The California Statewide Baseline Study of the Nonresidential New Construction Market

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ABSTRACT

This paper summarizes the findings from the California statewide baseline study of the nonresidential new construction market. The information is developed from qualitative and quantitative surveys of 228 architects and engineers, together with on-site audits and DOE-2 models of 667 new construction projects completed from 1994 to 1998. The DOE-2 simulations were used to measure the efficiency of the sample buildings relative to the 1995 Title 24 California energy code. The market-actor surveys were used to characterize market behavior and look for barriers to efficiency.

A few highlights of the findings from the simulations: A substantial majority of the buildings were at least 30% more energy efficient than Title 24. Buildings participating in utility new-construction programs were somewhat more efficient than non-participants, but we found outstanding buildings in both groups. Public-sector buildings tended to be the most efficient, followed by owner-occupied private buildings, and then speculative buildings. Efficient lighting was responsible for the vast majority of the savings.

The market-actor surveys shed light on the simulation findings. We found that most designers satisfy Title 24, but relatively few strive to go beyond code. When asked why some buildings fall short of code, the most common answer was value engineering.

This study was carried out for Southern California Edison and the California Board for Energy Efficiency by RLW Analytics and Architectural Energy Corporation with technical study direction by the Heshong Mahone Group.

Introduction

This paper summarizes the findings from the California statewide baseline study of the nonresidential new construction market (RLW Analytics. 1999). The goals of this study were to:

- Understand current design and building practice in the nonresidential new construction (NRNC) market,
- Understand the attitudes and motivations of market actors, and
- Create a baseline for future market transformation efforts.

We surveyed 228 architects and engineers active in the NRNC market to explore their attitudes and practices and to identify market barriers to energy efficiency. Twelve of the interviews were carried out to help plan the study, 56 were indepth interviews designed to explore issues in an unstructured way, and 160 interviews were structured surveys designed to quantify the main issues.

We also analyzed on-site audit and DOE-2 simulation data of 667 nonresidential new construction projects completed from 1994 to 1998. These 667 sites were in four targeted segments – office, retail, school and public assembly. These segments were chosen because they account for 70% of all square footage in the NRNC market. 487 of these audits had been carried out in prior impact evaluation studies of utility energy-efficiency programs while 180 audits were new in this study.

All of the sample sites were post-stratified by segment, square footage and program participation, and weighted to the NRNC population. For this purpose, the population was characterized by program tracking databases and F. W. Dodge new construction data. The findings are believed to be representative of these four segments in the California new construction market between 1994 and 1998.

Findings from the Buildings

Based on detailed site surveys of the 667 sample sites, DOE-2 simulations were used to develop information about the energy efficiency of each building. Basically we used two simulations for each site: one describing the building as it was found in the on-site audit, and a second describing the building if it had been built to 1995 Title-24 California energy code. In the second, baseline simulation, all of the physical attributes of the building were reset to Title 24 norms. For example, we changed the lighting power densities (LPD) and equipment efficiencies to the levels required by Title 24, and resized the HVAC system proportionately to reflect the modified load. But we used the occupancy schedules from the on-site audit and as-built simulation.

The simulations were used to calculate a measure of the efficiency of each building that we called the *energy ratio*. The energy ratio is the as-build annual electricity use divided by the baseline use from the two simulations. For example, an energy ratio of 0.8 would indicate that a building would be expected to use 20% less energy than if it had been built to code. Then we used stratified ratio estimation to project the energy ratios found for the sample buildings to the NRNC population and used the results to estimate the population distribution of energy efficiency.

Efficiency by Building Type

Figure 1 illustrates one of our major findings – Most buildings were found to exceed Title 24 code in all four segments. The inset box shows the percentage of sites better than the baseline as well as the estimated value of the energy ratio in the population. For example, by extrapolating our sample to the California population, we estimated that almost 85% of all offices are built better than code in terms of the energy ratio, and all new offices have an average energy ratio of 0.88, i.e., about 12% better than code. The figure shows something else that seems very important – *a substantial fraction of the buildings in each of these building types are substantially better than code* – with an energy ratio of about 0.7 or better.

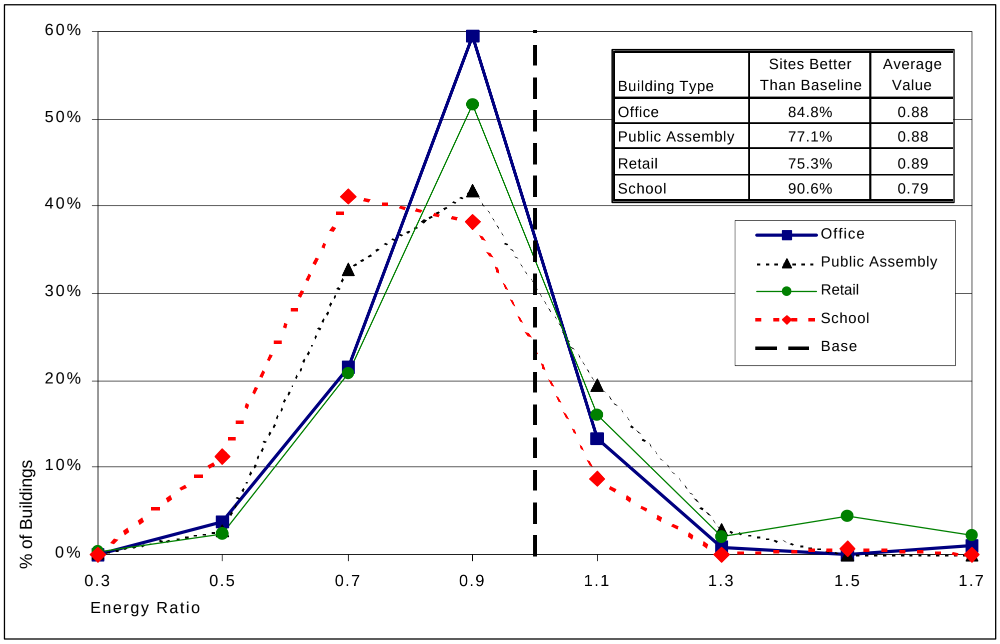

Figure 1. Energy Efficiency by Building Type

Efficiency by Program Participation

We also compared the energy ratio of participants and non-participants in the NRNC programs offered by PG&E and SCE. By comparing the program tracking data to the F. W. Dodge new construction data, we estimated that the programs had about 15% market

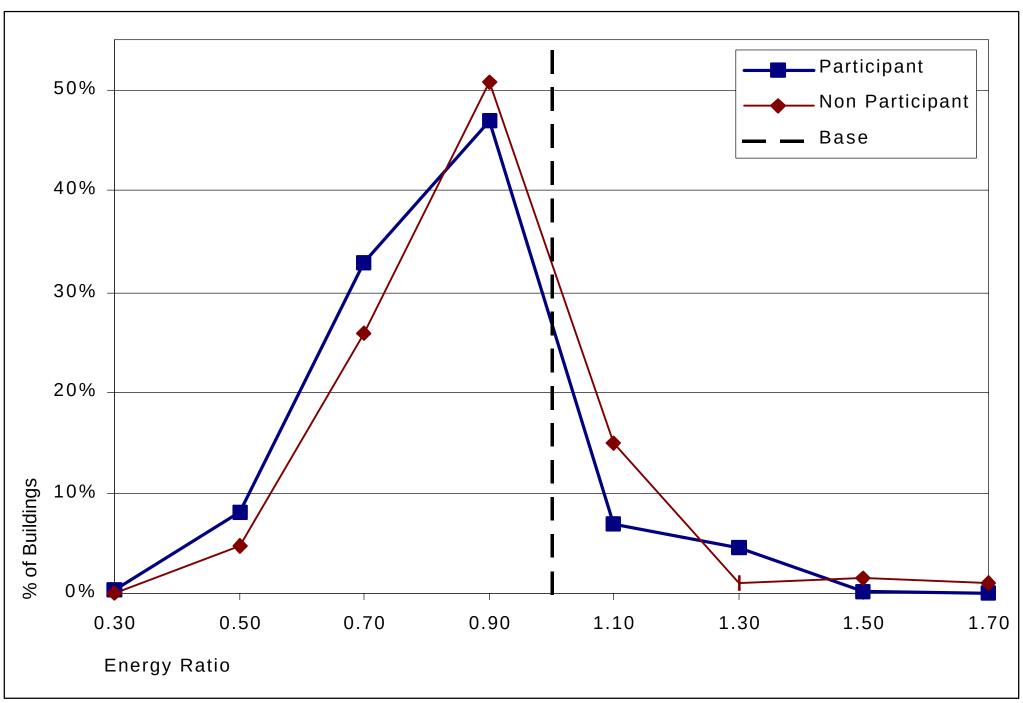

Figure 2. Energy Ratio of Participants versus Non-Participants

penetration, measured both by square footage and energy use. We found that the program participants were somewhat more efficient than the non-participants, with an energy ratio of 0.89 versus 0.83. In other words, on average, the participants were about 17% better than the baseline whereas the non-participants were about 11% better. But when we looked at the distribution of the energy ratio as in Figure 2, it is striking that very efficient buildings are found among both participants and non-participants.

Efficiency by Year and Ownership

We also compared the efficiency of buildings built from 1994 to 1998. There was no significant change. But we found a significant difference by ownership – public, owner occupied, and speculative. Public buildings had an average efficiency of 0.84, owner occupied had 0.87, and speculative had 0.92. But again, a substantial number of highly efficient buildings were found in all three ownership classes.

End Use Results

Our DOE-2 simulations also gave us estimates of electricity use in each of the major end uses – lighting, cooling, and fans. The calculations showed that 73% of the energy savings were associated with the lighting end-use. The remaining energy savings were about equally divided between cooling and fans, and some of those savings were secondary effects of lighting energy reductions. Figure 3 shows the distribution of the energy ratios for the lighting end use. These distributions are remarkably better than the whole-building energy ratios shown in Figure 1. This reflects the importance of lighting. These results indicate that the majority of these buildings had lighting systems that were substantially more efficient than the 1995 Title 24 requirements. A substantial number of buildings were using half as

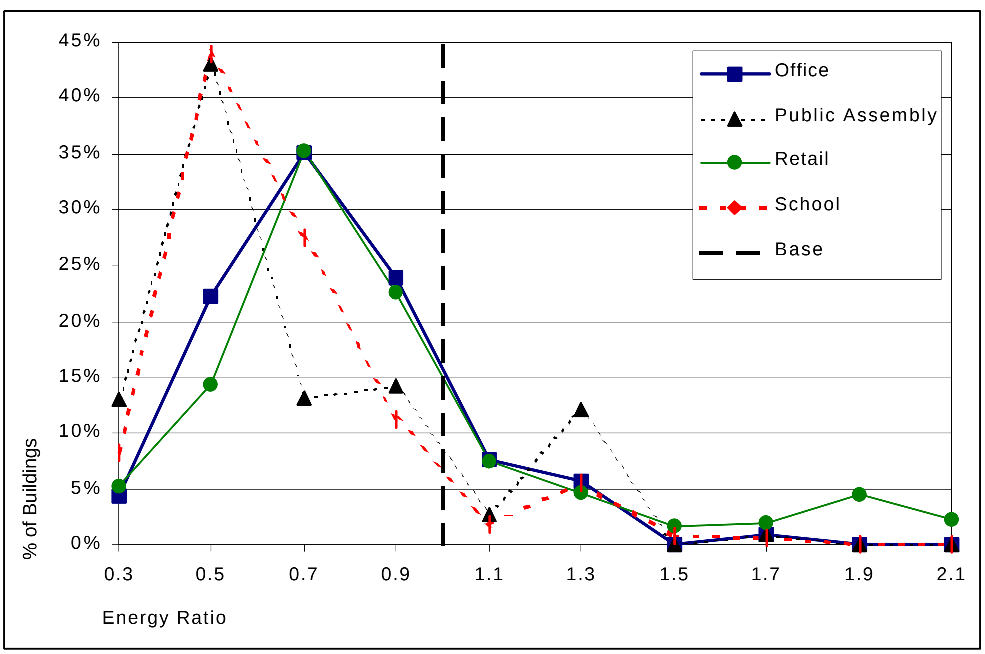

Figure 3: Lighting Energy Ratios by Building Type

much energy for lighting as required. Interestingly, Title 24's lighting requirements were further strengthened in 1999. Research underway in 2000 will compare these buildings to the new lighting baselines.

As might be expected, the lighting savings could be traced to lower LPDs than required. With the exception of retail, a significant number of these buildings had LPD's below 1 watt per square foot. For comparison, the newly adopted ASHRAE 90.1-1999 energy standard sets the whole building requirement for office buildings at 1.3 W/sf and 1.9 W/sf for retail buildings. We are currently engaged in a follow-up study to check the accuracy of the audits.

We also found that the cooling systems were more efficient than required by code. Moreover, our simulations indicated that the systems were generally sized quite close to the DOE-2 optimal sizing.

Findings from the Market Actors

As previously stated, we carried out interviews or surveys with almost 230 of the architects and engineers designing NRNC buildings in California. These interviews gave us a better understanding about the attitudes and practices behind the building characteristics that we observed.

Energy Code

Our interview with architects and engineers provided important insights into the role of the energy code in California. Two-thirds of the respondents reported that energy efficiency is a strong factor in design. And about half reported that they have noticed an increase in the demand for more efficient buildings.

But, reading between the lines, we felt that many of the respondents were equating energy efficiency with complying with Title 24. Indeed, three-fourths of the respondents told us that code tends to drive efficiency rather than vice versa. A typical response was, "Title 24 forces energy efficiency to be a factor. To pass Title 24 the building must be energy efficient."

If we compare these responses with the information about the actual buildings, we observe that:

1. The leaders push efficiency practice substantially beyond current code, but
2. Many designers feel that satisfying code is good enough.

From this, we have concluded that *the codes must be periodically strengthened to move general practice along*.

We also asked the designers why some buildings fail to comply with code. They pointed the finger at *value engineering*. The most common response was "cost cutting after the initial specification of equipment" or "changes by the owner in the equipment and material that they specified." They also sited inconsistent enforcement of Title 24.

Based on both the interviews and simulations we concluded that there are three important ways to improve efficiency:

- **Design Improvement –** making the good buildings even better by pulling these building toward the best buildings,

- **Code Enforcement** – reducing the number of noncompliant buildings, and
- **Code Improvement –** raising the bar for all buildings.

These mechanisms are illustrated in Figure 4.

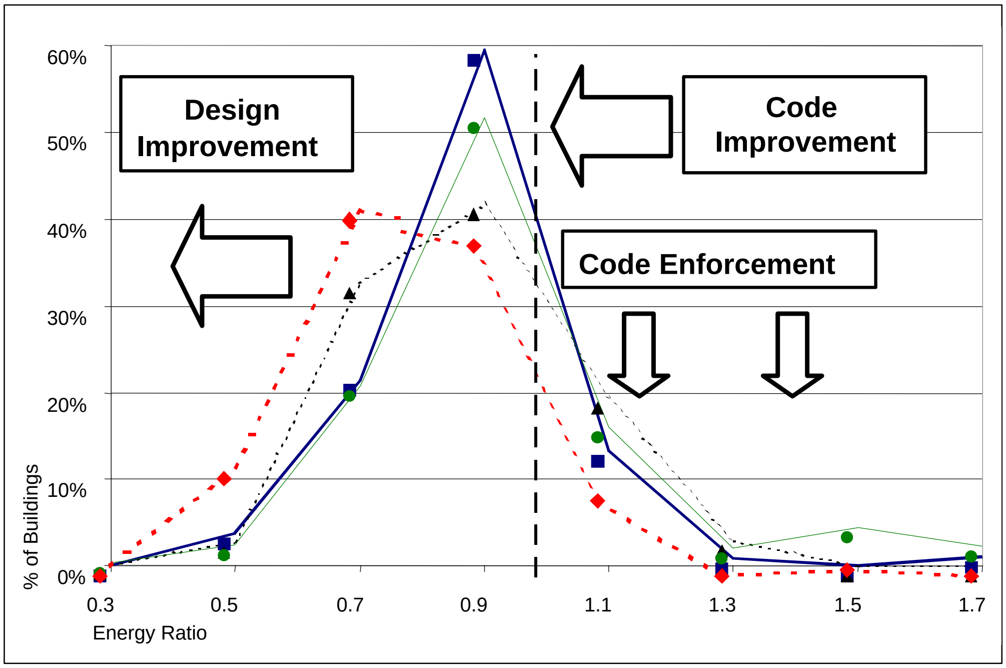

Figure 4. Three Ways to Improve Efficiency

The Decision-Making Process

The designers who were surveyed also helped us characterize how decisions affecting energy efficiency are made. First two general observations:

The role of ownership. Innovation tends to occur most frequently in the public sector. The public sector leads practice in the private sector. Innovation is less common in the speculative sector – but not unknown.

Integrated design and commissioning. Most of our respondents indicated that they did *not* use integrated design in the majority of their buildings. The engineers indicated that they were seldom included in an integrated design team working with the owner. The designers told us that they did some of the elements of commissioning, but they seldom used an independent commissioning agent.

To better understand these observations, we need to consider the relationship between the major market actors. In the course of several studies, we have evolved the model shown in Figure 5. We asked both the architects and engineers who plays the most important role in decisions about energy efficiency. They both most frequently answered that it was the owner. But the next most common answer from the architects was the architects whereas the engineers tended to site the engineers. We took this to be an indicator of tension between the two groups.

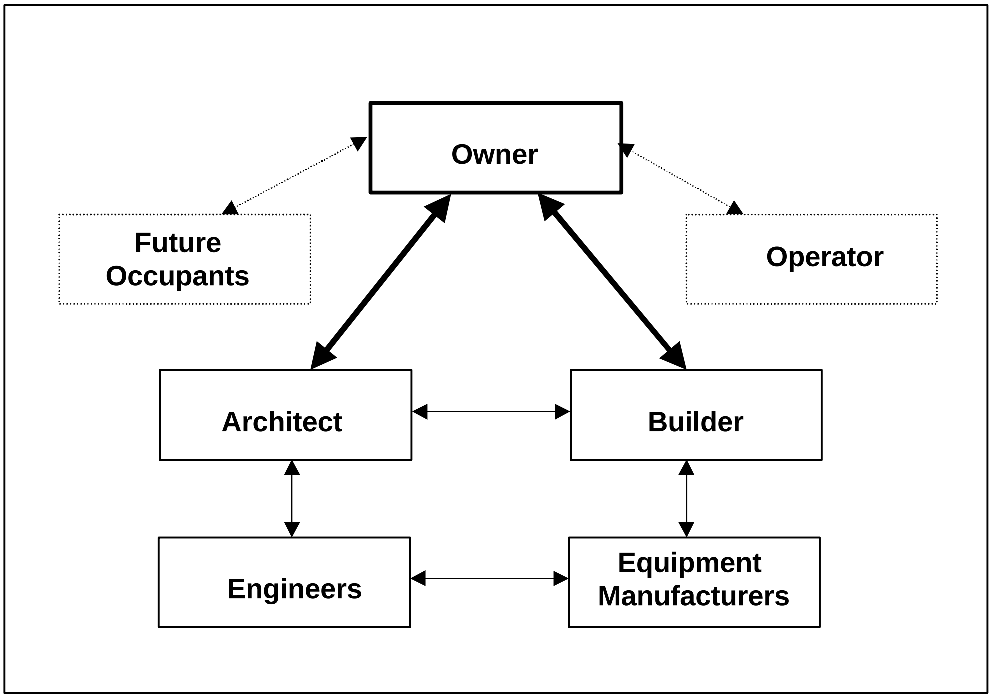

Figure 5. Relationships between the major market actors

In followup studies, we have found that the relationships between the actors are not static but vary from project to project and even over the course of a single project. The roles are significantly affected by five factors:

- The strength of the **constraints –** both cost and schedule.
- The **ownership structure –** owner occupied, built to suit, or built on spec.
- The type of **bidding process –** competitive bid or design / build.
- The **stage** in the process – design or construction.
- The presence or absence of a **construction manager** or other intermediary and his or her approach and skill.

The owner (or developer) is clearly the key decision-maker. The key factors affecting the owner's receptivity to efficiency innovations are the strength of the cost and schedule constraints during design and construction. When these constraints are strong, options simply will *not* be considered if they delay the project or increase its cost.

The future occupants and building operator are not usually active in the design process. But, depending on the strength of the constraints and the ownership structure, the owner may or may not consider their interests in making decisions that affect occupant needs and comfort and tradeoffs between first costs and operating costs. Moreover, the owner may reject innovations if he fears that they may be difficult to operate or maintain.

How the owner interacts with the architect and builder varies depending on the bidding process – competitive bid or design build.

Competitive bid. During the design stage of the competitive-bid process, the owner and architect work closely together. The architect calls on the engineers when they are needed for technical input, but the engineers have little contact with the owner and are seldom in a position to explain design options. Under the competitive-bid process, the builder is generally not in the picture during design.

The roles change in the construction stage. Traditionally the architect would serve as the owner's agent during construction, but this seldom happens in practice. Instead, the owner works directly with the builder. In response to the constraints and to gain a competitive advantage, the builder may offer value-engineering suggestions that compromise energy efficiency or even code compliance. The architect typically has little influence over the owner's decisions at this stage.

So the competitive-bid approach tends to foster communication problems. Communication is especially vulnerable in two areas: (1) between the owner / architect and the engineers during design, and (2) between the owner / builder and architect during construction. *However, there is indication that these problems can be reduced if the owner used a construction manager or other intermediary throughout the design / build process*. The participants in the followup study indicated that the construction manager can be especially effective if he or she follows a open, receptive approach to resolving problems.

Design / build. Under the design / build approach, there are stronger links between the design team and the builder. Under this approach the owner works simultaneously with both the designer and the builder. Both designer and builder have an influence on value-engineering decisions. But, depending on the cost and schedule constraints and on the ownership structure, the owner may place a low priority on efficiency.

Other Market Actors. The interviews also shed light on the roles played by secondary market actors. These include code officials, code designers, and lenders / appraisers. Code officials can either require compliance with energy code or encourage abuses. Code designers must periodically revise the code as allowed by available technology and the market. In practice, lenders and appraisers have little influence on energy efficiency but they could influence the tradeoff between first costs and operating costs.

General Observations and Recommendations

Building on this large body of research, we have come to the following general observations.

- The relationship between the owner and architect is strong but weaker than expected. Generally, the owner makes the final decisions whenever costs are affected.
- The owner is driven by first costs and schedules and seldom considers longer-term operating costs.
- The architect depends on the engineers for their technical knowledge about equipment and technical options. But the engineers are often cut off from the owners.
- The owner may work directly with the builder and override the architect. This can lead to lost efficiency and even violation of Title 24 requirements.

Despite all of this, most buildings in California comply with code, and many do much better than code. This suggests that we need to find ways to leverage the leading-edge buildings to improve the design of the next tier of buildings. To do this, we need more research to understand the conditions that yield the best buildings. We suspect that some of the answers may be found in the five factors that we have identified as affecting the roles of the market players:

- The strength of the **constraints –** both cost and schedule.
- The **ownership structure –** owner occupied, built to suit, or built on spec.
- The type of **bidding process –** competitive bid or design / build.
- The **stage** in the process – design or construction.
- The presence or absence of a **construction manager** or other intermediary and his or her approach and skill.

Of course, a multi-faceted approach is needed to move the nonresidential new construction market. Based on this study, we offer the following additional recommendations:

- Encourage diffusion from public to private
- Aim programs at owners
- Train code officials to watch for design changes
- Continually review and upgrade Title 24
- Strengthen the links between architects and engineers and architects and builders
- Encourage the use of construction managers
- Encourage commissioning

References

RLW Analytics. 1999. *Final Report, Non-Residential New Construction Baseline Study*. Rosemead, Calif.: Southern California Edison Company. The report and appendix can be downloaded from the publications section of RLW's website: rlw.com. The full ULR is http://www.rlw.com/publications.html.