highly recommended. According to our focus group respondents, there are still many contractors who operate simply by rule of thumb and by "we've always done it this way" thinking despite improved technologies and installation practices. By requiring such certification, contractors might be able to see the benefits that new practices offer (i.e., not only in performance, but also in reducing installation costs), and decide on their own that they will change. In regards to developing appropriate training mechanisms, it was pointed out that several organizations, including the North American Technician Excellence (NATE), already provide diagnostic testing training or certification courses and that there is opportunity for utilities to boost these efforts, rather than create something new.

One of the more surprising findings was that most of the respondents in the focus groups supported the idea of self-inspection, and were, in general, much more trusting of each other than

previous studies have shown. The concept of self-inspection, as certified contractors, will alleviate any added costs of hiring a third-party inspector. Furthermore, avoiding third-party inspection requirements—indicating a level of trust in the industry—might also decrease the often negative and adversarial attitude many builders have toward government regulators and energy efficiency programs.

Caveats to Recommendation 2: Several items clearly need to be addressed to implement this recommendation. One is to determine how certification relates to current contractor licensing. Another is procurement of long-term funding to cover the costs of the certification program. Implicit in this recommendation is the use of existing PGC funds to partially or fully offset the cost of setting up the training and certification. There is precedence for using PGC funds for this purpose. Since that funding is not expected to last in perpetuity, however, other mechanisms need to be explored to sustain the activity. The utility and CEC already have some contact with professional organizations that could provide training and certification; in particular, Charles Segerstrom at PG&E and Jeff Johnson at New Buildings Institute indicated familiarity with possible avenues for residential contractor/installer training. Finally, in order to really work, someone (or some organization) will have to champion it. PGC-funded programs can play a role here.

3. Establish mechanisms to conduct random, third-party inspections for quality control.

These inspections would be conducted by people who are not local building inspectors. The inspections would cover a sample of homes constructed by each builder. CBIA strongly supports the concept of independent, third-party inspections and using a sampling approach to control costs. Sampling is also a feature of EPA's ENERGY STAR Homes program.

Having third-party random inspections was one of the more controversial aspects of our interviews and focus group discussions. Most of the non-field representatives felt this was necessary; there were also several contractors who felt that they already used third-party inspections. In addition, all of the insurance focus group representatives said they had to use third-party inspectors simply to protect them from litigation. The skepticism, however, was primarily among the larger builders speaking about the smaller contractors and custom builders. The larger builders, who were the only ones represented in the focus groups, said that shoddy construction practices are associated with smaller builders and contractors, and the only way to "keep them honest" is to make them pay for random third-party inspections.

Caveats to Recommendation 3: Being one of the more controversial results, it was no surprise that this recommendation is surrounded by a large number of concerns. Before this recommendation

can be implemented, quite a number of issues need to be resolved, such as: to whom will the third-party inspectors report? The effectiveness of this recommendation will rest on how these inspection results are used. One suggestion is to use an approach similar to that used by CHEERS. This would put the authority with the local building department, who would oversee but not conduct the inspections. Given that the inspections will be made on only a sample of the homes, there are several considerations the implementors need to address regarding the sampling. How will the homes be chosen? Will the homes all need to be inspected at the same stage of construction? If not, will there be designated acceptable stages in the construction process at which inspections must be conducted? The sampling issue is already under investigation. For example, the ComfortWise program is using a sampling approach. Regarding the timing of testing, this was apparently discussed at length in the adoption of compliance credits for the 1998 standards, and is being addressed through CHEERS and ComfortWise's implementation of the credits and ENERGY STAR Homes qualification. This is also being considered in the PIER-funded Residential Commissioning project that LBL is leading and that includes representatives of CEC and utilities. Finally, since inspections will cost money, a long-term funding mechanism must be developed to ensure the sustainability of this practice. Again, PGC funds could be used to create the third-party inspection guidelines, train the inspectors, and initially pay for the inspections, but this is not a permanent solution. At this time, it is unclear whether this could become a self-sustaining market-based change or whether a long-term funding mechanism will be necessary to ensure the sustainability of this practice.

4. Use PGC funds to conduct contractor and installer training on proper installation, proper testing, and recent changes to Title 24.

Nearly everyone during the data collection process felt that a good use of PGC funds would be to conduct specific contractor training on proper installation, testing, and recent changes to Title 24. While there were several suggestions as to how to best communicate this information to busy contractors, most supported the idea, for example, of on-site hands-on exhibitions during construction, or demonstrations of proper installation. Respondents agreed that while such programs would be expensive, they would be effective in educating contractors. In addition, by going to the job site, one can target the installers, not just the contractors who employ them. Lastly, there was discussion about if and how changes in Title 24 are communicated to field staff—most felt they are not communicated well. Thus, using PGC funds to create better mechanisms to take the message directly to field staff could be a good idea. Several suggestions that were mentioned included providing a special section on the CEC website that provides a quick overview of the Title

24 changes, in an easy–to-read format, using simple and clear verbiage. Another suggestion was to produce a newsletter that includes recent changes.

Caveats to Recommendation 4: This recommendation is already a work-in-progress. The utilities have a number of training sessions available to members of the building industry—including Title 24 consultants, local building officials, HVAC contractors and installers, architects, mechanical engineers, equipment suppliers, developers, and Realtors. A list of these training sessions is included in Volume II, Appendix E of this report. Despite offering training at alternative locations and times, the utilities find they are not always successful at persuading the intended market actors to attend the training sessions. Conducting training sessions at the construction site may address this barrier.

5. Use PGC funds to augment and train local building inspectors on the "house as a system" approach.

This recommendation stems from the concern that energy-inefficient construction is as much due to under-skilled building inspectors as to builders and contractors. Many of those interviewed felt that the local building inspectors are not up to date on the new energy-efficient technologies, and do not understand the interactive nature of a home's component systems and the implications of the poor performance of any one component on the others. Moreover, it was felt that few inspectors take the time to keep abreast of the latest standards and technologies so the overall pool of qualified inspectors needs to be increased. One approach to this training would be similar to the proposed contractor training. Having inspectors trained at actual homes would be an effective way to deliver training on diagnostics and quality construction results.

Comments on this recommendation were all favorable, both during the focus groups and in subsequent review. Reviewers thought that having building inspectors trained on the "house as a system" approach would enhance compliance. Most, but not all, agreed that having more trained inspectors would be beneficial in decreasing potential construction delays that could arise from inspectors being unfamiliar with the methods.

Caveats to Recommendation 5: Barriers go far beyond the need for training and are more related to lack of local government budget resources, low priority of energy efficiency relative to health and safety code requirements, and lack of educational and professional expertise. Implementing this recommendation will require the utilities to enlist the support of and collaborate with several parties. Partnerships with professionals who can provide the training will be necessary. Interactions to gain

the support of local building officials will be necessary. Finally, this will likely need a non-utility champion to make it happen.

6. Conduct additional research to quantify potential non-energy benefits of a systems approach to home construction. Quantify the benefits from reduced callbacks and reduced exposure to litigation.

Throughout our study it has become clear that an area in need of additional research is insurance and liability. Conducting a study that investigates actual claims related to construction defect litigation would help indicate the potential value for linking building quality and avoided litigation costs. To date, we have heard of only one such study, and have yet to learn who performed it. One suggestion is to work directly with the insurance industry, perhaps by co-sponsoring a study, to identify the impacts of construction quality on their industry. Most of the insurance representatives we spoke with during our in-depth interviews indicated that this is currently a "hot issue" at industry conferences, and that now would be a great time to initiate such a study.

Caveats to Recommendation 6: We need to emphasize that the litigation referred to is rarely, if ever, due to energy efficiency performance failures and energy standards cannot be used to enforce construction quality. Nonetheless, we are already seeing a convergence of interests here that reinforce the value of conducting energy efficiency measure benefit assessments. The AAMA has been working with window manufacturers because of leakage litigation problems, offering an opportunity to also discuss improving energy efficiency through better construction and installation of window units. Also, the Building Industry Institute has been successful in associating improved quality in energy efficient construction with reduced builder exposure to liability. Finally, it should be noted that quantifying non-energy benefits of building energy efficiency improvements in ways that are meaningful and actionable for the insurance industry may be difficult to accomplish.

7. Increase consumer education on energy efficiency by way of a mass media public awareness campaign.

There was quite a bit of debate during data collection efforts regarding the role of consumer demand in driving the marketplace toward higher efficiency and quality construction. Tradesmen felt that consumers have not attached a value to energy efficiency, and therefore do not care about it—thus providing builders little incentive to spend resources improving a home's efficiency. However, they also thought that the reason consumers do not care about energy efficiency is because they do not know what makes a house efficient nor how this impacts the homeowner's expenses. By increasing consumer education and creating value for quality construction and

energy efficiency, builders and contractors alike believe consumers will begin asking for more efficient homes.

Caveats to Recommendation 7: The utilities already have some energy efficiency consumer awareness programs in place. To help builders see the value of energy efficiency, these programs could be more focused on identifying and educating consumers about a few specific measures that they should look for in a new home. This might prompt consumers to start asking for energy efficiency measures and related quality construction.

8. Establish simple, standardized diagnostic testing procedures.

While nearly everyone agreed that diagnostic testing procedures should be required, the dilemma is with how to define such procedures. There are many different ways of testing a home, and not everyone agrees which test is the best indicator of a home's performance. By establishing common protocols in the standards, everyone will have access to information on how to conduct diagnostic testing.

Caveats to Recommendation 8: This has already been accomplished for duct testing. That standard is the Duct Blaster test, performed by sealing all the ducts and pressurizing to a standard level (usually 25 Pa). The Duct Blaster provides a method for determining flow based on how hard the Duct Blaster fan is working to achieve the required duct pressure. This type of standardization needs to be extended to other HVAC components and the building envelope. PGC funds could perhaps be used to facilitate this extension.

9. Simplify Title 24 while raising the standards (i.e., make them more stringent but easier to understand and apply).

Title 24 is believed to be far too complicated and hard to understand. As one focus group respondent said, "…the Codes and Standards are written like encyclopedias—and we expect users to memorize them." Simplifying the standards would reduce confusion and improve the likelihood of compliance. Simplification could include two types of changes: word changes (e.g., use "windows" instead of "fenestration") and elimination of minor requirements (e.g., requiring R19 insulation for one home orientation and R22 for a different orientation). In addition, higher or more stringent standards should be required, such as offering fewer credits for easy trade-offs such as installing window shading. Using the previous example, perhaps all orientations of the same home would require R22 insulation. Many respondents complained that contractors and builders opt for the easiest credits, even if they doubt their effectiveness, and therefore sacrifice energy efficiency.

Caveats to Recommendation 9: There was considerable concurrence on this recommendation, despite the potential restrictiveness of it. In the focus groups, (large) builder representatives said they expect there would be support among builders for simpler requirements even if they are more stringent. CBIA, which might be more widely representative of builder views, supports the mandate that any update to Title 24 must be cost-effective in its entirety when compared with historical practice. To implement this recommendation, it is evident that representatives from many groups will have to grapple with the trade-off between the increased compliance that simplicity would facilitate and the additional costs that increased stringency would likely impose. The "devil is in the details" adage seems applicable here. Thus, this could be a long time in coming.

10. Offer state tax credit for "green" (and tested) energy-efficient buildings to both builders and consumers.

By offering a state tax credit for "green" (and tested) energy-efficient buildings, market actors are being encouraged to pursue field-verified energy efficiency. Respondents believed that this might be more successful if associated with construction of "green" buildings. By splitting the incentive, so that both owners and builders receive a portion of the tax credit, it would ideally create a symbiotic push-pull approach to market transformation. Obviously, the infrastructure would need to be in place to support the tax credit, as well as governmental buy-in. Everyone who reviewed this recommendation thought it would be helpful for promoting energy efficiency.

Caveats to Recommendation 10: This is clearly a recommendation that utilities cannot implement on their own. It will need a champion within the legislative process.

B. Nonresidential Recommendations

Seven final recommendations are presented here, based on results from the literature review, interviews, nonresidential building commissioning focus groups, and subsequent reviewer comments. Of these, most are analogous to the recommendations made for residential construction. There are, however, several differences worth pointing out. First is the recommendation of mandatory testing for nonresidential construction. Second is the absence of requiring third-party inspectors. Third is a provision that could prove especially helpful to smaller building owner/developers or potential commissioning agents: an equipment lending library. Finally, there were no recommendations to simplify and increase the stringency of the standards.

1. Require commissioning of the HVAC system and lighting controls with the mechanical engineer of record responsible for the HVAC system and the architect responsible for the lighting.

This recommendation represents feedback that we heard from the respondents in both the in-depth interviews and the focus groups. The systems most at risk for construction defect in new nonresidential buildings are the HVAC and the lighting controls systems. While architects and builders alike might be reluctant to commission the whole building due to cost and time constraints, these two systems in particular should addressed. In addition, because there are so many market actors involved from design to inspection, it is difficult to accurately determine who is at fault for poorly installed systems. Since the mechanical engineer is responsible for designing the HVAC system, it seems most appropriate assign responsibility to this party for ensuring that this system operates as designed. With respect to lighting controls, architects or lighting designers should see that lighting and the control systems are installed and function as initially planned. In particular, since occupants can and do override controls when the lights do not perform as needed, the lighting designer needs to ensure that the controls are appropriately installed and calibrated. That is, the lighting designer needs to stay involved throughout the construction process.

There is precedent for this recommendation in requirements Massachusetts put into effect in January 2000. These require the lighting engineer and engineer of record to document how the lighting and HVAC systems are supposed to operate and certify that the design intent has been implemented. Other areas, such as the City of Seattle, have written plan and design intent requirements.

Caveats to Recommendation 1: The biggest problem with implementation of this recommendation may be how to overcome the cost burden that this will impose on builders. Full building commissioning costs can be 10-20% of the construction cost of a building. Also, a commissioning infrastructure needs to be developed in California, including training for lighting designers and mechanical engineers on commissioning procedures. Public electricity charge funding is being used in the Pacific Northwest, New York, and other northeast states to develop a commissioning infrastructure in those parts of the country. PGC funds could be used to develop this infrastructure in California.

2. Use PGC funds to offset costs of commissioning.

Our interviewees and focus group participants were very concerned about the cost of requiring commissioning. Building owners and developers often see commissioning as a discretionary cost

that could lead to construction of the building going over the budget and eating up profits. Commissioning can be one of the first things to go when construction budgets get over-extended. By using PGC funds to offset the costs of commissioning, the likelihood of having commissioning cut from the plans could be alleviated.

Caveats to Recommendation 2: It is not anticipated that PGC funds will be available to cover the entire cost of commissioning or that they will be available indefinitely. Since building commissioning includes drafting written plans, conducting testing, and fixing mistakes, its unclear whether PGC funds should be applied to all or only some components of commissioning.

3. Design simple and uniform testing protocols.

Not unlike the residential diagnostic testing protocols, commissioning implies many things to many people. As such, having simple and uniform testing protocols would alleviate confusion regarding what constitutes the commissioning process. Some headway has been made in addressing this: ASHRAE has a committee on testing protocols. More locally, PG&E is developing testing guidelines.

Caveats to Recommendation 3: This recommendation will require collaboration between commissioning experts developing the guidelines and the professionals that will be trained to use them. Furthermore, while utilities can and are encouraging uniform protocols, they cannot impose them.

4. Use PGC funding to establish a standardized certification process to train and certify commissioning agents.

This recommendation directly addresses several of the commonly cited barriers to building commissioning: cost, lack of awareness of pervasive equipment performance problems, and lack of knowledge on how to perform testing. According to our focus group respondents, there are still many contractors who operate simply by rule of thumb and by “we’ve always done it this way” thinking despite improved technologies and installation practices. By requiring training and certification, professional commissioning agents would be able to see the benefits that commissioning offers, understand commissioning practices, and demonstrate their competency in applying the procedures.

Caveats to Recommendation 4: We realize the CEC does not currently have the authority to “certify” commissioning agents. Teaming with or encouraging professional organizations such as

ASHRAE or the Building Commissioning Association to certify them was seen by project participants as viable and highly recommended. Developing and sustaining this infrastructure component will likely require continued funding over the medium to long term.

5. Use PGC funds to create a library of testing equipment for builders and their commissioning agents to borrow.

This recommendation stems from feedback we received about the lack of ownership of equipment for testing building systems. Such equipment is often too expensive for a building owner/developer or potential commissioning agent to acquire for infrequent use. Activity is already underway on this recommendation. The Pacific Energy Center has started an equipment lending library. Increased access to testing equipment is part of the infrastructure needed for some of the other recommendations to be effective.

Caveats to Recommendation 5: The issues that need to be addressed for this recommendation include identifying which equipment to make available and establishing the locations from which the equipment might be obtained.

6. Use PGC funds to conduct additional studies on costs and benefits of building commissioning, including a quantitative cost-benefit analysis of commissioning relative to energy and non-energy benefits, such as improved air quality and better work environment resulting in higher productivity.

Suggestions for additional studies of the nonresidential sector primarily focus on generating and communicating findings from successful building commissioning demonstration projects. Many builders said that having such studies available would help them sell commissioning to building owners and justify allocating part of the project's budget to commissioning.

Caveats to Recommendation 6: This recommendation is similar to that made for residential construction. Again, the litigation referred to is rarely, if ever, due to energy efficiency performance failures and energy standards cannot be used to enforce construction quality. Nonetheless, a convergence of interests reinforce the value of conducting energy efficiency measure benefit assessments. The AAMA has been working with window manufacturers because of leakage litigation problems, offering an opportunity to also discuss improving energy efficiency through better construction and installation of window units. Obtaining meaningful and actionable results from these studies will likely be difficult and costly.

7. Offer state tax credits to builders and building owners for commissioning energy-efficient and green buildings.

Like the residential market, offering a state tax credit for "green" and energy-efficient, tested buildings, market actors are being encouraged to promote energy efficiency. In addition, by extending this to a split incentive, whereby owners and builders both receive the tax credit, it would ideally create a symbiotic push-pull relationship, leading to market growth and, ultimately, market transformation. Appropriate infrastructure, as well as governmental approval, would need to be in place to support this growth. Suggestions were made that perhaps calling this an "energy credit" but leaving a loose connection with so-called green buildings could make this appealing to people who could be instrumental in enacting it.

Caveats to Recommendation 7: This is clearly a recommendation that utilities cannot implement on their own. It will need a champion within the legislative process.

C. Recommendations for Future Research

Implementation of some of the recommendations made here will require or would greatly benefit from additional research. These items include:

- Conduct studies that assess and document the energy as well as non-energy benefits of diagnostic testing and/or building commissioning to market actors, including insurers, builders, and owners/buyers. These should be actuarial quality studies that would afford insurers confidence to reduce builders' premiums. We were told that a study attempting to do this was started by Heshong Mahone Group in 1992 but was not completed. It was suggested that a first step would be to select a specific focus or prioritized list as part of any benefits assessment research.
- Actively foster partnerships with professional associations in the construction industry to facilitate development and implementation of training and certification for diagnostic testing and building commissioning.
- Determine exactly how requirements of Title 24 (current and proposed) overlap with activities that comprise building commissioning. This may involve revisiting and/or revising the working definition of building commissioning for best use in California.
- Track how building commissioning in Massachusetts is working to gauge the likely practicability and benefit of the first nonresidential recommendation above. Information about the Massachusetts code can be accessed through the state's website at http://www.state.ma.us/bbrs/chapter13.htm.

- Since there is still some controversy regarding the use of third-party inspections in residential construction, conduct a study to investigate their need/acceptance and develop practical strategies for using them.
- The recommendations above are somewhat general. Further investigation needs to be made into which residential and nonresidential submarkets of the construction industry will be the best hosts for these recommendations. Utility/PGC-funded programs should be directed at implementing the recommendations in these markets first.