FINAL REPORT

NON-RESIDENTIAL
NEW CONSTRUCTION
BASELINE STUDY

Prepared By:
RLW Analytics, Inc.
1055 Broadway, Suite G
Sonoma, CA 95476

July 8, 1999

California State-Level Market Assessment and Evaluation Study

Project Manager: Marian Brown, Southern California Edison
CBEE Study Liaison: Ralph Prahl, Technical Consultant to CBEE

Funded with California Public Goods Charge Energy Efficiency Funds

Table of Contents

List of Figures

List of Tables

Executive Summary

This is the final report of a baseline study of the Non-Residential New Construction (NRNC) market in California. The study was conducted by RLW Analytics and Architectural Energy Corporation on behalf of the California Board for Energy Efficiency (CBEE) under the management of Southern California Edison Company. This study was intended to give CBEE and future program administrators and implementers some of the information they need to alter the long-term behavior of the actors in the NRNC market and to assess the impact of their programs.

Specifically, we hoped to contribute information needed to:

- Understand current design and building practice,
- Understand the attitudes and motivations of market actors, and
- Have a baseline against which to measure success of efforts to change both attitudes and design practice.

These goals were addressed by examining the NRNC market along the following major dimensions:

Building type: Does the energy efficiency of buildings vary by building type? Can we understand the NRNC market by comparing the characteristics of different types of buildings?

Building ownership: What factors affect the design of buildings that are publicly-owned versus those that are private and owner-occupied, versus those that are private but built for speculative development? Is there a systematic difference in the energy efficiency of these groups of buildings?

Program participation: How have prior utility programs affected the energy efficiency of buildings?

Time: How is the market changing over time? How rapid are these changes? How are the buildings themselves changing?

Two primary sources were used to develop the information presented in this study:

1. Qualitative and quantitative surveys of the designers of new buildings– architects and engineers, and
2. Onsite audits and DOE-2 simulations of the physical and energy attributes of the buildings themselves.

The surveys were used to understand how the NRNC market operates and to assess the strength of market barriers to energy efficiency. The on-site audits and modeling were used to understand actual building performance and characteristics. The building analysis focused on four sectors: office, retail, schools and public assembly. These four building types account for about 70% of the square footage in the total NRNC market.

We combined newly collected data with older information from both the surveys and onsite audits from several prior impact evaluation studies of the NRNC programs conducted by the utilities in California. Altogether, we used 228 qualitative and quantitative surveys of architects and engineers designing new nonresidential buildings, and engineering audits and energy simulations of 667 new construction projects completed in the last four years.

Our findings are presented under the following headings:

- The efficiency of buildings
- The market players
- Key technologies and approaches to design
- Key market segments
- The role of energy codes
- Other opportunities for effective intervention
- Recommendations for further research

Our findings are summarized in the following sections.

The efficiency of buildings

We found that most NRNC buildings exceed Title 24 energy code requirements. This was true in all market segments that we examined in depth. We found that the best buildings are using 30% less energy than typical buildings and 40% to 50% less than code. The buildings that are already exceeding code have the greatest potential for added savings.

The market players

Some owners provide crucial leadership in energy efficiency but others override the recommendations of their architects and engineers. Architects and engineers both find it more useful to educate owners using newsletters than more high-cost, hi-tech options such software tools. They also believe that prototype demonstrations are useful.

Furthermore, we found that:

- The relationship between the owner and architect is strong but not as strong as expected. Generally, the owner makes the final decisions whenever costs are affected.
- The owner sometimes works directly with the builder and overrides the recommendations of the architect. This can lead to occasional violations of Title 24 requirements.
- The operator and/or maintenance contractor can be an indirect but still significant factor in the process. The owner may be concerned about the operator’s ability to manage innovative equipment. Unfortunately, the architects and engineers may have little opportunity to train the operators because of turnover and other factors.
- The architects depend on the engineers for their technical knowledge about equipment and often about technical options that may improve energy efficiency. But, unfortunately, the engineers may be excluded from the design team working with the owners.

Due to the relatively weak link between the architects and engineers, and the even weaker link between the architects and equipment manufacturers, there is a weakened connection between (a) the engineers and equipment manufacturers who possess the technical knowledge about energy efficiency, and (b) the owners, architects, and builders who make the crucial decisions about the buildings.

Key technologies and approaches to design

Lighting is the single most important contributor to energy efficiency. The more stringent Title 24 lighting requirements of the 1998 code will narrow the margin for the more efficient sectors and close the margin for the speculative segment.

Cooling systems are generally sized correctly to reflect building characteristics and loads. Moreover, we found that cooling systems are becoming more efficient.

Over one-fourth of the architects and engineers use optimized energy design in more than 60% of their buildings. And we were told that the practice is growing.

Many architects and engineers go through some or all of the specific procedures involved in commissioning, but an independent agent is rarely involved.

Key market segments

We found consistent differences in most aspects of energy efficiency among the ownership sectors. But our building data also showed that energy efficient buildings are found in all sectors – public, private owner-occupied and private speculative.

We found that commissioning was most common in the public sector. We also found that the use of optimum energy design was most common in the public sector but was increasing most rapidly in the private owner-occupied sector. In our analysis of the buildings themselves, we confirmed our hypothesis that energy-efficiency was highest in the public sector, followed by the owner-occupied sector. Other key findings include:

- The public sector leads the private sector in virtually all aspects of energy efficiency. In particular, schools are the most efficient of the four building types that we studied in depth.
- The private owner-occupied sector leads the private speculative sector in virtually all aspects of energy efficiency.
- The public sector seems to draw the private owner-occupied sector toward more innovate design practices such as integrated design methods and building commissioning.
- However, the private owner-occupied sector does not seem to draw the private speculative sector toward these practices.

The role of energy codes

Energy codes were found to play a crucial role in raising energy efficiency in the NRNC market. They operate in two distinct ways:

- **Code Enforcement –** limits the number of buildings falling below the current energy code.
- **Code Revision –** gradually increases the requirements that all buildings must meet.

Our data showed that code enforcement is currently effective. But our study also indicated that one opportunity for improving code enforcement is to train building inspectors to watch for inappropriate changes by owners, builders and subcontractors after Title 24 review.

Unfortunately, many owners do not see the need to reach far beyond Title 24 requirements. So it is vital that codes be continually revised, as more efficient equipment becomes available. Without continued revision, the market might actually be held back by the widespread view that code represents appropriate design practice.

Other opportunities for effective intervention

The greatest danger to sustainable innovation appears to be the weak link between the owners / architects / builders and the engineers / manufacturers. This suggests that interventions in the NRNC market will not be effective if they are directed solely to manufacturers and engineers.

Conversely, interventions should be designed to strengthen the link between these two groups. This is also the key to increasing the use of commissioning since the engineers have to help the owners understand the merits of commissioning. Promoting integrated design teams and whole-systems approaches to design is one promising approach for strengthening the link between the owners / architects / builders and the engineers / manufacturers. This practice is already established among some architects and engineers.

The operator or maintenance contractor can be an important factor in the market. The owners must be confident in the ability of their operators to maintain any unconventional system that is recommended.

The owner is the most important decision-maker – market interventions should be aimed at the owner. Both architects and engineers feel that the best tool for reaching the owner is one of the simplest ones – a newsletter. They also cite demonstration projects as an effective tool.

Recommendations for Further Research

Six suggestions were identified for building on the present study:

- Verification of Lighting Power Densities
- Lighting Quality
- Ancillary Benefits of Energy Efficiency
- Drivers of Best Practice
- Raising the Efficiency of Good Buildings
- Energy Impacts of Strengthened Codes and Best Practice

We believe that these studies would deepen and broaden our findings and help both owners and architects understand that efficienct buildings can work well.

1. Introduction

This is the final report for the Non-Residential New Construction Baseline Study, conducted on behalf of the California Board for Energy Efficiency (CBEE). This first chapter describes the background and goals of the study, describes the target audience, summarizes the sources of information used in the study, provides an overview of the non-residential new construction market, summarizes the research questions to be addressed, and introduces the remainder of the report.

Background

In the past, the focus of energy conservation efforts was on an integrated approach to resource acquisition that balanced supply options with demand-side opportunities to reduce consumption. This led to utility energy-efficiency programs that were transactional in nature. That is, a specific project was given a rebate to offset the additional cost of more energy efficient equipment or the extra expense of exploring broader design options.

With the advent of an open electric market in California and the formation of the CBEE, the focus of market interventions has shifted from this transactional approach to an approach intended to alter the long-term behavior of market actors. To successfully accomplish this task, the CBEE and future program administrators and implementers need:

- An understanding of the barriers to more efficient design,
- An understanding of what can be done to remove those barriers so that the efficient practices will become standard industry practice, and
- An understanding of current practice so that changes in the market over time can be measured.

It is certainly important to track barriers in the marketplace over time. However, the ultimate measure of success in overcoming those barriers is the extent to which the efficiency of buildings actually increases. Therefore, a complete baseline study must include quantitative energy efficiency measures against which to compare future building practice. Moreover, an analysis of the energy efficiency of actual buildings can provide insights into design practices and indicate opportunities for future gains in efficiency. This will be informed by investigations into the attitudes and practices of building designers.

Goals

This study will seek to understand current practice in non-residential new construction (NRNC) in order to lay the foundation for upcoming energy efficiency and market transformation programs. This study is intended to provide much of the information needed by those working to transform the NRNC marketplace to:

- Understand current design and building practice,
- Understand the attitudes and motivations of market actors, and
- Have a baseline against which to measure success of efforts to change both attitudes and design practice.

The information and data developed in this study will also help future analysts:

- Provide market data to policy makers, administrators, and implementers,
- Evaluate the potential of proposed programs, and
- Track market transformation over time.

The purpose of this report is to summarize the information that has been developed and to provide the tools that future investigators will need to utilize the data effectively.

Audience

In designing the project and preparing this report, we have tried to anticipate the interests of as many potential users for the data as possible, including policy makers, program administrators, and program implementers. We have attempted to provide a broad spectrum of information about a large majority of the construction activity in California. This study has produced a great deal of information on the NRNC market in the state.

In this report we have sought to address the major issues and most important findings. However, no report can be all things to all people. So this report also provides the background information and documentation that future investigators will need to carry out their own analysis of these data.

The Data

Two primary sources have been used to develop the information presented in this study:

1. Qualitative and quantitative surveys of the designers of new buildings– architects and engineers, and
2. On-site audits and DOE-2 simulations of the physical and energy attributes of the buildings themselves.

The survey research has been used to understand how the NRNC market operates and to assess the strength of market barriers to energy efficiency. The on-site audits and modeling information have been used to understand actual building performance and characteristics. We have combined newly surveyed information with older information from both the surveys and on-site audits from several prior impact evaluation studies of the NRNC programs conducted by the utilities in California.

Designers

In the planning phase of this project, we interviewed 12 architects to better understand recent trends in the NRNC market. Then in-depth interviews were conducted with 56 additional architects and engineers who were involved with energy efficiency decisions on a non-residential new construction project during 1998. Building on this information, we designed and implemented a more structured survey of almost 160 architects, mechanical engineers, and electrical engineers.

In conducting the 68 qualitative surveys, we found that it was very difficult to interview architects and engineers by telephone, because the designers that we wanted to interview were very busy. Repeated callbacks were generally required to find them in the office and free to talk to us. A high proportion refused to be interviewed.

In planning the quantitative survey, we felt that these problems would be even more severe, both due to the detailed information that we wanted to collect and the larger sample size we required. We were concerned about minimizing the inconvenience to the respondents as well as the time and effort required to collect the information. We were also concerned about the potential bias from a low response rate.

We sought to address these issues by allowing the respondent to complete the survey on the Internet or by fax. We hoped this approach would allow the respondents to complete the survey in less time and whenever their schedules allowed. At the same time, we wanted to minimize nonresponse bias, so we used the telephone, email and a periodic lottery to encourage the respondents to complete the survey. We feel that these efforts were successful.

These primary data have been supplemented with information collected through surveys and focus groups in prior studies of the NRNC market. We have drawn on the impact evaluation studies of the 1994 and 1996 NRNC energy efficiency programs administered by PG&E and SCE.[1] We have used this information to provide background for the present study, but we have not attempted to combine it systematically with our primary survey data.

Buildings

A second, primary data collection effort was to conduct 180 detailed on-site audits and energy simulations for a sample drawn from the 1997/1998 NRNC market. In order to provide the most meaningful information with the available resources, the sample was restricted to four building types – office, retail, schools and public assembly. We focused on these four building types because they account for about 70% of the square footage in the total NRNC market. To the extent possible, we excluded participants in utility energy-efficiency programs.

In the audits we collected information on a very extensive range of physical characteristics such as types of lighting equipment and lighting power densities, types and efficiency of HVAC equipment, insulation levels, and glazing. We also collected relevant behavior characteristics such as occupancy schedules, equipment control strategies and equipment set points.

Using this information, we created two DOE-2 energy simulations for each sample building:

1. The as-built energy usage of the building, and
2. The baseline energy usage that would have been expected if the building had just complied with Title 24.

Both the as-built and baseline simulations assumed the equipment types and occupancy schedules that we found, but the HVAC equipment was resized for the baseline simulation. We used these simulations to estimate the efficiency of the sample buildings and to compare the efficiency levels achieved in the various market segments.[2]

[1] These studies were carried out in 1995 and 1997 by RLW and AEC for the two utilities.

[2] Although these comparisons shed light on the extent of compliance with Title 24 requirements, it is important to be aware that Title 24 is based on assumed occupancy levels and schedules. A specific building

We supplemented the primary data with audits collected in the prior impact evaluation studies of the 1994 and 1996 NRNC energy efficiency programs. In the prior PG&E and SCE studies, almost 800 NRNC projects were audited and simulated. Another thirty audits were added from the impact evaluation of the 1995 SDG&E NRNC program. These samples included both participants and nonparticipants in about equal numbers. The nonparticipant samples were designed to match the types of buildings found among the program participants. The existing data represent almost all building types whereas our new audits tend to give us greater depth in the four selected building types

We have assembled all of these data into a consistent integrated database describing the 667 buildings. Also, we have prepared new DOE-2 baseline and as-built simulations for the earlier sites using modeling techniques that are consistent with those used for the new sites. In carrying out our analysis, we have sought to take full advantage of these extensive data while minimizing bias arising from the use of data collected in past projects with different objectives. Fortunately, the same principle contractors carried out the various studies using consistent methods.

However, we had several concerns about combining the samples. We considered:

- The appropriateness of combining samples collected over a several year period, especially if there are significant changes in the market over the period,
- The practice in the secondary studies of using separate sample designs for program participants and nonparticipants, thereby over-representing the participants and potentially providing a distorted picture of the general population,
- The practice in the secondary studies of matching the sample of nonparticipants to the sample of program participants, possibly providing a biased sample of the building types occurring in the NRNC market, and
- The difference in the building types represented in the secondary samples and the primary sample.
- The desire to describe the baseline status of the NRNC market both with and without the energy efficiency programs offered by the utilities.

In carrying out our analysis, we have sought to minimize bias arising from the use of the combined data. In particular, we calculated new weights by building type and size for both the participants and nonparticipant buildings in the prior samples. The new weights reflect the NRNC population in each year and the saturation of program participants in the population of NRNC projects. This should go far to reduce any bias due to the original sample designs. We have also tried to select the most appropriate subsets of the data for the various comparisons. For example we restricted the comparisons of participants and nonparticipants to the 1994 and 1996 data since participants were excluded from the 1998 sample. Similarly in looking for trends between the 1994, 1996 and 1998 studies, we restricted the analysis to nonparticipants in the four building types

---

that just complied with Title 24 at the design stage may be above or below our baseline due to the its actual occupancy and schedule.

targeted in the 1998 sample. We have also been cautious to combine the data from different years only to the extent that it is justified.

We have used these data to describe construction characteristics and practices in California's NRNC marketplace. We have taken advantage of this large sample to look for meaningful trends over time and significant differences between market segments. In addition, we have used the results of the DOE-2 simulations to compare the energy efficiency of buildings in different markets and over time.

Overview of the Market

To set the stage for the remainder of the report, this section will provide a summary of the structure of the non-residential new construction market. We will draw on our experience in conducting prior NRNC studies in California and elsewhere.[3] We will discuss the market actors, the new construction process, drivers of energy efficiency, barriers to greater energy efficiency in the NRNC market, the segments in the market, and the prior energy efficiency programs. We will build on this discussion to suggest some of the hypotheses to be examined in this study.

The Importance of the NRNC Market

The ultimate goal of market transformation activities in the NRNC market is to improve the actual energy efficiency of new buildings. The new construction market is especially important because more options are available at a substantially lower cost when energy efficiency is designed into buildings right from the start rather than later through retrofit measures. Lost opportunities and lifetime savings are especially relevant to nonresidential new construction.

The Key Building Parameters

The key parameters that differentiate the energy usage in nonresidential buildings include:

- Hours and days of operation
- Climate
- Occupant density
- Occupant activities
- Lighting system type and efficiency
- HVAC system type and efficiency
- Insulation and glazing
- Orientation and configuration
- Other energy using systems (refrigeration, elevators, process loads, plug loads, etc.)

The first four of the preceding parameters – hours of operation, climate, occupant density, and occupant activities – are generally beyond the control of building designers. The remaining five parameters – lighting systems, HVAC systems, insulation and glazing,

[3] RLW and AEC were the principle contractors for the NRNC impact evaluation studies conducted for PG&E and SCE jointly in 1994 and separately for the two utilities in 1996.

orientation, and internal systems – can be manipulated through good design and the use of energy efficient technologies to improve the overall efficiency of the building. These are the ultimate targets of market transformation efforts for NRNC.

The Systems Approach

The new construction market differs from the retrofit market in that the emphasis can be on the efficiency of the whole building rather than on the saturation of specific measures. In designing a building from the start, it is best to consider the entire system – envelope, lighting, HVAC, etc. A substantial portion of the saving can come from the interaction between the elements of a building. For example, well orientated and properly shaded windows can decrease the load on the cooling system. The cooling system load can also be reduced if natural lighting can be used to reduce the lighting power density. But to capture all of the potential savings, the cooling system must be sized smaller to match the lower load. This requires a systems view of the building.

Consider a modern office building. To optimize its overall energy efficiency, the designers need to consider the level of lighting, how the waste heat from the lighting fixtures is removed, how the windows are orientated, the reflection and convection of the glazing, the type, size and efficiency of the air conditioning, etc. Moreover the designers have to think of the building as a system of zones - each with their own characteristics and subsystems, each interacting with one another.

In this report, we will discuss two central issues:

- Do the architects and engineers work together as a coordinated design team?
- Do the architects and engineers use integrated design tools to consider the building as a whole?

Market Actors

The key actors in the non-residential new construction market are:

- Designers (Architects and Engineers)
- Owners
- Builders (Contractors and Subcontractors)
- Equipment manufacturers

These groups are inter-related in the new construction market in a variety of possible relationships. A model of the relationships between market actors is shown in Figure 1. In this structure, the architect is assumed to be the primary contact with the owner and is the project leader.

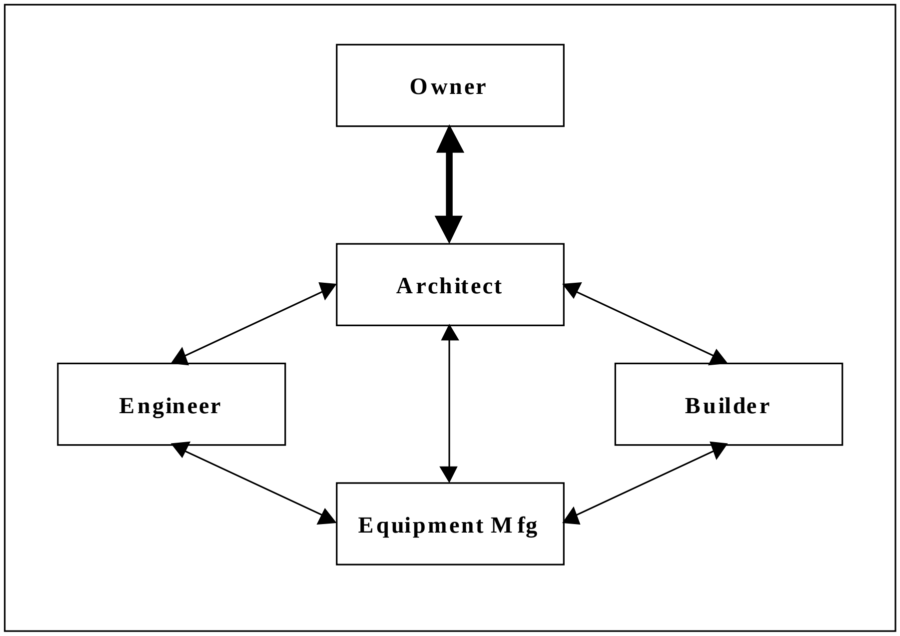

Figure 1: Basic Relationships in New Construction

Each of the market actors has a specific role in the process of designing and constructing buildings. They can be summarized as follows:

Owners The owners originate the project, but may or may not be the ultimate users of the building. Because this group provides the financing for the work, final approval of construction details, including any energy efficiency options, and budgets falls to this group. Building owners have traditionally received the incentives provided by utility sponsored programs in new construction.

Architects Architects are the principal designers of the building and traditionally the leaders of the design teams. The architect is responsible for the overall conceptual design, detailed design for the construction trades, project management, and interface with the building owner.

Engineers Mechanical, structural, and electrical engineers support the architects on technical aspects of the design. Of specific interest to energy efficiency are the mechanical and electrical engineers who specify the major energy using systems in the buildings.

Builders The builders (general contractor and sub-contractors) will physically construct the building. The experience, knowledge, and skill of the builders will effect the installation and operation of energy efficient equipment.

Equip. Mfg. Equipment manufacturers supply the new construction market with the components and systems to build the structures. The availability of efficient equipment and components from manufacturers affects the ability of architects and owners to build more efficient buildings.

In this study, we will look at the relationship between the market actors. In particular, we will look for aspects of the relationships that might create barriers to energy efficiency.

New Construction Process

The process of constructing a non-residential building is generally a long one, taking from one to three years from initial design to occupancy. The process is summarized in Figure 2. The owner will generally approve each step of the process.

Changes to the design to achieve greater energy efficiency become more costly and logistically difficult with each step in the process. Commissioning is included in the process diagram in Figure 2, but our prior NRNC studies have indicated that it is not currently a widespread practice in the market. Figure 2 also shows the primary market actors and issues at each stage of the typical new construction process.

Of course, a new construction process will not generally follow the linear progression shown in Figure 2. In practice, there will be many feedback loops and multiple iterations through the steps.

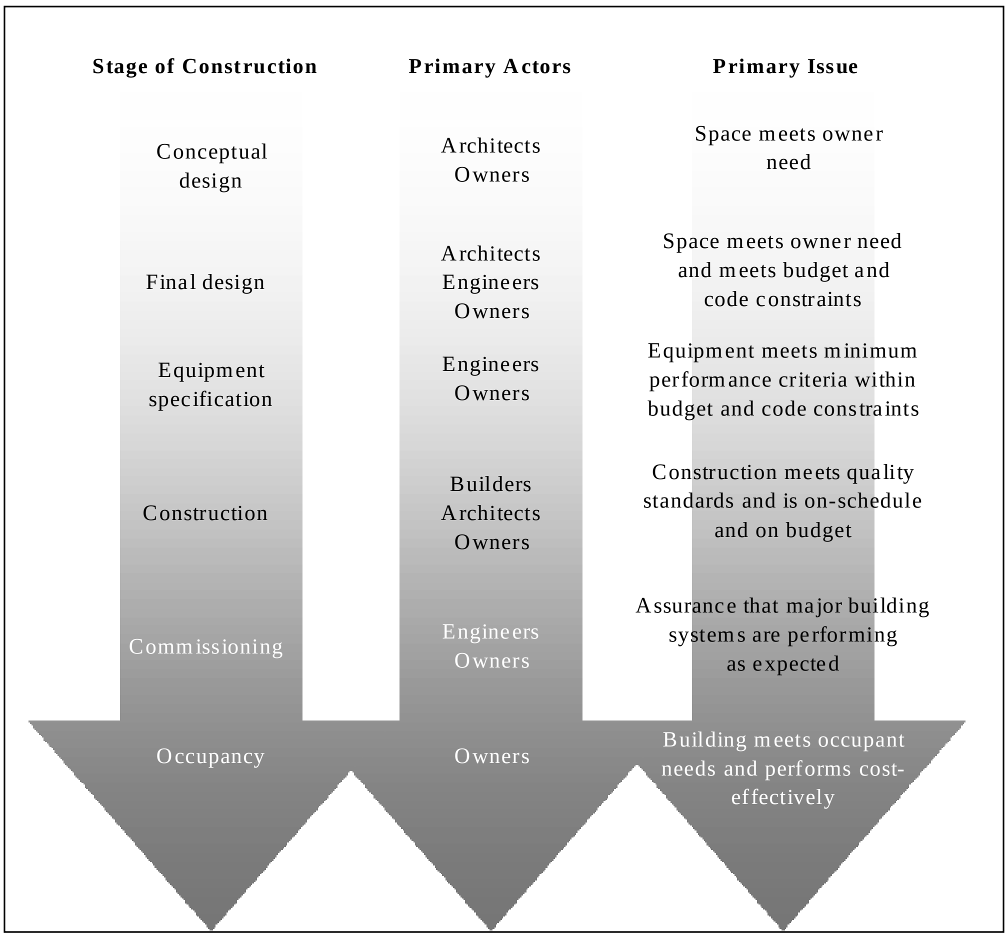

Figure 2: New Construction Process

Drivers of Energy Efficiency

There are thought to be two primary factors driving energy efficiency in the NRNC market. One factor is simple economic motivation to realize a return (in energy cost savings) from an investment (in improved efficiency). This motivation has always been present for NRNC projects, but it is often overshadowed by the issues described in the next section. The other factor is regulatory - energy codes require a minimum degree of energy efficiency in new buildings. The building industry is highly regulated, and builders are accustomed to building code requirements placed on their buildings.

In the NRNC marketplace, the voluntary and the regulatory aspects of energy efficiency tend to leap frog each other. As a given energy efficiency technique moves from an innovative toward a common practice, it eventually gets adopted into the energy code. By that point, the technique will be demonstrably cost-effective and widely adopted, and its codification only impacts those builders who are lagging standard practice or who are pushing hardest to reduce first costs. Thus, energy codes have the effect of locking in the market penetration of energy efficiency techniques, and of helping to counteract first cost pressures that would otherwise prevent sensible efficiency investments.

Barriers to Energy Efficiency

The following factors have been suggested as potential barriers to energy efficiency.[4] These factors may impede the adoption of more efficient equipment choices and design alternatives. We will seek to determine the importance of these and other factors in the California NRNC market.

Product Unavailability

Inadequate supply may be a barrier to the market penetration of a product. This can be caused by limited distribution or manufacturing. Due to limited availability, the product may be sold at a premium price compared with other less efficient equipment.

Organization Practices

Organizational practices can make it difficult to incorporate energy efficiency. For example, public school districts operate under statewide new-construction policies that limit initial spending over a certain amount. These limits can preclude an energy-efficient option due to its higher price, even though it would save money in the long run.

Performance Uncertainties

Uncertainty about the performance of an innovative measure may discourage its application. The owners may fear increased maintenance or replacement costs. The designers and builders may be concerned about construction problems, comfort or reliability.

Information Costs

Information barriers may arise if it is difficult or time consuming to access credible information about the availability and effectiveness of more efficient alternatives.

---

[4] Eto, J., R. Prahl, and J. Schlegal, 1996. A Scoping Study on Energy-Efficiency Market Transformation by California Utility DSM Programs. Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-39058.

Hassle Costs

Adapting energy efficient options can cause complications such as stocking nonstandard equipment or training operators on new procedures.

Asymmetric Information

This can arise when engineers have better information about energy efficient options than the actual decision-makers such as the owners and architects.

Bounded Rationality

Both owners and designers may follow rules of thumb rather than economically rational behavior. In the NRNC market, for example, designers may feel that their buildings are energy efficient as long as they meet Title 24 requirements.

Access to Financing

Future energy savings may be difficult to demonstrate to financing agents, so it may be difficult to obtain the added financing required for energy-efficient options.

Split Incentives

Economic motivations to adapt energy efficiency measures may be distorted if the incentives of an agent charged with purchasing energy efficiency (e.g. speculative developers) are not aligned with those of the persons who would benefit from such a purchase (e.g. tenants). For example, when the owners will not occupy or pay the energy costs for a building, they may be reluctant to invest in measures that could reduce energy costs. The incentive to prepare a least-cost bid may also motivate contractors to suggest lower cost replacements for energy-efficient measures.

Market Segments

The NRNC market is quite heterogeneous compared to most other markets. In this report[5] we will consider the following ways of segmenting the market:

- **Building Type**. We will look at four specific building types: offices, retail, schools and public assembly.
- **Ownership**. We will compare public projects to private projects built for occupancy by the owner and private projects built on speculation.
- **Program Participation**. We will compare projects that participated in utility-sponsored energy efficiency programs to those that did not participate in these programs.
- **Time**. We will look for changes in the market over time. In particular, we will compare projects built in 1994, 1996 and 1998.

Building Type

The NRNC market includes many distinct types of buildings that have evolved to suit diverse uses. Consider the physical and operational differences between the following examples:

[5] The data developed in this study are available for other types of analysis such as by climate zone.

- Grocery store - single story, open plan sales area, warehouse-style storage areas, windows only at front, large refrigerated display cases, chain ownership, seven days twenty-four hour operation.
- High rise office building - multiple story, many private offices and small rooms, large window areas on all sides, multiple tenants with investor or corporate ownership, ground floor retail, five day 9-to-5 operation.
- Movie theater complex - single story, lobby plus screening rooms, high occupant densities, no windows except lobby, chain ownership, seven-day evening operation.
- Hotel - multiple story, many uses in addition to guest rooms (restaurant, banquet, lobby, retail, health, office), corporate or investor ownership, large window areas, large hot water usage, seven-day, twenty-four hour operation.
- Public library - single or multiple story, stacks and reading areas, moderate window areas, government ownership, variable hours of operation.

To identify common characteristics and patterns, individual buildings are classified into building-type categories. The building type is of concern because the use of the building strongly affects design and equipment choices. For example, large public assembly spaces may oversize cooling systems to ensure that the assembly space can be cooled when it fills for a function. The result can be a large cooling system that is run relatively infrequently. Retail stores may place a high value on quality display lighting to highlight merchandise, resulting in higher lighting power densities than other building types. Offices may have very large plug loads due to the large number of computers and other office equipment. By contrast, schools have shorter occupancy patterns and have been heavily targeted by utility programs.

Most of the results of this study have been developed for the following four building types:

Offices	Private offices, financial services, and government administration.
Retail	Stores, shopping centers and post offices.
Schools	Elementary schools, high schools, vocational schools, colleges and universities.
Public assembly	Theaters, museums, galleries, and other facilities whose primary use is for public gathering.

These four building types account for about 70% of the square footage in the total NRNC market. Offices and retail alone represent almost half of the market. Due to the specialized equipment and diversity of occupancy and schedules, we have excluded restaurants, grocery stores, hotels, motels, clinics, hospitals, libraries, arenas and stadiums.

Ownership

Classification by building type is only one of the myriad ways in which the NRNC market can be segmented. The challenge is to identify the market segmentation that will be most useful for advancing energy efficiency in new construction. A hypothesis of this study is that it is useful to segment the NRNC market according to building ownership.

This study will examine the following three ownership segments:

1. Public buildings
2. Private owner-occupied buildings
3. Private speculative development

This segmentation is expected to differentiate three fundamentally different sets of decision criteria in new construction and three levels of energy efficiency. Figure 3 shows how the three ownership segments are expected to compare on the typical level of energy efficiency and on the importance of first cost versus long-term operating cost.

Public buildings are those buildings owned and operated by Federal, State, or local governments. These buildings tend to be office buildings, public assembly space, and specialized uses such as police and fire stations. Our hypothesis is that publicly owned buildings are significantly more efficient than private buildings.

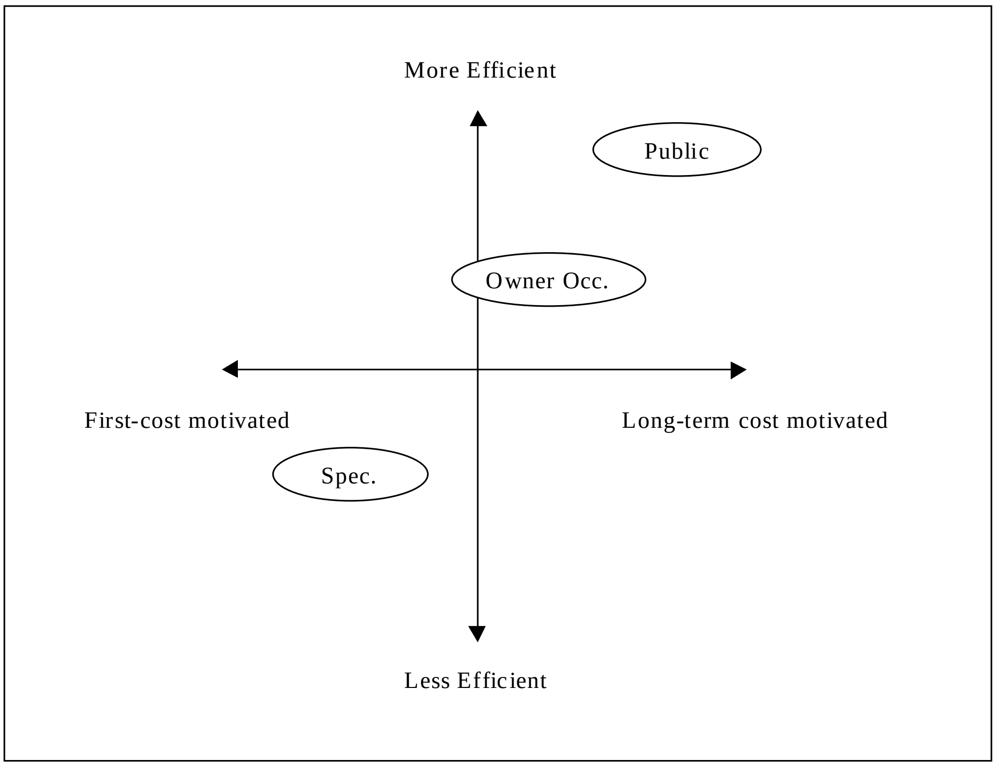

Figure 3: NRNC Market Segments

Program Participation

For many years the California utilities have conducted energy efficiency programs in the NRNC market. The main methods have been to provide:

1. Information to design professionals
2. Financial incentives to building owners.

The primary approach of the utility-sponsored programs has been to offer financial incentives for the installation of efficient equipment. These incentives have been calculated on either a prescriptive or an overall performance basis. The prescriptive incentives essentially used a price list of rebates for the installation of equipment of a particular efficiency level. The performance-based incentives used building energy simulations to compare overall building performance to a baseline, usually a percentage below building code requirements.

These programs have been primarily transactional in nature. This has occurred mostly because the utility contact with the projects tend to occur in the early construction stages, when the need to plan power delivery to the site motivate the owners and builders to involve the utility. Of course, there are examples of earlier utility involvement in projects, particularly with those that participated in the programs on a performance basis.

Currently, the emphasis is switching to market transformation programs. As explained earlier, the primary purpose of this study is to provide the baseline information needed to plan and monitor the new generation of programs.

Changes over Time

As already discussed, changes over time are important because they may affect the validity of pooling the building data collected over several years. It is also important to understand how the NRNC market changes over time in order to understand the market fully and to set realistic expectations for transforming the market. In the surveys of architects and engineers we asked several questions about how practices have changed in the last five years. We also compared the actual buildings constructed in 1994, 1996 and 1998.

Research Questions

With this overview of the NRNC market, we can state the goals of this study more specifically. This study will seek to address the following research questions:

1. Which building parameters have responded the most to utility-sponsored programs in the past?
2. Where are the unrealized efficiency gains in each segment of the market?
3. What opportunities for market interventions exist? Do they differ by ownership or building type?
4. What are the differences between public and private building efficiency choices? What are the drivers of those choices?
5. What are the differences between owner-occupied and speculative efficiency choices? What are the drivers of those choices?
6. How does the construction process differ between public, private, and speculative projects?
7. How has the market evolved over time?
8. What are the barriers to increased energy efficiency in NRNC?
9. What is the current baseline for non-residential new construction practice?

These questions will be addressed by examining the NRNC market along the following major dimensions:

Building type: Does the energy efficiency of buildings vary by building type? Can we understand the NRNC market by comparing the characteristics of different types of buildings?

Building ownership: What factors affect the design of buildings that are publicly-owned versus those that are private and owner-occupied, versus those that are private but built for speculative development? Is there a systematic difference in the energy efficiency of these groups of buildings?

Program participation: How have prior utility programs affected the energy efficiency of buildings?

Time: How is the market changing over time? How rapid are these changes? How are the buildings themselves changing?

To address these questions we will draw on both the surveys of designers and the audits and simulations of buildings.

Preview of the Remainder of the Report

Following this introduction, the report provides the following sections:

Summary of Results – Chapter 2 will give a summary of the findings and recommendations derived from the study. This chapter will consolidate and integrate the information from the following three chapters. This information will be used to formulate recommendations for transforming the market, including the types of intervention that might be effective, the market segments and technologies that seem to be most critical in moving the market, how to empower the most important actors, and the role of energy codes.

The Designers – Chapter 3 and 4 will give a summary of the findings of the designer surveys. These chapters will describe how architects and engineers view the market. It will discuss the structure of the market, how decisions about energy efficiency are made, and the barriers to energy efficiency in the NRNC market. Chapter 3 will describe the qualitative interviews and chapter 4 will report the findings of the quantitative survey.

The Buildings – Chapter 5 will give a summary of the findings of the onsite audits and energy simulations. This chapter will describe the physical characteristics and energy efficiency of the current stock of buildings in the California NRNC market. This chapter will describe trends in actual energy efficiency over time, examine the impact of the utility efficiency programs, and examine differences between buildings in different market segments.

Further Research – Chapter 6 will give suggestions for further research building on and extending this study.

A series of technical appendices will accompany the main report for readers who wish to delve more deeply into these data:

Quantitative Survey of Market Actors – a detailed description of the methodology used to develop these data, including the survey instrument and the technical documentation for the resulting database. This appendix will also discuss our experience in using the Internet to collect these data.

Audit and Modeling Methodology – a detailed description of the procedures used to develop the information about NRNC buildings, including the auditing and modeling methodology.

The NRNC Buildings Database – technical documentation of the database developed in this study. This provides the information needed to extract additional technical information from the database.

The MBSS Analysis Tool – documentation of the software that has been provided with the buildings database.

Instruments – Five data collection instruments used in the surveys and audits.

2. Summary of Results

In this chapter, we will summarize the major findings about the non-residential new construction (NRNC) market in California, and suggest how market barriers to energy efficiency can be reduced. This section will draw on all of the information collected in this study – 228 qualitative and quantitative surveys of architects and engineers designing new, nonresidential buildings, and engineering audits and energy simulations of 667 new construction projects completed in the last four years.

This chapter is organized into the following sections:

- The efficiency of buildings
- The market players
- Key technologies and approaches to design
- Key market segments
- Market barriers
- The role of energy codes
- Other opportunities for effective intervention

The Efficiency of the Buildings

One of our most important observations is the following:

Most NRNC buildings exceed Title 24 energy code requirements. Most buildings are efficient in all market segments that we examined in depth.

Our audits and simulations showed that most NRNC buildings satisfy Title 24 requirements. Figure 4 tells the story. The graph describes the energy ratio, defined to be the consumption of a building or set of buildings relative to what their consumption would have been under Title 24. An energy ratio of one, indicated by the vertical dashed line, indicates that the buildings are performing just at our Title 24 baseline. An energy ratio below one indicates that the buildings are using less energy.

Figure 4 shows the distribution of energy ratios for the buildings in four market segments – office, retail, school and public assembly. For example, the figure shows that 11% of new schools in California have an energy ratio of about 0.5; these schools are using about half of the energy that would have been expected if they had been built exactly to the Title 24 requirements.[6]

From the figure itself and the statistical insert, it is clear that the vast majority of the buildings have energy consumption below the Title 24 baseline. Schools were most energy efficient with 90% meeting or exceeding code, followed by offices with about 85% exceeding code. In the public assembly and retail sectors, about 75% exceeded code.

[6] More precisely, our data indicates that 11% of new schools in California have an ernergy ratio between 0.4 and 0.6.

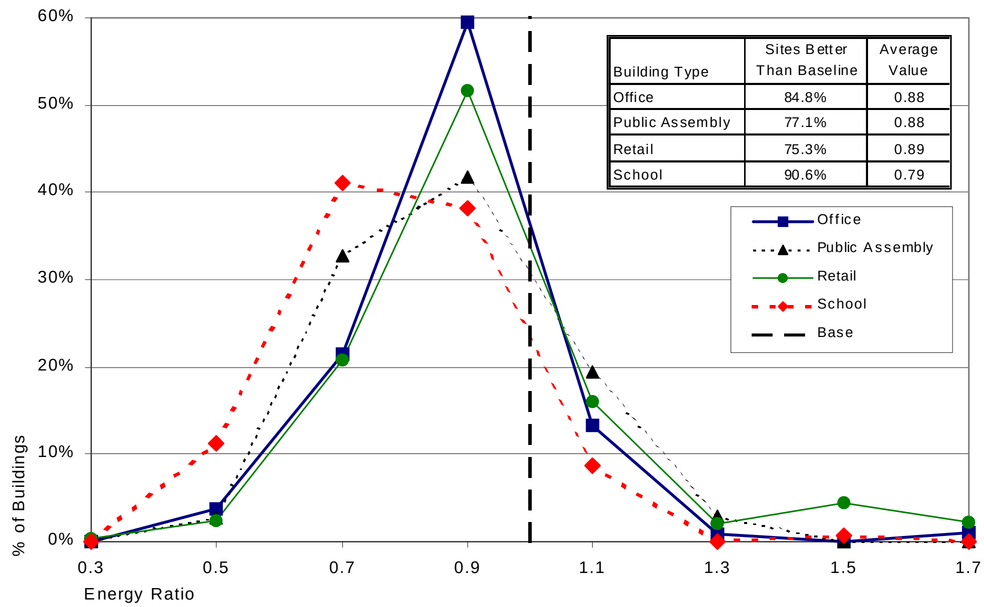

Figure 4: Whole Building Energy Ratio by Building Type

Figure 4 also shows the average value, i.e., the overall energy ratio, in each of the four market segments. The overall energy ratio is the total as-built energy of the entire segment of buildings relative to what the energy would have been if the buildings had been built just to the Title 24 requirements. This confirms that schools have the best overall efficiency. Taken together, they have an energy ratio of 0.79, i.e., they use 21% less energy than code requires. The remaining three segments – offices, retail and public assembly –use 11% to 12% less total energy than code.

This was confirmed in our surveys of architects and engineers. In our quantitative survey, the designers were asked what percentage of non-residential new buildings they believed failed to meet Title 24 requirements. As shown in Figure 5, over 60% of all respondents believed that 80% or more non-residential new buildings meet Title 24 requirements. Many respondents commented that they had no personal knowledge of buildings that did not comply with Title 24.

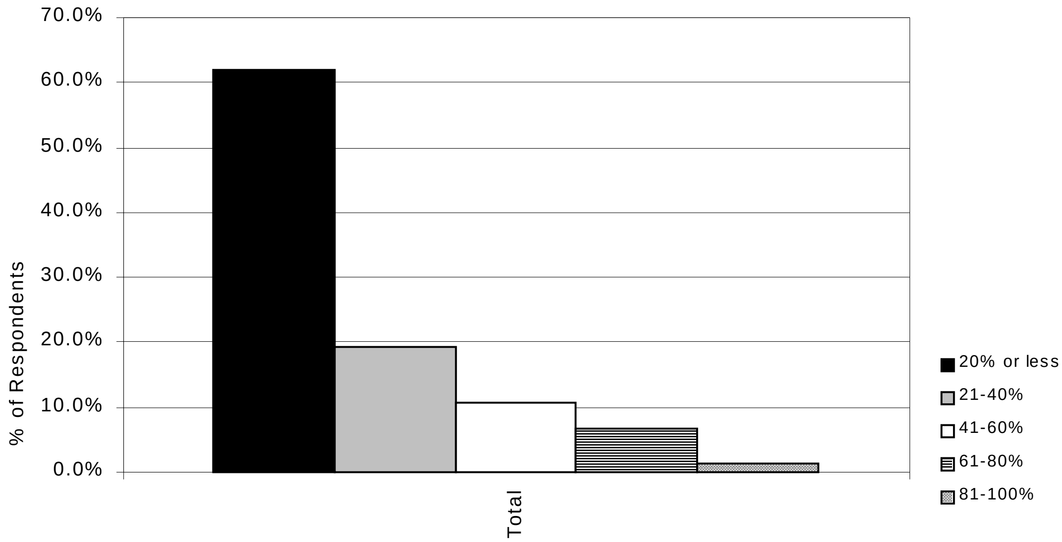

Figure 5: Percentage of NRNC Buildings Believed to be below Title 24 Requirements

This is a remarkable success story for California. Title 24 is a demanding code. Most of the NRNC buildings are meeting code and doing even better!

Changes over Time

We postulated that NRNC market is slow to change. A typical project takes one to three years from the time the building is designed until it is built and occupied. Furthermore, designers are motivated to standardize their plans and specifications, repeating system designs and choices of equipment that have worked well in previous projects. Change is gradual at the whole building level, as individual systems evolve and as designers experiment with newer design options.

We asked the designers about changes in the NRNC market in recent years. Most of them confirmed that the market changed gradually. In the last ten years, there were significant changes but only small changes in the last five years.

Designers did report an increase in the level of interest in energy efficiency over the past five years. As shown in Figure 6, designers who work primarily in the public and owner occupied sectors reported a substantial increase in the level of interest, whereas those working primarily in the speculative sector reported little change.

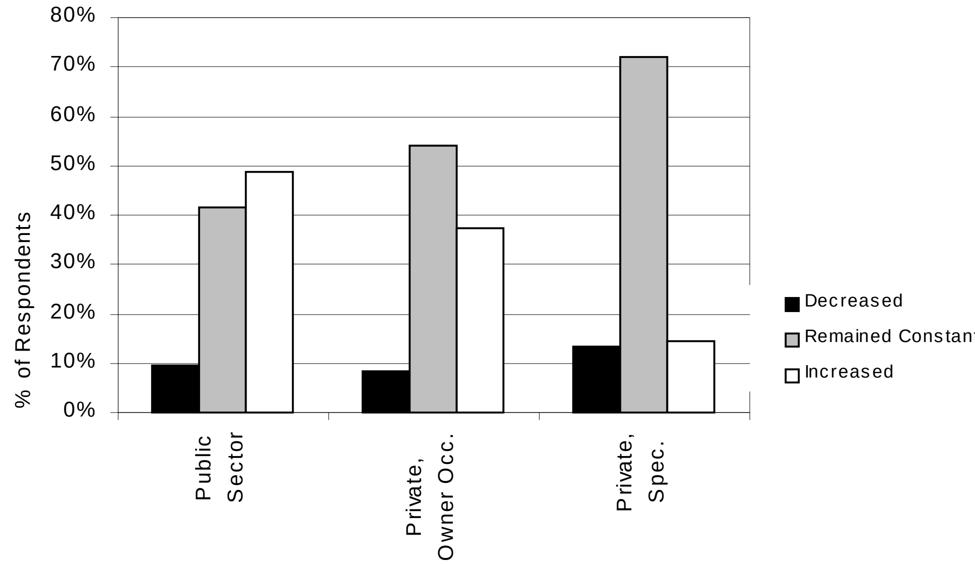

Figure 6: Change in Level of Interest in Energy Efficiency

We also looked for changes in the buildings over time. Figure 7 shows the whole-building energy ratios from 1994 through 1998. The overall energy use relative to baseline did not change significantly. The overall energy ratio was between 0.86 and 0.89 in all three years. However, we did see a significant trend in an improved cooling energy ratio, which dropped from 1.0 to 0.88 and then to 0.75 over the years 1994, 1996 and 1998. This appears to be due to improved efficiency in packaged and built-up cooling systems.

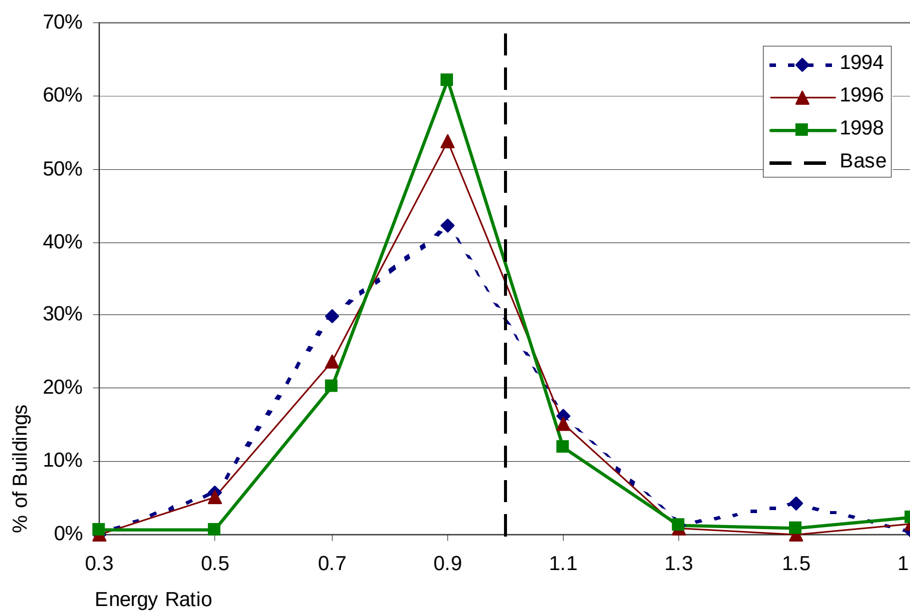

Figure 7: Whole Building Energy Ratio by Year

Differences by Ownership Class

Figure 8 shows the overall energy ratios in the public, owner occupied, and speculative market segments. As expected, the public-sector buildings have the lowest energy ratio, i.e., they are the most efficient relative to the Title 24 baseline across all buildings. The public buildings are followed by the owner occupied sector. The speculative sector is least efficient but is still 8% better than baseline.

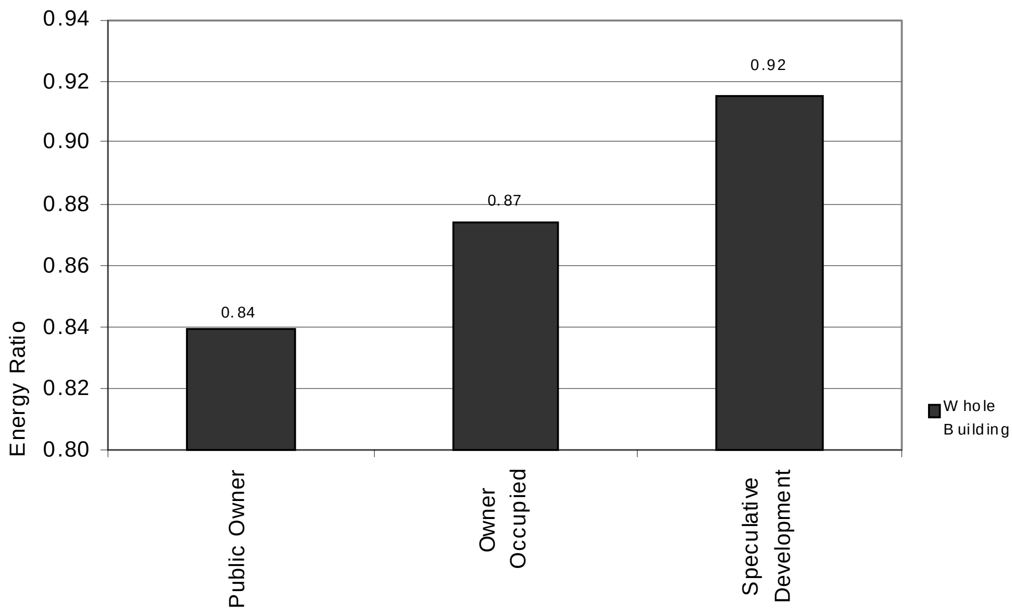

Figure 8: Overall Energy Ratio by Ownership

Figure 9 shows the range of the whole building energy ratio among the individual buildings within each ownership segment. In all three sectors, the vast majority of buildings are using less energy than the Title 24 baseline. However the public buildings tend to have lower energy ratios that the other sector. The speculative buildings tend to be similar to the owner occupied buildings except for the 8% of speculative buildings that have an energy ratio around 1.6. These buildings are much less efficient than required.

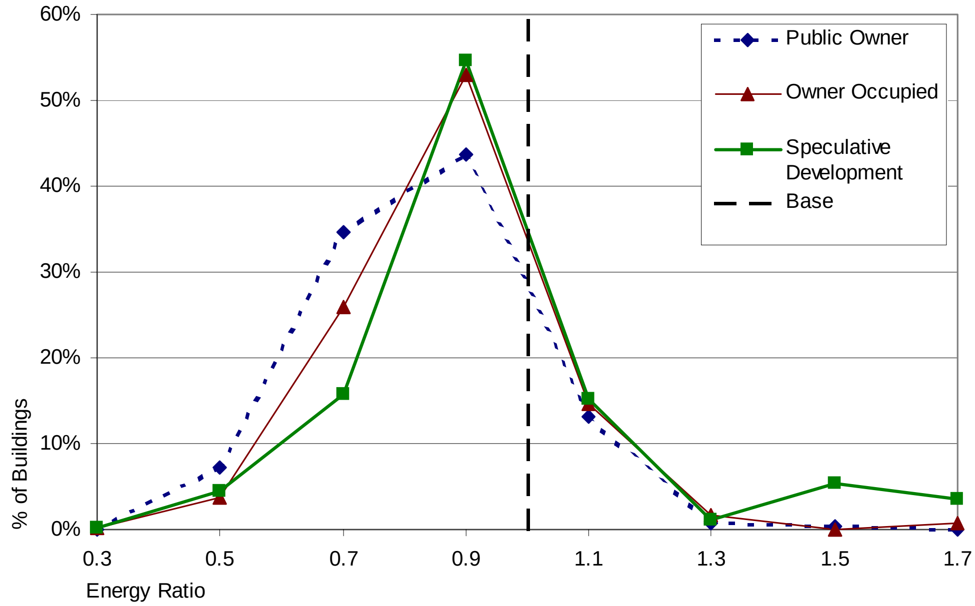

Figure 9: Whole Building Energy Ratio by Ownership

We asked the architects and engineers why some new buildings fail to comply with Title 24 requirements. As Figure 10 shows, over 40% of the respondents attributed it to cost cutting after the initial equipment specification. Other respondents blamed changes by the owner or inconsistent Title 24 enforcement. A few respondents mentioned substitutions by subcontractors.

Contractors sometimes suggest changes to the buildings' systems, in order to save the building owners money. This attractive reduction in first cost is difficult for building owners to pass up, even if an alternative equipment choice would allow them to save money over time. One engineer reported:

> *"Contractors tell building owners 'I can save you $100,000 now if you select different equipment.'"*

It is clear from the surveys and from our building data, however, that these practices are relatively rare and found mostly in the speculative segment.

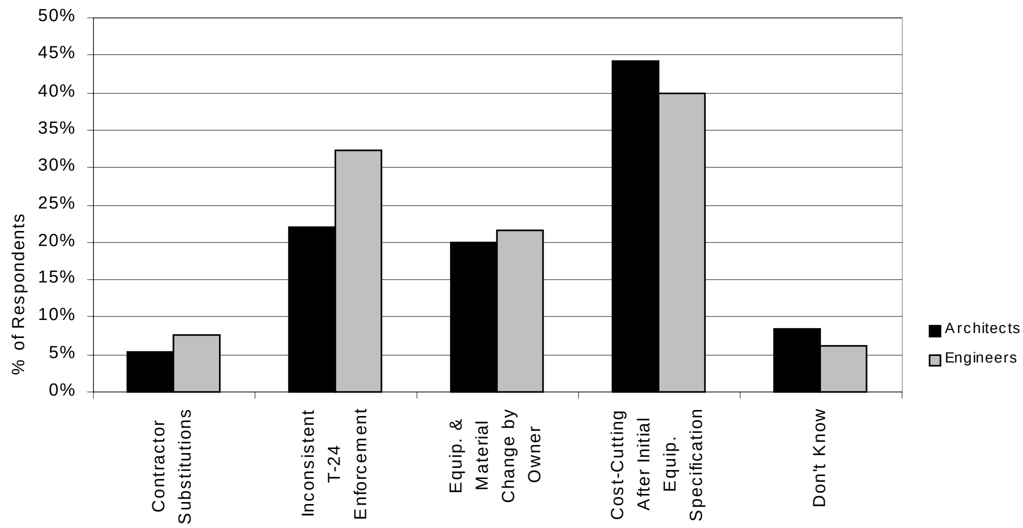

Figure 10: Primary Reason Reported for Failure to Comply with Title 24 Requirements

Program Participation

We get essentially the same picture when we compare buildings built under the utility programs to nonparticipant buildings. The participant buildings are somewhat more efficient over all, with an energy ratio of 0.83 compared to 0.89 for the nonparticipants. But, as shown in Figure 11, the vast majority of buildings in both groups are more efficient than required by Title 24.

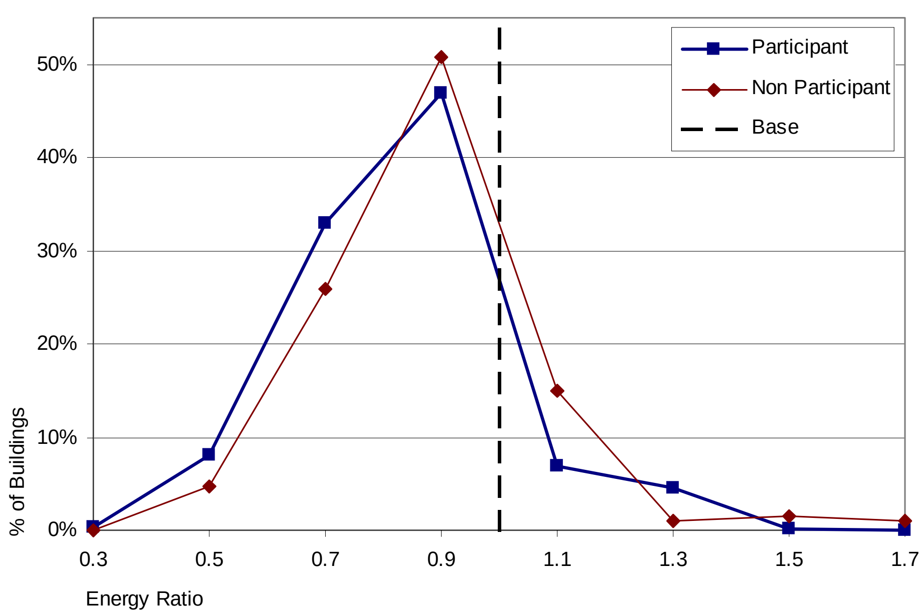

Figure 11: Whole Building Energy Ratio by Program Participation

The Potential for Added Savings

The best buildings are using 40% to 50% less energy than code. The buildings that are already exceeding Title 24 may offer the greatest potential for added savings.

Figure 12 takes another look at Figure 4. It is clear that some added savings can be won by enforcing Title 24 more completely. But a relatively small number of buildings would be improved. It may be more important to notice that most buildings are more efficient than baseline but less efficient than the best buildings in their sector. The greatest savings can be achieved by moving buildings that are already exceeding Title 24 toward the efficiency levels achieved by the best buildings.

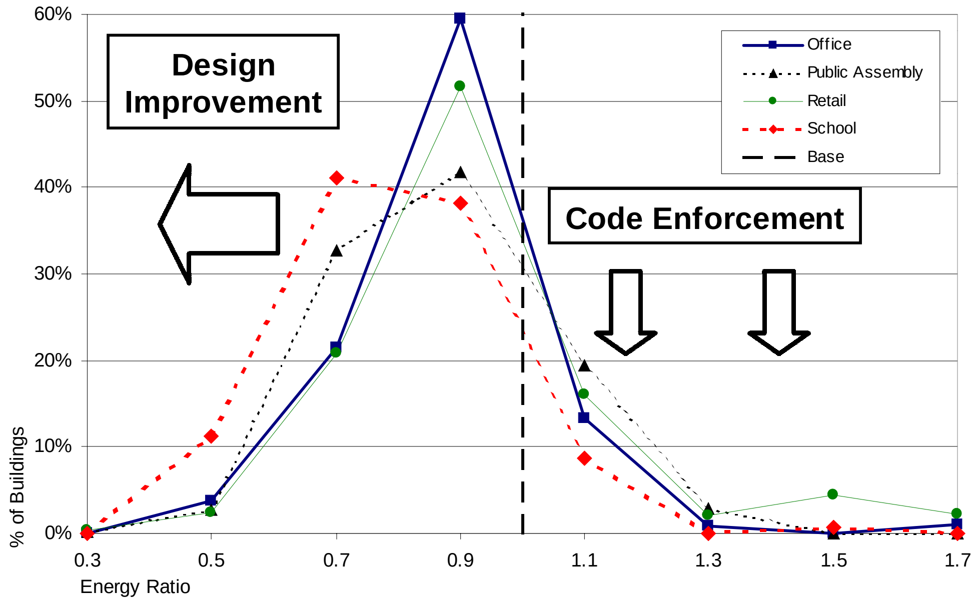

Figure 12: Where are the Added Savings?

The Market Players

The key question from the preceding section is this. Why are some buildings in California so much more efficient than the norm? To look for an answer, we turn to the key players in the market. As a starting point, Figure 13 summarizes the market participants and their expected relationships. We discussed this figure in Chapter 1, postulating that the strongest relationship was between the owner and the architect.

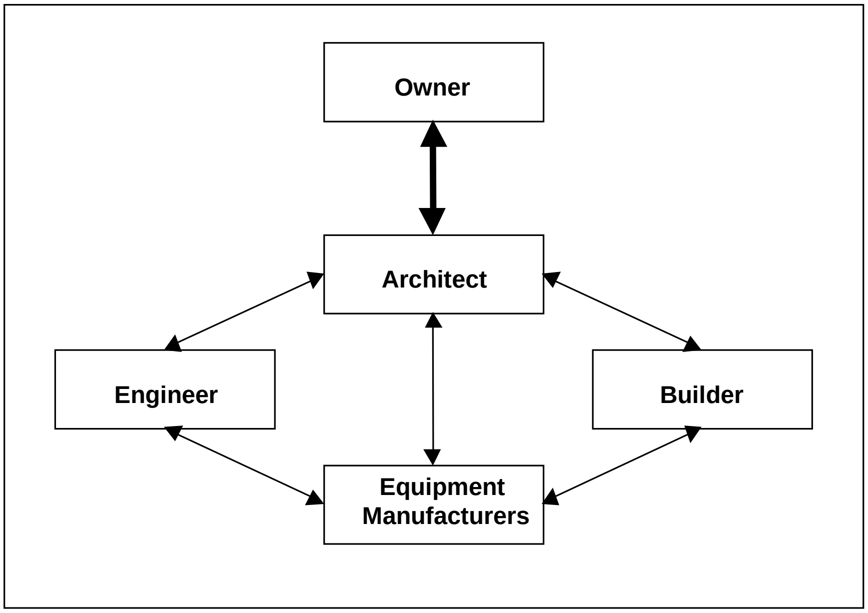

Figure 13: Principle Actors in the NRNC Market

The Role of Owners

When we asked the architects and engineers who was responsible for designing buildings to be energy efficient, we obtained the answers shown in Figure 14. About 30% of both architects and engineers indicated that the owners have the primary responsibility for the energy efficiency of buildings. One engineer put it this way:

> *"Ultimately, efficiency decisions are up to the owners since they are the people who must pay the cost of the equipment as well as the utility bills."*

It may be that the most efficient buildings are due to pull by the owners. Perhaps a small number of owners are willing to accept the extra cost in the design process or to invest in the more expensive measures and options.

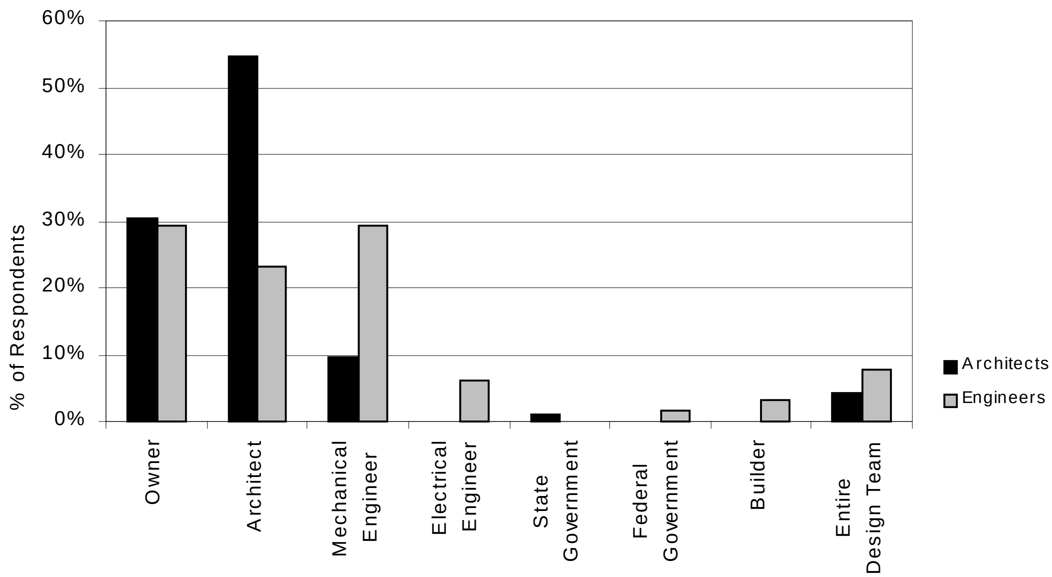

Figure 14: Who has the Primary Responsibility for Efficient Design?

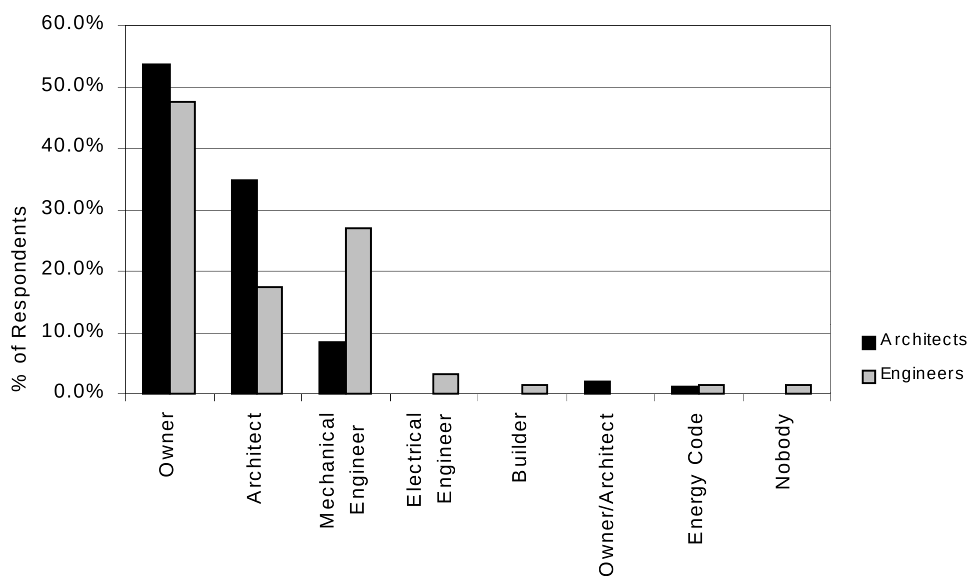

Figure 15: Who Makes the Primary Decisions?

However, when we asked who is the primary decision-maker, we got the responses shown in Figure 15. About 50% of the architects and engineers responded that the primary decision-maker was the owner. It is interesting that 30% of the architects and engineers felt that owners have the primary *responsibility*, whereas about 50% thought that they made the primary *decisions*. It may be that the architects and engineers often find themselves outvoted by the owners.

To summarize:

Some owners may provide crucial leadership in energy efficiency but others may override the recommendations of their architects and engineers.

Educating the Owners

Many of the architects and engineers emphasized the importance of educating the owners about energy-efficient options.

> *"Many clients don't understand about the choices. Some clients are very environmentally aware and the cost benefit is secondary, while other clients aren't as aware and the cost benefit is the primary consideration. We need easy to understand information to explain the benefits to both client types."*

The vast majority of the architects and engineers try to educate their clients about energy efficiency. The majority said they found the most effective approach to be to discuss O&M costs relative to initial costs. This reinforces the impression that owners are primarily concerned about cost.

We also asked them what they thought were the most useful tools in educating their clients. Surprisingly, both the architects and engineers preferred newsletters to seminars, utility reps, utility guidelines, databases, software, websites, and prototype demonstrations.

Architects and engineers both found it more useful to educate owners using newsletters than more high-cost, hi-tech options such prototype demonstrations and software tools.

Role of the Builder

When we asked architects and engineers why some buildings fail to comply with Title 24, they pointed to changes by the owner and cost-cutting during bidding and construction. They told us that they have seen contractors and subcontractors recommend changes to less efficient options in order to reduce cost, simplify construction, or improve maintenance. Some suggested that these changes were made as part of the 'value engineering' process, as the owners sought to stay in budget and the contractors and subcontractors competed for the winning bid.

The architects and engineers also suggested that lax enforcement of Title 24 contributes to the problem. It may be that building inspectors need training on how to spot these design alterations.

Operators and Maintenance Staff

The architects and engineers mentioned another group of actors, the operator staff and maintenance contractors. They pointed out the need to educate the facilities people on the advantages of energy-efficient equipment and on its proper operation.

> *"Steps need to be taken to educate the people who run the building, the facilities people. Educating the facilities people on the long-term benefits of certain equipment will encourage the client to select certain equipment for the building."*

> *"The training of the operators is sometimes futile because of job turnover. The knowledge of the system never gets transferred. I have also seen cases where the system is configured, and the main person knows how to use it, but they never train the people who are going to actually use the systems."*

> *"The operator of facilities used to be aware of how the system was intended to operate. Now, many people are manipulating the controls on systems. I am not sure people are being educated on how to use the systems. The issue that arises for the owners is: do you spend more time helping your staff learn the system or keep the money in the bank (by installing standard systems)."*

> *"My practice is located in a rural area; most contractors in the area are not knowledgeable about maintaining energy efficient equipment. Usually the same contractor is responsible for installation and maintenance of the equipment, so it would require significantly more effort and dollars in this area. However, I have worked on several industrial projects near San Francisco. I have found that more people are willing to try new equipment, primarily because the contractors can handle the complexity of system maintenance."*

Interaction between Architects and Engineers

Architects and engineers may sometimes fail to act as a team.

Returning to Figure 14 we can get another insight. The majority of architects said that they had the primary responsibility for the efficiency of the design. By contrast, the engineers seem to believe that their role is more important than the architects. Figure 15 shows a similar divergence. Both architects and engineers felt more important in the decision-making process than their counterpart.

The divergence in these two results is striking. It suggests an imbalance in the relationship between these two vital elements of the design process. These findings suggest that architects and engineers may not always respect each other's role in the design process.

Some of the engineers that we talked to also felt that they did not have as much influence on the design process as they wanted because they did not have an opportunity to meet with the owners, i.e., the architects controlled the relationship with the owners.

However, some architects and engineers recognize the role of an integrated design approach. 4% of the architects and 8% of the engineers that we surveyed wrote in the answer that the entire team was responsible for designing energy efficiency into buildings. Since this was not one of the available answers it is likely that the observed percentages understate this attitude. We will explore this promising issue in a following section.

Equipment Manufacturers

Another agent in the market is the equipment manufacturer. The architects and engineers generally feel that good, energy-efficient equipment was available. This information tended to be more familiar to the engineers than the architects. However, both groups voiced some concern about the accuracy of information provided to them by the manufacturers.

> *"Information about the equipment is not trustworthy. Good research, forthrightly shown from a trusted source is needed for me to believe the documentation. I tend to just go with the equipment that I know and trust."*

> *"I feel clients want a more trustworthy source of information from someone with experience using the systems instead of the current information from manufacturers they have now."*

A New Model for the NRNC Market

Based on the preceding key findings and other information from the surveys and onsite visits, we believe that the relationship between the market actors is different than we postulated in Figure 14. Our new model is summarized in Figure 16. The differences between our original model and our current model are important:

- The relationship between the owner and architect is strong but not as strong as expected. Generally, the owner makes the final decisions whenever costs are affected.
- The owner sometimes works directly with the builder and overrides the recommendations of the architect. This may lead to occasional violations of Title 24 requirements.
- The operator and/or maintenance contractor may be an indirect but still significant factor in the process. The owner's decisions may be affected by concern about the operator's ability to manage innovative equipment. Unfortunately, the architects and engineers may have little opportunity to train the operators because of operator turnover and other factors.
- The architects depend on the engineers for their technical knowledge about equipment and often about technical options that may improve energy efficiency. But, unfortunately, the engineers may be excluded from the design team working with the owners.

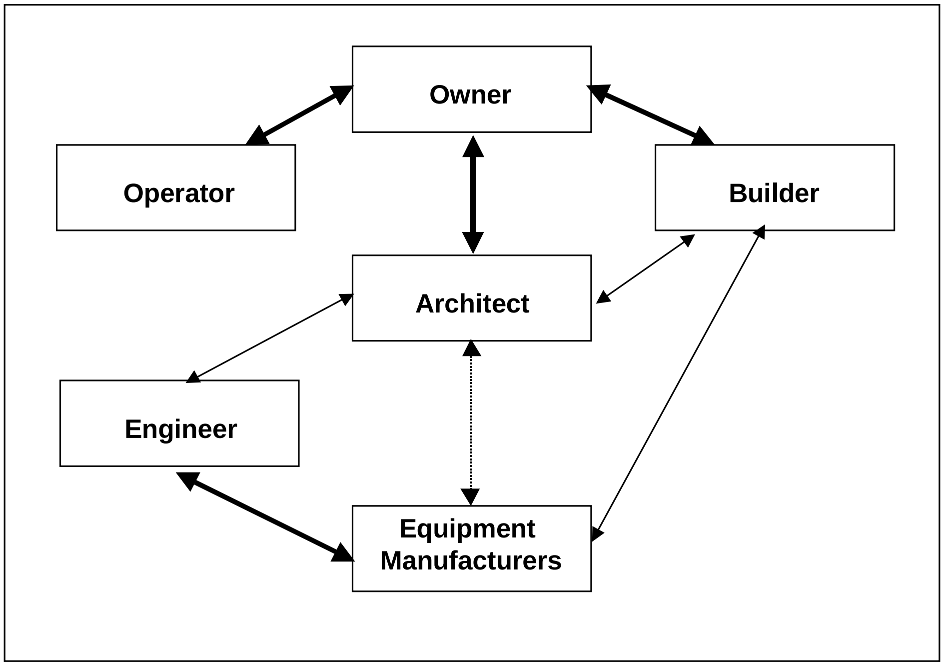

Figure 16: A New Model for the NRNC Market

The most important implication of the new model is the following.

Due to the relatively weak link between the architects and engineers, and the even weaker link between the architects and equipment manufacturers, there is a weakened connection between (a) the engineers and equipment manufacturers who possess the technical knowledge about energy efficiency, and (b) the owners, architects, and builders who make the crucial decisions about the buildings.

Key Technologies and Approaches to Design

End Uses

Lighting is the single most important contributor to energy efficiency.

What end uses are responsible for energy-efficiency? As shown in Figure 17, the buildings data indicated that about three-fourths of the savings are in the lighting end use. The remaining savings are equally split between cooling and fans. It appeared that most of the cooling and fan savings are due to interaction with the lower lighting loads. However, there is evidence of improved efficiencies in cooling systems.

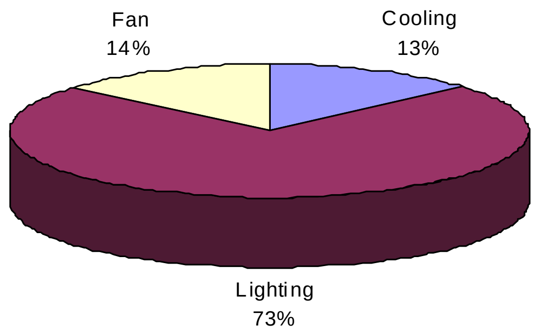

Figure 17: Energy Savings by End Use

Figure 18 shows the lighting usage relative to the Title 24 baseline. The proportion of buildings with lighting better than baseline is essentially the same as the whole building results shown in Figure 4. However, as shown in Figure 19, the lighting energy ratios are substantially lower than the whole-building ratios for each of the four building types. This supports our observation that the whole-building savings are largely attributable to lighting. Further analysis shows that the lighting efficiency is best in the public sector, followed by the private, owner-occupied sector. Even the speculative buildings have lighting loads 15% less than required under Title 24. The more stringent Title 24 lighting requirements introduced in June of 1999 will narrow the margin for the more efficient sectors and close the margin for the speculative segment.

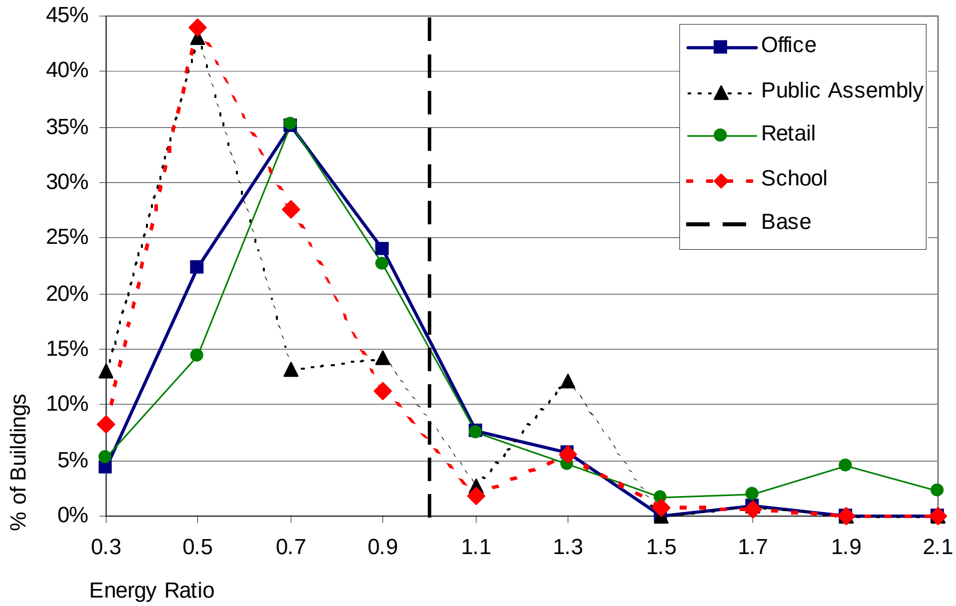

Figure 18: Lighting Energy Ratio by Building Type

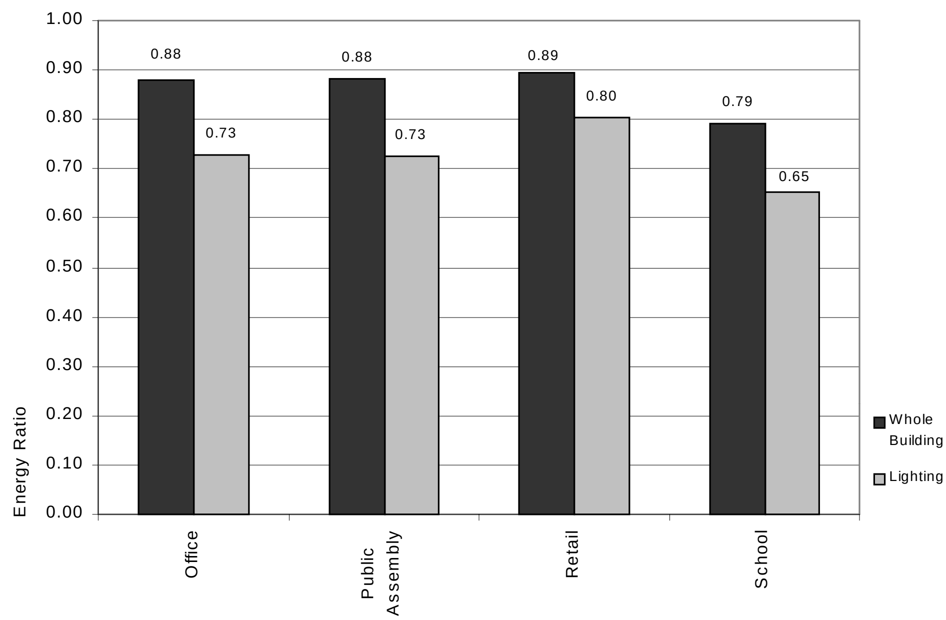

Figure 19: Average Lighting Energy Ratios compared to Whole-Building Ratios

Cooling Size Ratios

Cooling systems are generally sized correctly to reflect building characteristics and loads.

The cooling size ratio is an important indicator of whether the cooling systems are being correctly sized to reflect the lighting loads, envelope characteristics and internal loads.

Figure 20 shows the distribution of the cooling sizing ratio by building type. The cooling sizing ratio is the ratio of the installed cooling capacity to peak cooling load. As a rule of thumb, a correctly sized system should be within the range of 0.7 and 1.3.

The graph shows some differences by building type. Retail stores tend to have slightly higher sizing ratios than the other three building types. Across all four building types, we found that about 15% of the buildings have a size ratio lower that 0.7 and about 15% are sized above 1.3. We found that about 70% are correctly sized. This indicates that the cooling systems are generally sized about right. This means that the buildings are generally being designed properly to capture the interactive effects of lighting on cooling.

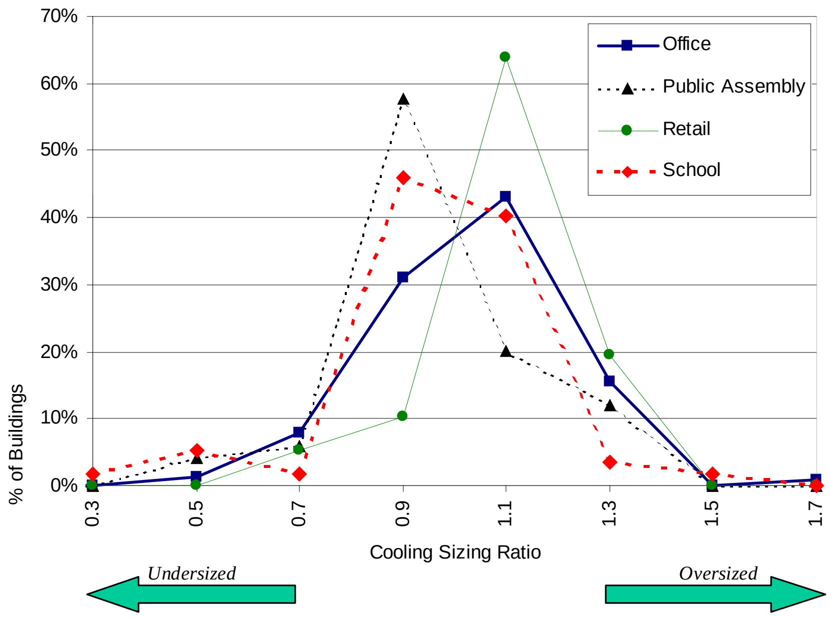

Figure 20: Cooling Sizing Ratio Distribution by Building Type

Use of Optimized Energy Design

Over one-fourth of the architects and engineers use optimized energy design in more than 60% of their buildings. And the practice is growing!

We are striving to explain how some buildings can be so much more efficient than the norm. In Chapter 1, we discussed the importance of a systems approach to the design of new buildings. We talked about the fact that the distinguishing feature of the new construction market is the opportunity to design the building as a whole system.

One hypothesis, then, is that the best buildings achieve their outstanding savings because their systems and subsystems work well together. Unfortunately, we do not know the design approach used for the specific buildings in our database. However, in our surveys of architects and engineers, we asked about the use of optimized energy design. In the question, we defined optimized energy design to mean "conscientious teamwork to create an energy-efficient building by optimizing system components and interactions of the components."

We classified the respondents according to the ownership sector that they mostly served. Figure 21 summarizes the results. In each of the three ownership sectors, a third or more of the designers reported that they use this practice in less than 20% of their projects. But among those working in the public sector, over 35% of the architects and engineers indicated that they used optimized energy design in more than 60% of their buildings. Across all three segments, over 25% indicated that they use optimized energy design in more than 60% of their buildings.

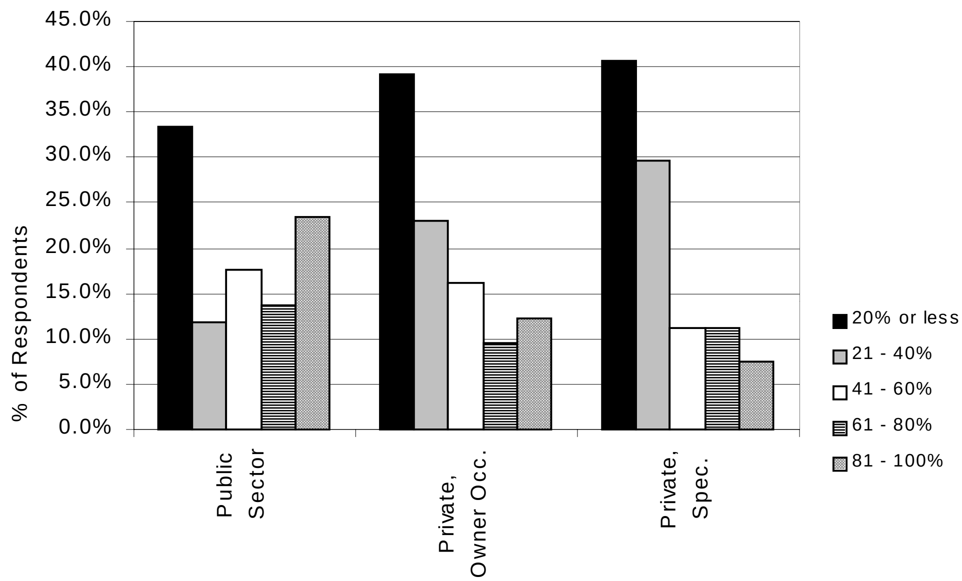

Figure 21: Reported Frequency of Use of Optimized Energy Design

We also asked the designers how use of optimized energy design has changed over the past five years. Figure 22 shows the results. The majority of respondents working in each sector indicated that the use of optimized energy design has remained constant. Note, however, that a full 40% of those who work primarily on private sector, owner-occupied projects indicated the use of optimized energy design has increased over the past five years. These results suggest that public sector projects initiated the use of optimized energy design and the trend is carrying over to the private sector.

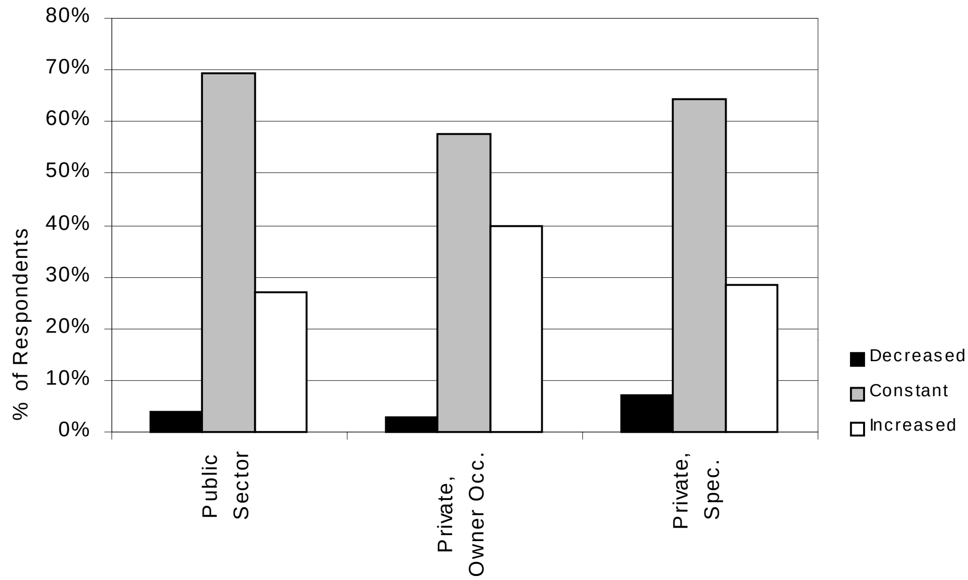

Figure 22: Change in Use of Optimized Energy Design in Last Five Years

Commissioning

Many architects and engineers go through some or all of the specific procedures involved in commissioning, but an independent agent is rarely involved.

Commissioning is the practice of having an independent agent verify the proper operation of the building's systems before turning the building over to the owners. In doing the onsite audits we found that facility managers usually do not know whether or not the building was commissioned. So we asked about the use of commissioning in our surveys of architects and engineers. In the qualitative survey we found that there was confusion about the meaning of the term. Therefore in the quantitative survey we asked whether the respondent usually did a list of specific procedures that are part of commissioning. We found that the respondents reported that they often did these practices, especially those working in the public sector.

However, when we pointed out in the qualitative interviews that commissioning involved an independent agent, the majority of architects and engineers indicated that commissioning rarely, if ever, occurred. Many engineers told us in the qualitative interviews that they recommend commissioning to their clients. But most clients feel that testing and balancing of systems by the responsible contractor is sufficient and opt not to follow their advice for complete, independent commissioning.

The following quotes illustrate the wide range of actual practice:

> *"Once buildings are completed, I arrange meetings with the manufacturers and the clients in order to ensure that the client knows how to operate the system to its full benefit."*

> *"The method I use for commissioning varies for each project. Usually we take a team of engineers and all department heads to the building and teach the client about the equipment."*

> *"Commissioning occurs at the close of construction. The equipment is started up to ensure it is operating per specification."*

We noticed a systematic difference in commissioning practices between the ownership segments.

> *"State and Federal Government clients do participate in commissioning when it is suggested."*

> *"For office space, no, we generally do not suggest commissioning. For hospitals and laboratories, yes, we most certainly suggest commissioning."*

> *"Owner-occupied clients take our advice if they have enough money, while speculative market clients never do."*

Synthesizing all of the information developed in this study, we believe the practice of commissioning is impaired by the comparatively weak links between the owners/architects/builders on the one hand and the engineers on the other. The architects are often not familiar with commissioning. Although the engineers are more aware of the value of commissioning by an independent agent, they are not in a position to sell the concept to the owners.

Key Market Segments

We found consistent differences in interest in all aspects of energy efficiency between the ownership sectors. As expected, we found the speculative sector lagging. One architect reported:

> *"Speculative projects are only interested in those types of options where they can pass the costs on to the tenants. Speculative clients are not interested in a higher first-time cost, as it is difficult to pass this cost on to the tenants."*

However, this view is overly simplistic. Another provided this view:

> *"Speculative developers are quite different from owner-occupied clients. Owner-occupied clients will select more efficient equipment for an increased initial cost if the long-term cost analysis shows savings over time. Speculative developers have a very different motivation. It is entirely dependent on how long they plan to have the property. If they will receive financial gain, then they are willing to be more efficient."*

This is consistent with our building data. A small proportion of speculative buildings failed to meet Title 24 requirements – mostly retail buildings. As expected, our data indicate that these projects did not participate in the utility programs. But our building data also show that energy efficient buildings are found in all sectors – public, private owner-occupied and private speculative.

Nevertheless we did find systematic patterns in efficiency and behavior. We found that commissioning was more common in the public sector. We also found that the use of optimum energy design was most common in the public sector but was increasing most rapidly in the private owner-occupied sector. In our analysis of the buildings themselves, we confirmed our hypothesis that energy-efficiency was highest in the public sector, followed by the owner-occupied sector.

Figure 23 summarizes the positions of the sectors. The key findings include:

- The public sector leads the private sector in virtually all aspects of energy efficiency. Among the four building types that we studied in depth, schools are the most efficient relative to the Title 24 baseline.
- The private owner-occupied sector leads the private speculative sector in virtually all aspects of energy efficiency.
- The public sector seems to draw the private owner-occupied sector toward more innovate design practices such as integrated design methods and building commissioning.
- The private owner-occupied sector does not seem to draw the private speculative sector toward more innovate design practices such as integrated design methods and building commissioning.

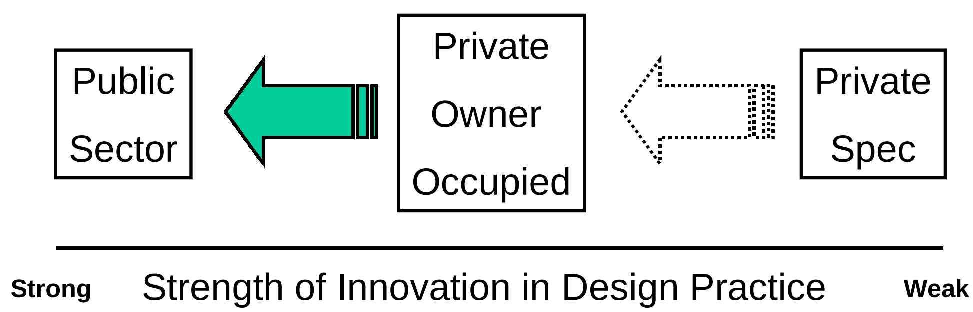

Figure 23: The Linkage between the Ownership Segments

Market Barriers

Figure 24 shows how the architects and engineers perceived the barriers to energy efficiency in the NRNC market. Split incentives, performance uncertainties and organizational practices were all thought to be strong barriers by both groups of designers. The following quotations are representative:

> *"Often, clients are hesitant to opt for high efficiency equipment if the long term plans for the facility are unsure. If the payback period is ten years and the client only plans to keep the building for three years, then the client is significantly less interested in efficiency."*

> *"Clients will ask 'Well, who else uses this equipment?' Nobody wants to be a guinea pig."*

> *"The primary barrier to making my designs more efficient is the bureaucratic division of money in school districts… Many times we cannot make a higher up-front investment even if a cost-benefit analysis shows that money (Energy) will be saved in the long run. There is a construction budget and a separate operating budget, and the money pools must not be mixed… Many times the school cannot choose the less costly option because they simply cannot swap the pools of money."*

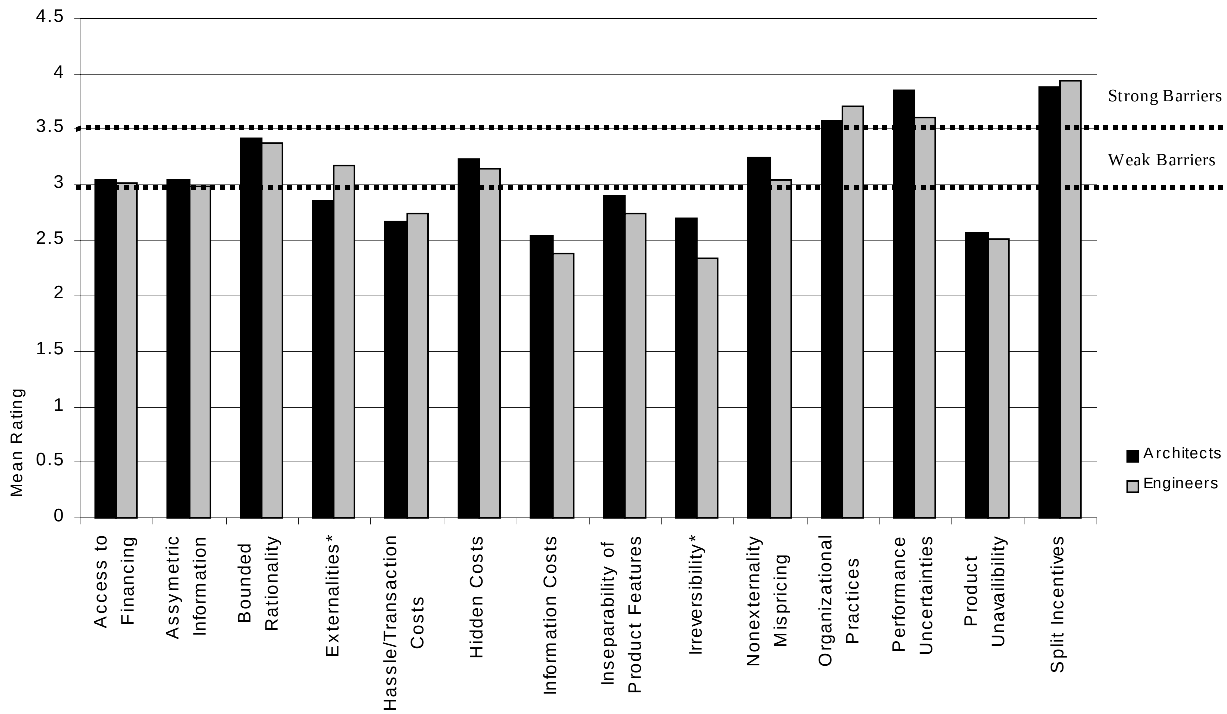

Figure 24: Market Barriers Perceived by Architects and Engineers

The Role of Energy Codes

Our surveys of designers and audits of buildings show that energy codes play a crucial role in raising energy efficiency in the NRNC market. They operate in two distinct ways:

Code Enforcement – limits the number of buildings falling below the current energy code.

Code Revision – gradually increases the requirements that all buildings must meet.

Figure 25 shows these two roles graphically. Code enforcement is targeted to buildings that are falling below the baseline. By contrast, the role of code revision is to gradually raise the baseline.

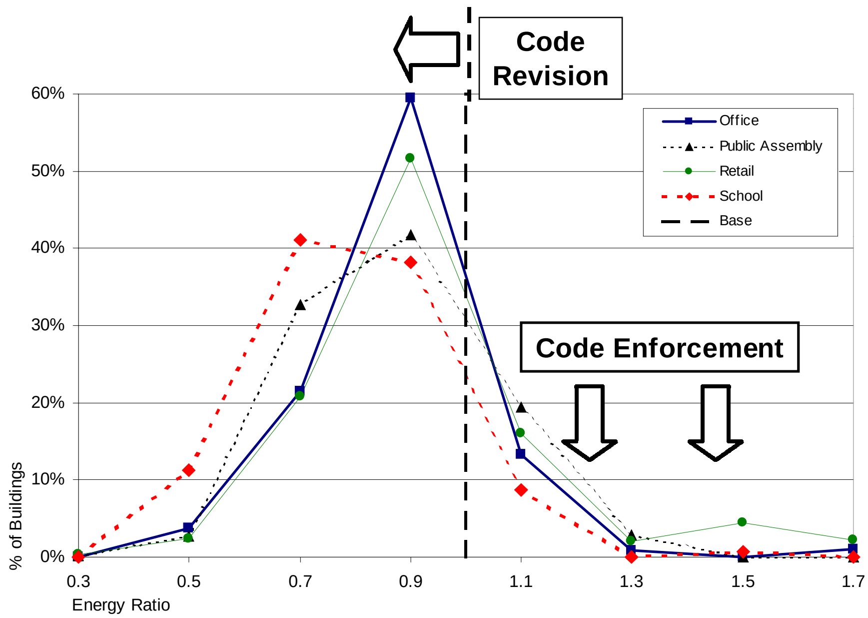

Figure 25: The Dual Role of Codes

As is clear from Figure 25, most new nonresidential buildings meet code in California. This was confirmed by our interviews with engineers and architects. This suggests that code enforcement is currently effective. Continued code enforcement is needed to hold the ground that has been won. Code enforcement is especially important in the market segments with relatively weak interest in energy efficiency, such as speculative development. Our study has indicated that one opportunity for improving code enforcement is to train building inspectors to watch for inappropriate changes by owners, builders and subcontractors after Title 24 review.

Periodic code revision is necessary to gain new ground. Our surveys indicate that the majority of architects and engineers feel that they are designing efficient buildings as long as they meet energy code requirements. The following quotes illustrate this view.

> *"Title 24 forces energy efficiency to be a factor. To pass Title 24, the building must be energy efficient."*
>
> *"Energy efficiency is always a factor since Title 24 contains such strict guidelines."*
>
> *"We exceed Title 24 if the owner is willing to pay for it. It really depends on the size of the project since exceeding Title 24 is usually only cost effective for large projects. We almost always perform a life cycle cost benefit analysis, but with small projects, there simply isn't enough energy involved for exceeding Title 24 to be cost beneficial."*

Unfortunately, many owners do not see the need to reach far beyond Title 24 requirements. So it is vital that codes be continually revised, as more efficient equipment becomes available. Without continued revision, the market might actually be held back by the widespread view that code represents appropriate design practice.

Of course, codes must be realistic. Stronger codes will only be accepted by architects, engineers and builders if they feel they are attainable. So any upgrades to codes must follow behind the leading edge of innovation. For example, Title 24's lighting standards were raised in June 1999. Our analysis of lighting shows that this revision was appropriate since the majority of buildings were exceeding the prior requirement.

To summarize:

Periodic code review and revision is necessary to win new ground; effective code enforcement is necessary to hold the ground.

Other Opportunities for Effective Intervention

Codes can be raised only as long as the leading edge continues to advance, i.e., as long as the best buildings continue to get even better. What does this study say about this?

- The greatest danger to sustainable innovation is the weak link between the owners/architects/builders and the engineers/manufacturers.
- This suggests that interventions in the NRNC market <u>will not be effective</u> if they are directed solely to manufactures and engineers.
- Conversely, interventions should be designed to strengthen the link between these two groups. This is also the key to increasing the use of commissioning since the engineers have to help the owners understand the merits of commissioning.
- Promoting integrated design teams and whole-systems approaches to design is one promising approach for strengthening the link between the owners/architects/builders and the engineers/manufacturers. This practice is already established among some architects and engineers.
- The owner is the most important decision-maker – market interventions should be aimed at the owner.
- Both architects and engineers feel that the best tool for reaching the owner is one of the simplest ones – a newsletter! They also cite demonstration projects as an effective tool.
- The operator or maintenance contractor can also be an important factor in the market. The operators must believe the energy efficient options are reliable and easy to maintain. The owners must be confident in the ability of their operators to maintain any unconventional system that is recommended.

3. Designer Qualitative Interviews

This section presents the findings of the qualitative interviews conducted with designers, i.e., architects and engineers. We interviewed 30 architects and 26 mechanical and electrical engineers who were involved with energy efficiency decisions on a non-residential new construction project during 1998. The qualitative interview findings were used to develop the quantitative survey instrument, and to provide information about the attitudes of decision-makers.

A total of seventy-four firms were contacted to locate the 30 architects who were qualified to participate in the study. Approximately one quarter of the architectural firms contacted were not qualified to participate in the study, due to the fact that they did not meet the criteria of the study, i.e. they were landscape architects or interior designers. We made as many attempts as possible to complete each interview. On average, three calls were made to complete the survey with the correct respondent. Once the correct respondent was identified and contacted, very few architects actually refused to participate in the study.

The engineer interviews proved to be much more difficult to conduct. We contacted one hundred sixteen firms to attempt to secure the twenty-six engineering interviews. Approximately one quarter of the engineering firms contacted were not qualified to participate in the study, due to the fact that they did not meet the criteria of the study, i.e. they were structural engineers or general contractors. The engineers as a group were harder to reach, and a little less willing than the architects to participate once we had them on the telephone. About 15% of the engineers refused to participate once we were speaking with them, but that was after the interviewers had already made multiple phone calls to most of the engineers. Similar to the architects, an average of approximately three calls were made to secure the twenty-six interviews.

Key Findings

Listed below are the key findings of the market actor qualitative interview portion of the study. The key findings were used to develop the market actor quantitative survey instrument. Key findings gleaned from the qualitative research also provided useful insights regarding the decision-making process.

- Most architects and engineers work on a wide variety of projects, designing buildings for various uses and types of owners.
- Approximately two-thirds of all respondents claim energy efficiency is a strong factor in design considerations.
- Even though engineers tend to be the most knowledgeable about energy efficient options, they have limited client contact and, thus, limited opportunities to educate and convince owners about efficiency.
- Performance uncertainties, organizational practices, and split incentives are the most commonly mentioned barriers among all respondents.
- Suggestions for overcoming barriers to energy efficiency include educating building owners and utility-sponsored incentive programs.

- Information about energy efficiency is obtained from a wide variety of sources. The second most common source of information for architects is the engineering community.
- The majority of architects and engineers claim energy efficiency information is easy to locate.
- Ease of understanding efficiency information is highly dependent on one's level of expertise.
- The majority of engineers have noticed changes in their approach to energy efficiency, while the majority of architects have not noticed any such changes.
- About half of all respondents have noticed an increase in the demand for more efficient buildings over time.
- Nearly all respondents believe that code requirements drive most decisions about energy efficiency.

Focus of Work

The architects and engineers were asked a series of questions to determine if the scope of their work qualified them to be a respondent for this interview. The questions focused on the type of work their company was involved in, and their personal focus in the company. A question was asked to determine what percentage of the company's work was in office buildings, retail, public assembly, and schools. Since these building types are the focus of the study, respondents were screened to ensure that at least 50% of their projects belonged to these uses. Information about the proportion of public sector projects, private sector owner occupied projects, and private sector speculative market projects was also collected. The final question in this section probed the architects and engineers about whom, beside themselves, was involved in the energy efficiency decisions on the projects.

The following list summarizes the key findings from this series of questions:

- Of those who worked in the four building segments, about one-third of architects and half of engineers work over half of the time in the public sector;
- Among architects and engineers who work primarily for the private sector, approximately three-fifths work predominantly on owner-occupied projects;
- Approximately three-quarters of the architects replied that the distribution of project types and building uses has not changed at all in the last 10 years;
- Among engineers who are involved with public sector school projects, about two-thirds have experienced a significant increase in the proportion of schools over the past several years;
- Those involved with energy efficiency decisions include mechanical engineers, electrical engineers, architects, and building owners.

Architects

Approximately one-third of the architects interviewed worked over half of their time in the public sector. A few architects stated they worked primarily on schools in the public sector, while others claimed to do a variety of work in the public sector. The building types that fell into the public sector are as follows:

- Schools
- Government Offices
- Healthcare
- Civic/Institutional
- Public Assembly

The remaining two-thirds of the architects worked over 50% of their time in the private sector. Architects who worked in the private were categorized according to the majority of the project types on which they worked (approximate percentages) as follows:

- 25% - half speculative, half owner occupied
- 15% - majority speculative building
- 60% - majority owner occupied building

The building uses that fell into the speculative market category are as follows:

- Commercial Offices
- Retail Spaces
- Warehouses

The building uses that fell into the owner occupied types are as follows:

- Commercial Offices
- Retail Spaces
- Light Industrial
- Healthcare
- Theatres
- Churches
- Institutional
- Manufacturing
- Hotels/Motels
- Grocery Stores
- Stadiums

The architects were then asked who, beside themselves, was involved with energy efficiency, lighting, and mechanical decisions that are made in the buildings they design. More than half of the architects stated that their mechanical and electrical engineers were also involved with the energy efficiency decisions in the buildings they design. The second most common response was the clients. Also mentioned as being involved with energy decisions were project managers, developers, general contractors, and tenants.

Engineers

All engineers were asked to indicate the percentage of their firm's projects that are public sector projects, private sector owner-occupied projects, and private sector speculative projects. All firms were involved with a mixture of the three project types. All respondents were classified according to whether the majority of their firm's projects were public sector or private sector projects. About half of engineers work primarily for the public sector. Among engineers who primarily work for the private sector, about two-fifths work primarily on speculative market projects.

Within each sector, respondents were asked to indicate the percentage breakdown of project building types among schools, public assembly buildings, retail space, office space, and other types. Retail and office space were the only building types mentioned among private sector speculative market projects. The predominant building types among private sector owner-occupied projects were office and retail space, although several engineers mentioned involvement with private sector owner-occupied schools, public assembly buildings, and manufacturing facilities. The predominant building types for public sector projects were schools and government office space; about one-quarter of engineers involved in public sector projects also mention involvement with medical projects consisting of hospitals and laboratories.

All respondents were asked to indicate who, beside themselves, were involved with energy efficiency decisions and lighting and mechanical choices in the buildings they design. The majority of engineers initially indicate that teams of mechanical and electrical engineers are primarily responsible for all energy efficiency decisions.

> "*They (architects and building owners) are looking for us to make the decisions.*"

Probing of the engineers reveals that architects and building owners are greatly involved with energy efficiency decisions and lighting and mechanical choices.

> "*Ultimately, efficiency decisions are up to the owners since they are the people who must pay the cost of the equipment as well as the utility bills.*"

Energy Efficiency in Design

This section of the interview attempted to determine how large a factor energy efficiency was in design considerations. All respondents were asked who best knew about the energy efficiency choices that are made in the buildings they design, how much direction they receive from clients to consider energy efficiency, what their role is with clients with regards to energy choices, and how well informed they felt about energy efficient options. Respondents were also asked about their familiarity with Title 24 requirements, and whether they strive to design better than code. They were then asked if they attempted to design-in comfort, or relied on mechanical systems. All respondents were asked a series of questions regarding the term 'commissioning': if they knew what it was, whether they suggested this service to their clients, and if it actually occurred on their projects. For those respondents who could not accurately define commissioning, they were read the following description:

> *Commissioning is a process of ensuring that the building systems perform according to their design intent, and meet the needs of the occupants. It is a process that ensures the contractor delivers a building that works the way the architect or engineer designed it. Commissioning is generally coordinated through an independent commissioning agent.*

The following list summarizes the key findings regarding energy efficiency in design:

- Approximately three-fifths of the architects and three-quarters of the engineers stated that energy efficiency is a strong consideration in their design practice;
- At least three-quarters of architects felt moderately to well informed about energy efficient options, and as a group engineers felt very well informed about energy efficient options;
- A little more than half of the architects and about two-thirds of engineers strive to design better than Title 24 requirements;
- About one out of five architects said that they do not attempt to design-in occupant comfort, but rely solely on mechanical systems to provide comfort;
- Most engineers feel that final energy efficiency decisions are made through the architect. Engineers have limited, if any contact with building owners;
- Building owners seldom inquire about energy efficiency and often opt for less efficient equipment when presented with final costs;
- Slightly more than half of the architects and approximately two-fifths of engineers do not know what commissioning is. Upon hearing the definition of commissioning, a full one-third of architects and one-fifth of engineers admit they have never heard of such a service. Perhaps this is because commissioning is a utility industry term and not a term widely used in the design community.

Architects

The architect interviewees were asked a series of questions about energy efficiency in their design practice. When they were asked how large a factor energy efficiency is in their design considerations, a majority of the architects replied that they consider energy efficiency to be a moderate to strong consideration in their design practice. Among those who do not consider energy efficiency in their design practice, most stated that it is company practice not to concentrate on this factor, and they only address the issue if the client brings it up. Most of the architects responded similarly when asked who best knew about energy choices made on their projects. Mechanical engineers were mentioned most often, while electrical engineers, clients, sales representatives, design-build engineers, and manufacturers were also mentioned. Interestingly, none of the architects directly stated that they were the most familiar with the energy choices. A small handful implied that their firm as a whole was the most familiar, but for the most part, the responsibility for energy choices was delegated to the engineers and consultants working on the project.

Although the majority of this group of architects indicated that they felt the engineers on the project were more familiar with the energy choices, more than three-quarters of the architects stated that they felt at least moderately informed about energy efficient options. Very few architects went as far to say that they felt very well informed about the available options. Among those who felt they were less than moderately informed, the general consensus was that they could rely mainly on engineering consultants for this information.

The architects were asked to discuss how much direction they receive from clients to consider or not consider energy efficiency, and then to describe their role in design and equipment choices with clients. Approximately three-fifths of the architects replied that they did receive client input on energy choices. The architects found that client input varies quite a bit, and for the most part, they try to inform the client about the options. The architects mentioned providing advice on cost-benefit analyses, orientation guidelines, glazing advice, long term operational costs, budget-based options, and general information on efficient equipment. Some of the techniques that architects mentioned that they used to educate their clients are as follows:

> *"I begin the project by telling the clients about the available options, along with a detailed analysis of life cycle costs compared to first costs, and recommending particular options based on their budgetary constraints and usage plans for the building."*
>
> *"We go through an educational process with all our clients, but most of our clients are sophisticated and have their own A & E department. The energy efficiency decisions largely depend on the requirements of the space that we are constructing."*
>
> *"We consider the intended use of the space by the occupant and calculate a system that works for the use and we look at systems and offer choices to the client including a low and high cost payback."*
>
> *"Energy efficiency issues are discussed with the clients in several places in the design process. Early, in the schematic design phase, global issues are discussed at a conceptual level to find out how the client views efficiency. Later in the design development stage, specific issues such as equipment selection and orientation issues are discussed."*

One architect commented on the differing treatment between speculative and owner occupant builders:

> *"With a corporate headquarters, we force the issue with them and deal with life cycle cost. From a speculative standpoint, we address long term energy management. We do this by breaking*

> *down the mechanical and electrical components into the individual spaces, thereby setting the building up so that the (spec) tenants are responsible for making the energy payments."*

Among the remaining two-fifths of architects who receive little client input, the majority stated that they do not bring up the subject unless the client addresses it. The following architect response summarizes the majority of this group of architect opinions:

> *"I receive no direction from clients with regard to considering energy efficiency. They leave it up to me; the clients expect it already. Clients expect me to consider energy efficiency without specifically saying so. My clients have unspoken expectations regarding energy efficiency."*

The interviewees were then probed to determine if they strive to design better than Title 24 requirements. More than half of the architects claimed they try to design better than Title 24. Many of these architects stated that they did this in order to help their clients benefit economically. Most architects stated that client resistance to the energy efficient equipment is very prevalent. The general theme among this group of architects was that they would try to design the building as efficiently as possible, keeping in mind the space and client needs.

> *"We always meet Title 24 and often we suggest exceeding Title 24, but often the school districts are not interested in cutting-edge options. They just aren't willing to risk it."*

> *"I strive to design better than Title 24 because the state rewards schools (monetarily) for doing so."*

Approximately four out of five architects stated they attempt to design-in occupant comfort rather than relying completely on mechanical systems. Many of the architects stated that window orientation and glazing were primary areas where they tried to design-in comfort. Another aspect of the building that was repeatedly mentioned was the lighting design. Many architects stated that they try to design-in daylighting through the use of windows and skylights in order to provide a more natural setting, and also to lower utility costs. Building ventilation was another issue that the architects repeatedly mentioned.

> *"When we can, (if the client is willing), we do orient sensibly, shape sensibly, use shading devices, and install high performance glazing."*

> *"We include shading devices on a glassy façade, use plant materials to cool buildings, and try to use solar energy or day-lighting whenever possible. My firm designs-in occupant comfort rather than relying on mechanical systems quite a bit. We build-in operable windows and doors, skylights and make use of day-lighting whenever possible in order to reduce reliance on mechanical systems."*

When asked what the term 'commissioning' meant to them in terms of the building's energy systems, slightly less than half of the architects spontaneously defined commissioning correctly. After hearing the explanation of commissioning agents, approximately two-thirds stated that they were familiar with this type of service. To determine if commissioning is actually being practiced, the architects were then asked if they actually engaged in commissioning activities. Only a small handful mentioned that they suggested independent commissioning agents to their clients. The rest of the architects who were aware of commissioning stated that either the engineers on the project or the manufacturer representatives provided that type of service. The overall consensus was that it was a good idea, but independent agents do not provide the service very frequently.

> *"Once buildings are completed, I arrange meetings with the manufacturers and the clients in order to ensure that the client knows how to operate the system to its full benefit."*
>
> *"The method I use for commissioning varies for each project. Usually we take a team of engineers and all department heads to the building and teach the client about the equipment."*
>
> *"Commissioning occurs at the close of construction. The equipment is started up to ensure it is operating per specification."*

Most of the architects that were not aware of commissioning were not interested in the service, simply because they did not think it directly applied to their practice. Interestingly, some of the architects that were not aware of commissioning responded most enthusiastically to the description of a commissioning agent. Some of their responses are below:

> *"The mechanical engineers specify the systems, but many times the contractors substitute things and then talk their way into it. They talk the clients into accepting the substitution. In this situation, it would be a good idea to send in an independent agent to check equipment equivalency and determine retrofits."*
>
> *"I know of a classroom renovation project where for two years the school had been complaining that they could not control the temperature in certain classrooms. Eventually, it was determined that there was a cross-wiring problem where the thermostat in one room controlled the temperature in another room. I do not know why this happened, but I think commissioning would have been great here because the problem would have been identified at the beginning."*

Engineers

The mechanical and electrical engineering communities are directly involved in the practical aspects of implementing energy efficient options in buildings. Three-fourths of engineers say that energy efficiency is a strong factor in design considerations, although one third of such engineers admit energy efficiency is a strong factor because of Title 24 requirements.

> *"Title 24 forces energy efficiency to be a factor. To pass Title 24, the building must be energy efficient."*

> *"Energy efficiency is always a factor since Title 24 contains such strict guidelines."*

Even though engineers tend to be the most knowledgeable about lighting and mechanical equipment options, most engineers state they have a very limited role in the final decision-making process. There are few, if any, opportunities to meet with the building owner directly. Generally, the engineer works with the architect, who, in turn, is the direct link to the building owner. This practice provides little opportunity for the engineer to educate the building owner about equipment choices.

When asked how much direction they receive from building owners to either consider or not consider energy efficiency, all but one engineer stated that building owners provide little-to-no direction to consider energy efficiency; owners seldom ask about energy efficiency.

> *"As a mechanical engineering consulting firm, small and medium size clients are relying on our expertise to make the best equipment decisions. With large clients, they often have corporate specifications to follow."*

A handful of engineers state that about one-fifth of building owners inquire specifically about energy efficient options, with one engineer claiming that 70% of his clients wish to explore energy saving options.

To educate building owners about energy efficient equipment options, most engineers provide a list of equipment choices along with the benefits and drawbacks of each option. In addition, the engineer will present his/her recommended pieces of equipment. Some engineers provide a cost per square foot for each piece of equipment. A handful of engineering firms provide a complementary life cycle cost benefit analysis as a part of the contractual agreement, while most charge an additional fee for the service and do so only if the building owner is interested in pursuing efficiency. To educate building owners on efficiency, it is necessary to first educate the architect since the architect serves as the link between the engineer and the building owner. Specifically, many times the engineer must provide information on equipment options to the architect who, in turn, distributes the information to the building owner. This serves to weaken the ability of engineers to educate owners on energy efficient options.

Overall, engineers feel very well informed about energy efficient options. Approximately three-quarters of engineers describe themselves as very well informed about energy efficient options, while the remainder describe themselves as fairly well informed about such options.

Engineers were asked if they strive to design better than Title 24 requirements, and, if so, to what extent. Approximately two-thirds of engineers claim they always strive to design better than Title 24, although most encounter hesitancy to fund such designs on the part of building owners.

> *"We have always believed that Title 24 is a minimum standard. For example, Title 24 only requires R-11 for roof insulation, but we always suggest the use of R-19."*

> *"They (building owners) are primarily concerned with first cost; energy efficiency is one of the first things out the door."*

Many engineers state that exceeding Title 24 requirements depends on the given application and the owner's needs.

> *"We exceed Title 24 if the owner is willing to pay for it. It really depends on the size of the project since exceeding Title 24 is usually only cost effective for large projects. We almost always perform a life cycle cost benefit analysis, but with small projects, there simply isn't enough energy involved for exceeding Title 24 to be cost beneficial."*

Others recognize the building must at least slightly exceed Title 24 in order to pass code requirements.

> *"We have to exceed Title 24. We're required to. We are always above and beyond Title 24. In fact, I specify equipment without considering Title 24 and then deal with Title 24 after the fact. This has never been a limitation; there has never been a case where I've failed to meet Title 24."*

Respondents were asked to spontaneously describe what commissioning meant to them in terms of the building's energy systems. Approximately two-fifths of engineers reveal they do not know the meaning of commissioning. Even after hearing the definition of commissioning, one-fifth of engineers stated they have never heard of such a service.

About half of engineers have recommended the use of commissioning to their clients, and a handful require commissioning as part of their contractual agreement. For many engineers, the suggestion of commissioning activities depends on the type of client, while others recommend commissioning to all clients.

> *"For office space, no, we generally do not suggest commissioning. For hospitals and laboratories, yes, we most certainly suggest commissioning."*

Building owners seldom utilize commissioning agents; they do not wish to pay for the service, although willingness does vary by client type.

> *"Owner-occupied clients take our advice if they have enough money, while speculative market clients never do."*

> *"State and Federal Government clients do participate in commissioning when it is suggested."*

A few engineers mention that their firm provides a commissioning service, while others state that an independent commissioning agent must be used to eliminate potential conflicts of interest. Additionally, engineers claim many building owners feel that testing and balancing the systems is sufficient.

> *"Many clients just do minimal testing and balancing of the systems. They usually rely on the mechanical contractor who installed the equipment to provide this service. There is a definite conflict of interest doing it this way because these contractors have an incentive to find the systems are configured and functioning properly. By having the installers configure the system, it will initially function correctly, but may not hold up as long as it would have if an independent agent had provided the commissioning."*

A handful of engineers state there has been an independent commissioning agent on one or more of their projects in the past; those building owners have been pleased with the results of the use of an independent agent.

Barriers to Energy Efficiency

The architects and engineers were asked to name any barriers they felt were present in the market for energy efficient products or services. All respondents were read the following definition of a barrier and asked to indicate the primary barriers to making their building designs more energy efficient.

> *A barrier is a characteristic of the market that helps to explain the gap between energy efficiency, or level of investment in, and the increased level that would be cost beneficial and that the cost benefit might be influenced by both energy and non-energy conditions.*

Additionally, information about attempts to educate clients and the extent to which respondents exceed code requirements in their efficiency practices along with suggestions for overcoming the barriers was collected. They were asked if the barriers varied by client type, and who the leaders in overcoming the barriers should be. The questions in this section also attempted to probe how the architects and engineers handled mixed-use properties.

Below are the key findings from the architect and engineer interviews:

- The current level of energy efficiency varies by type, size, and sophistication of the building owner.
- The market barriers differ by the size of the project, and between owner occupied and speculative buildings
- A list of the market barriers to energy efficiency that were mentioned by both the architects and engineers are as follows:
    - Performance Uncertainties
    - Lack of Education/Foresight
    - Organizational Practices
    - Misplaced or Split Incentives

    - Hidden Costs
- Additionally, architects mentioned that information costs, low energy costs, and asymmetric information were barriers
- Engineers also mentioned the following as primary barriers to energy efficiency:
    - Access to Financing
    - Architectural and Aesthetic Features
    - Contractors Changing Engineering Specs
    - Hassle and Transaction Costs
    - Inseparability of Product Features
    - Bounded Rationality on the part of Building Owners
- Some common suggestions given by both the architects and engineers for overcoming the barriers are listed below:
    - More utility rebate programs
    - Reduction in the cost of equipment
    - Incentive programs from government
    - Educational programs for decision makers
    - Access to Financing
- Some suggestions for overcoming barriers to energy efficiency from engineers include:
    - Educating Architects and Building Owners
    - Lucrative incentive programs
    - Increasing the Cost of Energy
    - Providing State Funding to Increase Construction Budgets on Public Sector Projects
- The majority of architects stated that utility companies should be the leaders in overcoming the barriers to energy efficiency
- Most engineers believe that engineers, architects, and utility companies should be the leaders in overcoming barriers to energy efficiency.

Primary Barriers to Efficiency

Architects

The architects were asked during the interview to discuss the primary barriers that prevented them from making their building designs more energy efficient. High first cost was given as the single most common response when this group of interviewees was asked about barriers, confirming the findings of previous studies. A little over half of the architects interviewed stated that first cost of equipment was definitely a barrier to energy efficiency. When a first cost response was given, the architects were further probed to understand if this was in fact the true barrier that prevented them from installing efficient equipment, or if there were other underlying factors that caused them to consider other choices above efficiency. This section also attempts to summarize the answers given by the architect in response to a question about why they thought these barriers existed.

Information Costs

The second most common barrier to energy efficient design that was mentioned by the architects was the cost of obtaining information about energy efficient products or services. Over one-quarter of all the architects stated that information costs prevented them from making their building designs more energy efficient. There were various opinions among the architects who felt that information costs were a barrier, the majority opinion being that the information that is currently available needs to be easier to understand. Their point was not that the information was terribly difficult to find, but in the process of explaining it to the client, they needed it in a format that could be understood by someone who was not completely knowledgeable about the topic, as many of the clients tend to be. They did not find the currently available information to be as useful as it could be. The following statements are comments from the architects on this subject:

> *"The primary barrier to making my designs more efficient is my understanding of passive design and equipment choices. I must rely on my consulting engineers for information on equipment and mechanical choices, in areas such as A/C systems and thermal insulation. I feel that I can only be as up-to-date as the consulting engineers are."*

> *"I would like to see the up-front costs vs. long-term savings displayed in an easy to understand format."*

> *"Another barrier is the lack of awareness regarding available equipment, etc. Every year, the available equipment is more efficient than previously, and people just seem to be unaware."*

One differing opinion that was heard among the responses was that there was too much information for architects to sift through in a limited time:

> *"I just turn to the standard manufacturer catalogues that I know because I don't have the time to go through all the vendor information I receive. I have too much information."*

Performance Uncertainties

Uncertainty about the ability of a piece of equipment to perform as assumed was another barrier that was mentioned quite often by the architects. Over one-fifth of the architects stated that equipment performance uncertainties were a barrier to energy efficient design. These architects stated that sometimes they or their clients are not willing to take chances on new technology that has been proven effective in a research lab, but not in an actual workplace. Some architects mentioned that a long-term cost benefit analysis could not be provided, seeing that the technology was so new. The clients and the architects both want to ensure that the systems will work according to plans, and the easiest way for them to secure this is by installing systems that they know and trust through previous work.

> *"The districts have a conservative approach to equipment choices. They want equipment that is tried and true. If we cannot provide a local example of use, they aren't interested."*

> *"I do not experiment with new systems…. There is a general reluctance to try things without a track record. I do not want to take chances with my clients on bad equipment."*

Low Energy Costs

Another issue that surfaced as a barrier was the fact that architects felt the low energy prices may actually dissuade people from installing energy efficient equipment. Approximately 20% of the architects stated that they felt there was not enough money to be saved to justify the high initial cost of the systems.

> *"The primary barrier to energy efficiency is the fact that it just isn't painful enough to not be more efficient. The high initial cost of efficient materials and equipment combined with the low cost of energy does little to persuade people to be more efficient."*

> *"Energy costs are such a small cost relative to the cost of the whole building, they become somewhat unimportant."*

Lack of Education and Foresight

A little less than one-fifth of the architects stated that lack of education and foresight on the part of the client was a barrier to the energy efficient design of buildings. Some architects outright stated that their clients are not concerned about energy efficiency, and are not at all interested in the efficient technology.

> *"The primary barrier to energy efficiency is client willingness and misperceptions on the part of the client with regard to initial costs. Many times, the initial cost of being energy efficient is higher, but the life-cycle cost is better. Clients seem to perceive that the initial cost is more important than the life-cycle cost."*

> *"There is real lack of interest in energy efficiency on the part of the clients. It is difficult for our firm to convince clients to be more efficient since our firm is not capable of providing a long-term cost benefit analysis."*

Split Incentives

Almost 20% of the architects stated that speculative owners are not interested in lowering long-term operational costs. There is no incentive for them to try and install energy efficient equipment if they will not reap the benefits. Furthermore, the higher cost of the efficient equipment discourages them from selecting that option, even if the benefits are clearly explained to them since they will not ultimately pay the bills. The architects stated that these split incentives occurred mainly in the speculative market where the client is primarily concerned about keeping within the budget and just meeting code requirements.

> *"Speculative projects are only interested in those types of options where they can pass the costs on to the tenants. Speculative clients are not interested in a higher first-time cost, as it is difficult to pass this cost on to the tenants."*

> *"I don't want to overbuild with a tenant improvement because the tenant may want to change it all, so I try to design flexibly so they can change or add windows or skylights. …On TIs we just design to be flexible and not for much heat gain. We don't install any insulation or anything until there are working drawings. It's a lot tougher because you don't know ahead of time what will go in the space."*

Organizational Practices

A handful of interviewees stated that their building designs were not as energy efficient as possible due to barriers that they encountered in organizations. They tend to have a large bureaucracy to answer to, with strict guidelines that are not flexible enough to accommodate the higher initial cost of the equipment that will be beneficial in the long run. However, a couple architects implied that the school's monetary systems seem to be slowly improving. These quotations sum up the general consensus among architects regarding schools:

> *"The primary barrier to making my designs more efficient is the bureaucratic division of money in school districts… Many times we cannot make a higher up-front investment even if a cost-benefit analysis shows that money (energy) will be saved in the long run. There is a construction budget and a separate operating budget, and the money pools must not be mixed… Many times the school cannot choose the less costly option because they simply cannot swap the pools of money."*

> *"Some school districts request the same manufacturer for all the equipment because their operators know how to use it, but the state wants "equal" equipment types to be installed, and force a competitive bid. The equipment is usually not equal to the equipment the school wanted."*

Hidden Costs

A few architects stated that the hidden costs associated with installing the energy efficient equipment can be an obstacle to designing energy efficient buildings. Clients are concerned that the new equipment will require additional training for the maintenance staff, and this along with the high first cost of the equipment could cause them to choose the standard efficiency equipment rather than the newer energy efficient technology.

> *"The training of the operators is sometimes futile because of job turnover. The knowledge of the system never gets transferred. I have also seen cases where the system is configured, and the main person knows how to use it, but they never train the people who are going to actually use the systems."*

> *"The operator of facilities used to be aware of how the system was intended to operate. Now, many people are manipulating the controls on systems. I am not sure people are being educated on how to use the systems. The issue that arises for the owners is: do you spend more time helping your staff learn the system or keep the money in the bank (by installing standard systems)."*

Asymmetric Information

Another barrier that was briefly mentioned by a couple of architects was the fact that the information they received was not trustworthy. They had received numerous mailings and catalogues from salespeople, but did not feel that the information accurately and concisely reflected the type of information that they and their client found to be necessary. The group of architects that responded in this nature implied that they would like a source of information that was trusted and containing an extensive list of additional resources.

> *"Information about the equipment is not trustworthy. Good research, forthrightly shown from a trusted source is needed for them to believe the documentation. I tend to just go with the equipment that clients know and trust."*

> *"I feel clients want a more trustworthy source of information from someone with experience using the systems instead of the current information from manufacturers they have now."*

Engineers

Not surprisingly, approximately nine-tenths of engineers spontaneously mention high first cost as the primary barrier to being more energy efficient. Probing reveals various barriers underlying the high first cost response. One engineer initially states there are no barriers to energy efficiency.

> *"Many people bring up the cost issues, but this is invalid since the increased initial cost is easily amortized over time."*

Lack of Education and Foresight

Almost 50% of engineers spontaneously mention lack of education and foresight on the part of building owners as a primary barrier to energy efficiency. Several engineers indicate that a lack of education prevents building owners from fully understanding the impacts of different equipment options. Others state that building owners have difficulty understanding why they must incur such a great initial cost in order to save money in operating expenses over time. Additionally, a lack of foresight prevents owners from considering long-term costs.

> *"The majority of building owners are most concerned with the up-front capital expenditures involved. They willingly accept increased future operating expenses to keep the construction costs down."*

> *"Few building owners are inclined to accept an increased initial cost, even if they have been shown they will incur fewer costs over time."*

Misplaced or Split Incentives

Most engineers who work on private sector speculative market projects mention misplaced or split incentives as one of the major barriers to energy efficiency. Specifically, speculative market clients have no incentive to opt for more efficient equipment, unless they can pass the increased costs to their tenants. Speculative market clients wish to keep initial expenditures to a minimum, regardless of the effect on operating expenses, since they will not incur these costs. This usually involves selecting the minimum efficiency equipment.

> *"Often, clients are hesitant to opt for high efficiency equipment if the long term plans for the facility are unsure. If the payback period is ten years and the client only plans to keep the building for three years, then the client is significantly less interested in efficiency."*

Organizational Practices

Approximately one-quarter of engineers believe that organizational practices is one of the primary barriers to energy efficiency. Often, building owners have a limited construction budget that must be adhered to, even though such choices may not be the most cost effective over time. Generally, there is a predetermined construction budget with funds allocated to specific uses; these uses generally do not incorporate energy efficiency.

> *"For example, consider schools. They are allocated a certain number of dollars for construction. They must build within budget. If they cannot keep to budget, the school simply will not be built, and we will have children outside in tents trying to learn."*

Additionally, many times the building owner requests the use of specific equipment so that all affiliated facilities will be using the same equipment.

> *"Most public projects have particular equipment preferences at the onset of the project."*

> *"There is more bureaucracy at the schools. Often, there is a standard from five years ago. They want the lights to match exactly with the lights from five years ago so that the whole district will be using the same lights."*

Bounded Rationality

About one-quarter of engineers believe that bounded rationality is one of the principal barriers to energy efficiency. Since many building owners wish to keep overall expenses at a minimum, they initially express interest in exploring energy efficient options. A life cycle cost benefit analysis shows that overall expenses, specifically operating and maintenance expenses, can be greatly reduced by opting for more efficient equipment. Once the building owner realizes the initial construction costs that will be incurred, they usually opt for less efficient equipment, knowing operating and maintenance expenses will increase as a result.

> *"Only about 30% of building owners are inclined to accept a higher initial cost, even if they have been shown that they will incur lower overall costs over time."*

Performance Uncertainties

Approximately one-fifth of engineers mention performance uncertainty as a primary barrier to energy efficiency. Building owners are extremely hesitant to be the first in a region to use a particular piece of equipment. One engineer states he believes a lot of doubt about energy efficient products was fostered by the energy conservation fraud of the 1980s.

> *"Clients will ask 'Well, who else uses this equipment?' Nobody wants to be a guinea pig."*

> *"Schools want equipment that is tried and proven. We do not experiment with the schools unless it is beneficial to the school, such as the equipment is donated or free. We leave experimenting up to the manufacturers."*

Access to and Cost of Capital

About 20% of engineers mention access to and the cost of financing as a primary barrier to making their building designs more energy efficient. Building owners are not willing to invest in efficient equipment options unless there is a rapid payback period since usually they must borrow the capital required by such choices. Additionally, owners have difficulty qualifying to borrow the additional capital required by energy efficient equipment. Other times, the amount of operating expenses saved by efficient equipment simply is not great enough to offset the interest rates paid.

> *"I have not yet encountered a building owner who wasn't convinced that efficiency would be cost beneficial in the long run. All of my clients would love to have an energy efficient building, but many simply cannot afford it; they cannot qualify for the required loan."*

Hassle and Transaction Costs

Slightly less than one-fifth of engineers believe hassle and transaction costs are one of the primary barriers to energy efficiency. Construction projects are currently experiencing shorter and shorter construction schedules; often construction begins while the design stage is still ongoing. This leaves little time for discussion about equipment options. Also, energy efficient equipment is a special order, and so ordering and receiving efficient equipment requires more time than does ordering and receiving standard equipment.

> *"Owners are judged on their construction budget. To increase construction costs based on energy considerations requires a lengthier discussion. Since time is usually of the utmost importance, the owner will go with a less efficient, less expensive system simply to reduce the time until construction."*

Architectural and Aesthetic Features

A handful of engineers declare that architectural features and aesthetics are a primary barrier to making their building designs more energy efficient. Often, aesthetic preferences take priority over energy efficiency.

> *"Often, the Energy Management System is taken for granted. Most building owners feel it's nice to have efficient equipment, but when they realize they are spending $100,000 on an Energy Management System, it quickly takes a back seat to aesthetic concerns."*

One engineer claims to stress the value of using high efficiency insulation and glass in order to reduce air conditioning usage, but architects tend not to comply with his suggestions because they do not want the overall cost of the building to increase.

> *"I always urge the architect to install double-paned glass instead of single-paned glass in order to reduce energy usage in terms of the buildings heating and cooling systems. They rarely heed my advice because it is too costly for the construction budget."*

Inseparability of Product Features

A handful of engineers mention inseparability of product features as one of the primary barriers to making their building designs more energy efficient. Specifically, to obtain equipment with energy efficiency features, building owners must purchase equipment with additional, perhaps unwanted, costly features.

> *"The additional amount of money required is not proportional to the amount of efficiency received. To be more efficient than is required by Title 24, one must purchase sophisticated equipment which provides a lot more than energy saving features."*

> *"With 90% of my clients, they simply are unwilling to incur higher initial costs, particularly since the increased cost of the equipment comes from the fact the equipment has additional uses affiliated with it. Consider a DDC (Direct Digital Control Energy Management System). Unless a DDC can also be used for maintenance purposes, it is primarily a glorified time clock."*

Hidden Costs

A few engineers believe hidden costs are a primary barrier to energy efficiency. Specifically, energy efficient equipment is more complex and requires a more knowledgeable maintenance contractor than does a routinely installed standard system. These more knowledgeable maintenance contractors are more costly and more difficult to locate than are standard maintenance contractors. This barrier is less prominent in urban areas as there are more contractors available who are knowledgeable about the maintenance of energy efficient equipment.

> *"My practice is located in a rural area; most contractors in the area are not knowledgeable about maintaining energy efficient equipment. Usually the same contractor is responsible for installation and maintenance of the equipment, so it would require significantly more effort and dollars in this area. However, I have worked on several industrial projects near San Francisco. I have found that more people are willing to try new equipment, primarily because the contractors can handle the complexity of system maintenance."*

Contractors Substitutions

A small number of engineers spontaneously mention contractor substitutions as a primary barrier to energy efficiency. Contractors suggest and implement changes to the buildings' systems, claiming to save the building owners money. This attractive reduction in first cost is difficult for building owners to pass up, even if an alternative equipment choice would allow them to save money over time.

> *"Contractors tell building owners 'I can save you $100,000 now if you select different equipment.'"*

Overcoming Barriers to Energy Efficiency

Architects

The next question the architects were asked was what they did to change the way their clients thought about efficiency. About one-third of the respondents outright stated that they were doing nothing to change the way their clients viewed energy efficiency. The remaining two-thirds stated that they just generally tried to educate their clients on the available equipment options. Some architects also stated that they tried to present the benefits of the efficient equipment in the long term that would offset the higher initial costs. One architect mentioned that he tried to ease some of the apprehension related to new technology by showing some of his previous work to his clients. Some related statements are listed below:

> *"To change the way clients view efficiency, I urge them to carefully compare life-cycle cost to first-time cost."*

> *"To change how my clients think about efficiency, I present options and try to convince them to invest a little more in the initial cost."*

> *"To change how clients think about efficiency, I point out how they can reduce operational costs by adding glazing and insulation or by selecting a particular HVAC system."*

> *"To change how clients think about efficiency, I present historical data based on buildings from my personal experience. I provide examples of buildings in similar climates that have used particular equipment or designs in order to demonstrate the benefits of being efficient."*

The architects were asked a set of questions that attempted to get suggestions from the architects on how to overcome the barriers that they named. The architects proceeded to give detailed suggestions on how the barriers should be overcome and who should be the leaders in overcoming the barriers. The architects named the following people/agencies as possible leaders in overcoming energy efficiency: (listed in decreasing order of responses)

- Utilities
- Manufacturers
- Government (federal, state, local, legislators)
- Architects
- Engineers
- Clients

Over one-fifth of the architects mentioned that utilities should be the leaders because the utilities are a trusted source of information that for the most part are viewed as unbiased. Approximately 15% of the architects interviewed mention that manufacturers need to reduce the cost of the equipment and materials. The government was named as the agency that should offer incentives or tax programs for energy efficiency. Architects, engineers, and clients were only briefly mentioned as being the leaders by the interviewees.

Many differing suggestions were given by the architects to overcome the barriers named earlier. Some common themes surfaced in their responses. Approximately one-third of all the suggestions given were related to the need for more education about energy efficiency. Specifically, clients and the people who run the systems were mentioned as who should be more educated on this topic. They are the ultimate decision-makers, and the information is not easily accessible or understandable for them. The architects who suggested this felt that if the public was more educated, then there would be less resistance to installing the energy efficient measures. In particular, the architects would like to see the benefits of the equipment in an easier to understand format that can be explained to their clients. Some related comments are below:

> *"Steps need to be taken to educate the people who run the building, the Facilities People. Educating the facilities people on the long-term benefits of certain equipment will encourage the client to select certain equipment for the building."*

> *"Many clients don't understand about the choices. Some clients are very environmentally aware and the cost benefit is secondary, while other clients aren't as aware and the cost benefit is the primary consideration. We need easy to understand information to explain the benefits to both client types."*

Approximately 15% of the respondents suggested lowering the first cost of the equipment. They felt that this would increase access to the efficient equipment, and more people would adopt this as a practice. As mentioned earlier, the manufacturers were mentioned as the leaders to reducing first cost. One architect stated that the manufacturers needed to come up with a *"commercially viable product that is affordable"*.

Another suggestion given by a handful of architects that is related to lowering the price of the equipment were tax benefits or subsidies from the government. The architects who suggested this thought that the people who were investing in energy efficient equipment should be rewarded for their behavior by the federal, state, or local government agencies.

> *"To overcome the barriers, the government should provide more incentives (tax benefits) for using efficient equipment. The government needs to educate and incent people to behave in the desired fashion. By offering incentive programs for 2-4 years, people will incorporate efficiency into their behavior and this behavior will continue even when the incentives stop."*

> *"To overcome the barriers, the Federal Government should offer more subsidies/tax-breaks to property owners who use more efficient systems. More clients would want it. It is very important that an incentive system rather than a punishment system is used to encourage people."*

A couple of architects stated that energy prices should be increased in order to make energy efficient equipment more of a priority to clients. Other suggestions were made along the lines that school district budgets need to become more flexible to allow the project manager to mix the pots of money. Additional rebate programs from the utilities or the government were mentioned by a couple of architects.

The architects were asked how the barriers varied between owner occupied buildings and speculative development. The fundamental difference that surfaced was the budget constraints that the speculative builders had to adhere to. Most often, the budget on speculative buildings were so tight that there was no freedom of choice allowed for the mechanical systems. The spec client always went with lowest first cost, and thereby ruled out any higher priced efficient systems even if the long-term savings were proven to be beneficial. As mentioned earlier in the discussion about split incentives, the speculative clients are not concerned about long-term costs because they pass those costs on to the tenants. On the other hand, some architects noted that the owner occupant clients will be open to more expensive equipment if the benefits can be proven. The following quotation sums up the responses given by architects on this subject:

> *"Speculative developers are quite different from owner-occupied clients. Owner-occupied clients will select more efficient equipment for an increased initial cost if the long-term cost analysis shows savings over time. Speculative developers have a very different motivation. It is entirely dependent on how long they plan to have the property. If they will receive financial gain, then they are willing to be more efficient."*

On the differences between public and private projects, the responses from the architects indicated that public projects tend to be more concerned with the long term benefits for a building, while private owners generally are less concerned. This tends to be related to organizational rules that they must comply with, and the government usually has higher requirements than the general public.

> *"The public projects have a high priority on energy efficiency. It is a driving factor. They approach it from a life cycle cost perspective. The budget on these projects is not the big priority."*

> *"Efficiency is more significant in public buildings because of having other factors such as mandated or legislated considerations to adhere to."*

Engineers

All respondents were asked to state why the various barriers existed. The majority of engineers agree the existence of the barriers is directly related to a lack of education and foresight on the part of building owners. Specifically, many engineers believe that the owners' lack of education prevents them from fully understanding the impacts and benefits of being as energy efficient as possible. Additionally, many engineers stated that building owners simply are not considering the long-term effects of each choice; they appear to be primarily concerned with keeping initial costs at a minimum, regardless of long-term effects.

Nearly all engineers try to educate building owners about energy efficiency on a project-to-project basis. Generally, at the onset of the project, there is an initial meeting with the owner to determine their needs. Then, the engineer will provide a list of equipment choices along with the tradeoffs affiliated with each option.

> *"To educate my clients, I host a luncheon presentation where I bring in samples of the various lights so they can see the difference for themselves."*

> *"I discuss the payback period along with the long-term advantages to try to convince them to opt for more efficient lighting and equipment."*

> *"To educate my clients, I show examples of buildings which have been documented by Edison to be very energy efficient in order to demonstrate the value of efficiency."*

However, the majority of engineers reveal they have limited exposure to building owners. Generally, the engineer's client is the architect, who, in turn, is the direct connection to the building owner. Engineers must often relay equipment information to the owner through the architect. Architects have their own design considerations, particularly aesthetics, and some engineers feel architects are often not interested in compromising between aesthetic concerns and more efficient equipment. Engineers have limited opportunity to directly educate owners, making it quite difficult for them to convince owners to opt for more efficient equipment. Many engineers feel architects, in addition to building owners, need educating.

> *"It all starts with the architects, and they have no concept of energy efficiency ever since the energy crunch."*

To overcome the barriers to energy efficiency, engineers suggest:

- Educating Architects and Building Owners
- Lucrative incentive programs
- Increasing the Cost of Energy
- Providing State Funding to Increase Construction Budgets on Public Sector Projects

The most frequently mentioned suggestion for overcoming barriers to energy efficiency is educating architects and building owners.

> *"Clients must be educated about mechanical, electrical, and first time costs so that they can understand why they must incur such a high first time cost in order to save money in operating expenses over time."*

Also, about one-quarter of engineers recommend the implementation of lucrative incentive programs. Incentive programs make it easier to convince owners to make an increased initial investment. One engineer recommends utility companies provide a mechanism to see an expected incentive up-front. If engineers had a clear idea about the expected incentive, they could incorporate the incentive into their modeling methodology. A few engineers recommend increasing the cost of energy to overcome the barriers to efficiency.

> *"People need to be forced to overcome their current thinking. The cost of energy will drive it. Now energy is affordable, so nobody cares. It's all profit driven. How did we get everybody out of those enormous cars our parents used to drive around in? The oil crisis of the 1970's did it. We need something similar here to change people's approaches."*

Engineers also suggest providing state funding to increase construction budgets on public sector projects when alternative equipment yields long-term savings. Public sector projects receive limited funding for the construction budget. Increasing the construction budget will serve to allow these projects to opt for more efficient equipment and reduce operating and long-term expenses.

All respondents were asked how barriers to energy efficiency varied by client type. The majority of engineers feel public sector and private sector owner-occupied clients are more receptive to high efficiency equipment since they are the group who will derive the cost benefits of efficiency. Many public sector clients are required to consider life-cycle cost, and owner-occupied clients are significantly more likely to do so than are speculative market clients. Most feel corporate users are the easiest to convince since they tend to have more resources available. Public sector clients are more often dealing with limited funding for construction, and many have predetermined equipment preferences. Schools tend to be more difficult to convince since they often have preferred equipment choices in advance.

> *"With schools, the facility managers already know what equipment they want."*

All engineers involved with private sector speculative market clients agree they are the least willing to opt for more efficient equipment. The main objective of speculative market clients is to minimize construction costs; they are not willing to consider costs over time, particularly if additional costs cannot be passed on the tenants.

Most engineers believe the design community in general should be the leaders in overcoming barriers to energy efficiency. Specifically, most believe that engineers and architects should be leaders in overcoming barriers to efficiency.

> *"The leaders should be the architectural and engineering communities since they specify and determine what goes into buildings. One channel would be a joint meeting between engineering and architectural professional chapters to discuss the issues of being energy efficient."*

Others believe that utility companies ought to be the leaders since they have a vested interest in energy efficiency.

> *"Utilities need to offer lucrative incentive programs to offset the initial cost of being efficient."*

> *"I believe the utilities should be the leaders since end users will trust the utilities more than a general contractor to provide them with this knowledge."*

Information about Energy Efficiency

This section contains the varied architect and engineer responses that resulted from questions regarding energy efficiency information. The interviewees were specifically questioned about where they obtained this information and whether it was easy to find and understand. They were further probed for suggestions on how energy efficiency information should be distributed in the future in order to ensure that it is easy to obtain and understand. Below is a list of the key findings from the interviews for this section:

- Industry and environmental magazines/journals were the most commonly mentioned sources of information that architects used to obtain energy efficiency information;
- Trade magazines and professional trade organizations were the most commonly mentioned sources of information for engineers;

- Electrical and mechanical engineers were the second most commonly mentioned sources of energy related information for architects;
- The engineering community obtains efficiency information from a wide variety of sources;
- Additional sources of energy efficiency information that the architects and engineers mentioned were:
  - Manufacturers' information
  - Industry seminars, classes, and trade fairs
  - Internet
  - Utility programs
  - California mandates such as T-24 law
  - Clients
  - Books
  - Vendors
  - Advertisements
  - ASHRAE
  - Professional collaboration
  - California Energy Commission
  - Spec sheets
  - Local utility companies
  - Electrical engineers/lighting designers
- Most architects feel that energy efficiency information is easy to obtain, but somewhat difficult to understand
- Engineers also believe energy efficiency information is easy to find and most believe it is easy to understand
- Ease of understanding efficiency information is highly dependent on the level of expertise of the reader

Architects

All but two of the architects interviewed mentioned more than one source where they obtained energy efficiency information, indicating that the architects had a general idea of multiple sources they could turn to for information. There were a total of sixteen different sources the architects stated that they turned to for information.

Approximately half of all the architects interviewed stated that they read trade and industry-related magazines to obtain information about energy efficiency. Among this group that relied on trade magazines for information, only a few stated that magazines were their only source of information.

Over one-third of the architects interviewed stated that they relied on electrical and mechanical engineers for energy efficiency information. The majority of the architects that relied on engineers used outside firms for consulting services, but a couple architects mentioned that they consulted with their own engineering staff in their firm.

The general consensus among the architects was that energy efficiency information would be easy to find if they chose to take the time to search for such information. When the architects were further probed about the types of distribution channels they would prefer, they were quick to offer suggestions they thought would be beneficial. A common response the architects gave was they would prefer to have one central source they could turn to for information instead of information coming at them from many different sources. They expressed an interest that the central source contains links to various other resources, but the general questions could be addressed at the central source of information.

Another suggestion that was made by a few of the architects was that their clients should have easier access to energy efficiency information. The clients are ultimately going to make the decisions on the equipment, and if they were knowledgeable about the benefits, then they would be more likely to approve. But, the architects said there is no easy way for the clients to obtain information since they do not subscribe to industry magazines or attend industry-related seminars. Again, the subject of a central source that provided general information to the public surfaced around this topic.

Some of the specific architects' suggestions on this topic are listed below:

> *"To make it easier to get efficiency information, I suggest the state create a carefully designed web-site. The web-site should be designed so that the average person may get efficiency ideas but also professionals can access technical information as needed. Incentives could also be posted on the web-site; it could be similar to an electronic bulletin board."*

> *"Keep up the (utility company) seminars, but try to schedule them during a variety of time periods. Also, it would be helpful if the utility companies sent out information on recommended equipment and materials."*

> *"To make it easier to obtain efficiency information, I recommend web-sites that provide access to rudimentary information that can be used for client explanations and comparisons between buildings."*

> *"I think more should be done in mainstream magazines such as Sunset and House Beautiful."*

The architects were then asked if the energy efficiency information they were able to obtain was easy to understand. There were mixed responses to this question, but about three-quarters of the architects replied that it was relatively easy to understand. Among the remaining quarter of the architects who believed that the information was difficult to understand, all of them stated that they believed the information was too technical in nature and was geared toward engineers more than architects.

> *"Sometimes, it is too technical; I do not understand some of the terminology. To make it easier to understand, I recommend expressing the information in terms of dollars rather than BTU's. It is more convincing if they translate the information into dollars."*

> *"The information is far too technical; it usually involves physics and chemistry or computer projects. I do not understand anything to do with the computer projects."*

Engineers

Nearly all engineers believe efficiency information is easy to locate, although a small number mention difficulty in locating information about end-use results of particular systems.

> *"Many times users do not wish to disclose information about the cost and the effectiveness of the system being used. For example, consider the Federal Building in San Francisco. They recently did a renovation of their HVAC system. My firm was involved with the renovation project. Even though they are only located four blocks away, I cannot obtain reliable information about the system, not the cost or the effectiveness."*

Most engineers state efficiency information is easy to understand. At least half of engineers admit that efficiency information is probably difficult for architects and building owners to understand.

> *"It is written by engineers for engineers. It is most likely too technical for most people."*

> *"It's easy for me. It is absolutely not easy to understand for non-engineers."*

About half of the engineers had no suggestions for making it easier to obtain energy efficiency information. The remaining engineers offered the following suggestions:

- Government edict requiring disclosure of end-use results
- California Energy Commission newsletter
- Central Websites/Internet

> *"Organizations who wish to disseminate efficiency information should regularly send a newsletter through the California Energy Commission."*

> *"I recommend the use of central websites on energy efficiency. The website could include information for all levels of expertise. That might make it easier for the building owners."*

Energy Efficiency Trends over Time

The final section of the interview consisted of questions that probed the architects and engineers about changes they may have noticed regarding Title 24 increases, utility program driven increases, and equipment choices. In particular they were questioned about any changes in their approach to energy efficiency in the past 2, 5, or 10 years. Specifically, these questions determine what effect, if any, utility programs have had on their approaches to efficiency as well as how efficiency issues will be dealt with in the future. Respondents were also probed about changes in the demand for more energy efficient buildings. The final questions in this section were designed to determine if energy code requirements drive efficiency practices as well as discover any areas where code requirements have not caught up to standard practice.

The following list summarizes the key findings regarding energy efficiency over time:

- Approximately half of the architects and two-thirds of engineers have noticed changes in their approach to energy efficiency over time;
- Almost all of the architects and engineers whose approaches have changed over time stated that utility programs had an influence on their approach;
- About half of the architects and engineers stated that they had noticed an increased demand for more energy efficient buildings;
- Almost three-quarters of the architects and a majority of engineers stated that energy code tends to drive efficiency practices;
- Ninety percent of the engineers had not noticed any cases where code requirements have not caught up to efficiency practices.

Architects

As stated in the list of key findings, about half of the architects stated that there have been no changes in their approaches to efficiency over time. This group of respondents included those architects that do not consider energy efficiency in their design practice, indicating that they never considered it to begin with. This group also included some architects that do consider energy efficiency in their designs, indicating in this case that they have always put an effort into including energy efficiency in their design approach.

A small percentage of architects stated that they noticed a change in the last 3-5 years. Their responses were quite similar to those given by the architects who stated that there was a gradual change. The majority of the architects who noticed a change in their approach to energy efficiency stated that there has been a gradual change over time. Among the group who stated that there was a gradual change, there were two differing opinions. A small number stated that there was less awareness of energy efficiency nowadays compared to the past. One architect commented that the awareness in the 80s was due to the oil crises then, and energy efficiency is not as critical nowadays. Most of the architects in this group stated that there has been a gradual increase in the awareness of energy efficiency. Among this group of interviewees, utility programs were mentioned as having influenced their approach. For the most part, they were disappointed that the programs had ended. The architects implied that the programs helped them convince clients, and educate them on the different types of equipment that was available.

> *"I have noticed over time that client awareness has increased about energy efficiency, operating costs and financial incentives. PG&E offers rebates for efficient buildings usually on the upper end. Utility programs have a pretty good influence on efficiency decisions. Equipment information, general awareness, and the impact on the earth are some examples of newly learned practices."*

The architect responses varied when asked how they thought efficiency issues would be treated in the future. Approximately half stated that they feel efficiency will be treated the same in the future. The other half stated that energy efficiency will become a more important issue in the future. The primary reason for it becoming more of an issue will be public awareness. The response below is one reason that was given for an increase in energy efficiency issues:

> *"I think energy efficient practices will increase as younger, new people enter the firm. Nowadays, there are many older architects whose focus is not energy efficiency."*

A very small number of architects mentioned that they did notice improvements in equipment over time, but did not know what those improvements were a result of. When the architects were asked if there was an increased demand for more energy efficient buildings, more than half stated that they had noticed an increased demand. The reminder stated that there was not a change in the demand, with one exception stating that he noticed a decreased demand for more energy efficient buildings.

The last set of questions on the interview guide were related to energy code. The interviewees were asked if they thought code tended to drive efficiency, or if code was an acknowledgement of standard practice. Almost three-quarters of the architects stated that code tends to drive efficiency rather than vice versa. Among the remaining quarter, some reasons that were given for code trailing standard practice were that the available technology was much more advanced than the base usage and that awareness of energy efficiency causes people to look for more efficient measures.

> *"There are many areas where code has not caught up with standard practice. The systems today are so sophisticated. We rarely refer to the code. When we are stuck, we refer to it as a baseline, a minimum requirement."*

> *"Now it is standard practice to be efficient and seek out energy efficiency measures."*

> *"I think it is more standard practice that pushes code, but also competition among manufacturers that does it."*

These architects were not able to give specific examples of the areas that code was lagging behind standard practice.

Engineers

About two-thirds of engineers state they have noticed changes in their approach to efficiency. These engineers indicate they are becoming more concerned about efficiency over time.

> *"Most good engineers are currently considering efficiency; this will only increase with time."*

The majority of engineers who have not noticed changes to their approach claim this is because they have always considered energy efficiency to be important.

> *"We have always striven for energy efficiency. It's a holistic solution."*

> *"We have always used the most efficient equipment in certain applications, especially in rooftop packages."*

Most engineers state that utility rebate programs have influenced efficiency decisions to a great extent. Rebates were a very useful tool for influencing building owners to opt for efficiency.

> *"Sometimes the utilities will give financing back if certain equipment is installed. If we are aware of such a program, we always try to convince the building owner to take advantage. These programs were very useful in convincing building owners."*

Slightly more than half of engineers have noticed an increase in the demand for more efficient buildings. The majority of those who say they have not noticed changes in demand do say they have noticed a heightened awareness of energy efficiency among building owners.

> *"I have not observed many changes in the demand for efficient buildings, but I have noticed some changes. For example, some utilities have constructed prototype buildings for people to go walk around in and see for themselves what the utilities suggest. These are actual office buildings in use but also serve as a prototype for others to follow."*

> *"Clients are becoming more aware of energy efficiency. Since the deregulation, clients are unsure of what energy prices will be in the future."*

> *"We have seen a heightened awareness of energy efficiency among building owners, but at the same time, projects are going a lot faster these days. This is a serious conflict. Often, design is still on going when construction begins; this causes pressure. There is an openness to efficiency, but time is a serious roadblock."*

A small handful of engineers say they have not noticed any changes in demand for efficient buildings or in awareness of efficiency among building owners.

> *"We will not see any dramatic changes unless energy costs increase."*

> *"No, I haven't noticed any changes. People are simply interested in meeting the mandatory requirements. New construction must be energy efficient just to meet Title 24 requirements."*

More than four-fifths of engineers agree that energy code changes have tended to drive efficiency practices.

> *"Code is one way of channeling the public towards efficiency."*

> *"Consider Title 24. If we didn't have it, people wouldn't care less."*

A small portion of engineers believes code requirements are simply an acknowledgement of standard practice.

> *"It's very easy to comply with Title 24. For awhile, code did drive things; manufacturers were forced to upgrade their products. But code is not a driving force now. Code could be tightened a bit, but it has certainly achieved its goal."*

Nearly all engineers have not noticed any cases where code requirements have not caught up to efficiency practices.

> *"The framers of the code haven't missed much. The code writers tend to be more advanced while designers tend to be more conservative in their approach."*

> *"We can only be as good as the emerging technologies allow. Both California and Oregon have such strict codes that we can barely meet them now using the available technology."*

> *"California is always on the forefront, the leader. I simply cannot think of any cases."*

One engineer feels code does not adequately address duct insulation. Another says that Title 24 offers too many options and exclusions in the area of lighting.

> *"Title 24 doesn't pin down lighting levels enough."*

> *"Code does not address duct construction. One must refer to the Uniform Mechanical Code for duct insulation guidelines."*

4. Designer Quantitative Interviews

This section presents the findings from the 160 quantitative interviews conducted with designers of new non-residential buildings. These interviews were conducted with architects and mechanical and electrical engineers in order to better understand the attitudes and motivations of NRNC market actors as well as barriers to more efficient design practices.

In the planning phase of this project, 12 architects were interviewed to better understand recent trends in the NRNC marketplace. Then, in-depth qualitative interviews were conducted with 56 additional architects and engineers who were involved with energy efficiency decisions on a non-residential new construction project in 1997 or 1998. Using the results from these interviews – summarized in the preceding chapter – we designed and implemented a more structured quantitative survey of 160 architects, mechanical engineers, and electrical engineers. A total of 167 respondents completed the survey. However, 7 of the 167 were not architects, mechanical engineers, or electrical engineers and were eliminated from all analyses. All statistical tests were conducted at the 0.05 level of significance.

Characteristics of Designers

The population data for architectural and engineering firms was obtained from permit records for non-residential new construction projects in California in the F. W. Dodge New Construction Database. The Dodge New Construction Database for a given year contains a listing of construction projects that began during that year. Only permits for projects with a valuation of $200,000 or higher were included in the Dodge database.

For each permit record in the Dodge database, there are affiliated firms that provide various services for the project, including architectural, mechanical engineering, electrical engineering, and various other services. Since Dodge data does not reveal the primary business activity of a firm, firms were classified according to the type of services provided on projects. Firms who provided both types of services were included in both the architectural and engineering populations. Since Dodge data are permit records and not project completions, the permits dated during 1995 and 1997 were examined. Our aim was to identify architectural and engineering firms that worked on projects completed from 1996 through the present time. To ensure a large enough pool of engineers from which to sample, it was necessary to examine permits dated during 1994.

Architect Population

A total of 2,866 unique firms[7] comprised the architectural firm population. Since Dodge data does not contain information about a firm's annual revenue, the sum of the valuations of projects on which the firm provided architectural services during the time period of interest was utilized as a proxy for size instead of annual revenue. For firms who were members of both the architectural and engineering populations, total valuation was divided between the architectural and engineering components according to types of services provided.

[7] For the purposes of this project, two firms with the same name but different addresses are considered two unique firms.

The mean total valuation among architectural firms is $ 8,878,324, while the median total valuation is $1,250,000. This indicates that the distribution of total valuation among architectural firms is skewed to the left, as shown in Figure 26. In other words, there are a small number of architectural firms with large values of total valuation and a large number of architectural firms with small total valuation.

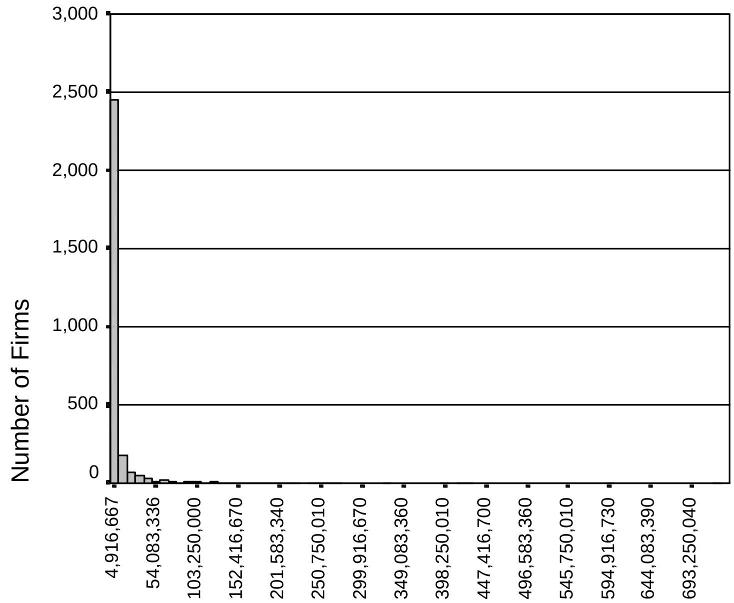

Figure 26: Total Valuation ($) Among Architectural Firms

The average number of permits per architectural firm is approximately 2.9 permits, while the median number of permits is 1, indicating that the distribution of the number of permits is also skewed to the left. The maximum number of permits for architectural firms was 68 permits. There are a small number of architectural firms involved with a large number of new construction projects and a large number of firms involved with a small number of projects. Note that more than 50% of architectural firms have only been involved in one project from 1996 through the present time. Refer to Figure 27 for a graphical representation of the distribution of the number of permits among architectural firms.

The small value for the median number of permits per firm calls into question the completeness of the Dodge database. One possible explanation is that many of these firms that have apparently worked on only one project during the time period of interest might work primarily on residential projects or on non-residential projects with valuations less than $200,000. However, it appears to be more likely that the Dodge database contains only a partial listing of non-residential construction projects in California. However, we believe that the Dodge database is the best available centralized database of non-residential construction permits in California.

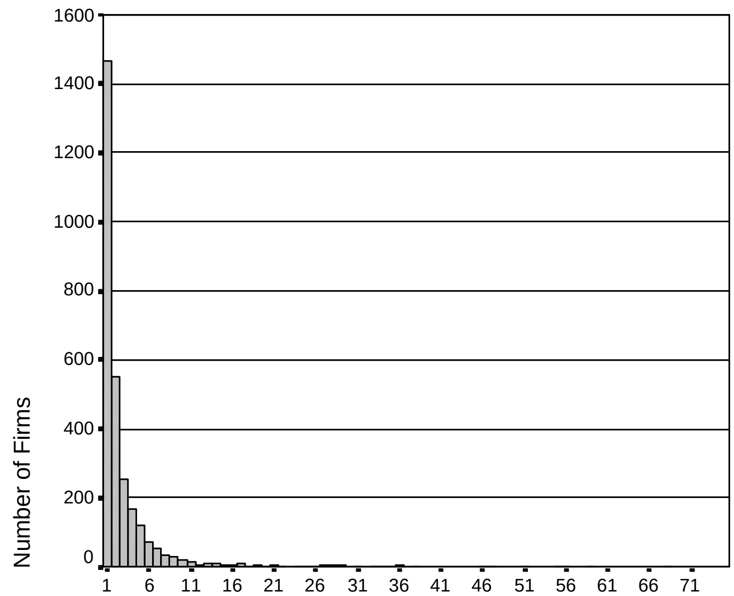

Figure 27: Number of Permits Among Architectural Firms

Mechanical and Electrical Engineer Population

A total of 533 unique firms comprised the mechanical and electrical engineering population. As with the architectural firm review, the sum of the valuations of projects on which the firm provided engineering services during the time period of interest was utilized as a proxy for size. Again, for firms who were members of both the architect and engineer populations, total valuation was divided between those components according to types of services provided.

The mean total valuation for engineering firms was $1,629,172 while the median total valuation was $500,000, again indicating that the distribution of total valuation among engineering firms is skewed to the left, although not as severely as the distribution among architectural firms. Alternatively stated, there are a small number of engineering firms with large values of total valuation and a large number of engineering firms with small values of total valuation. Refer to Figure 28 for a graphical representation of the distribution of total valuation among engineering firms.

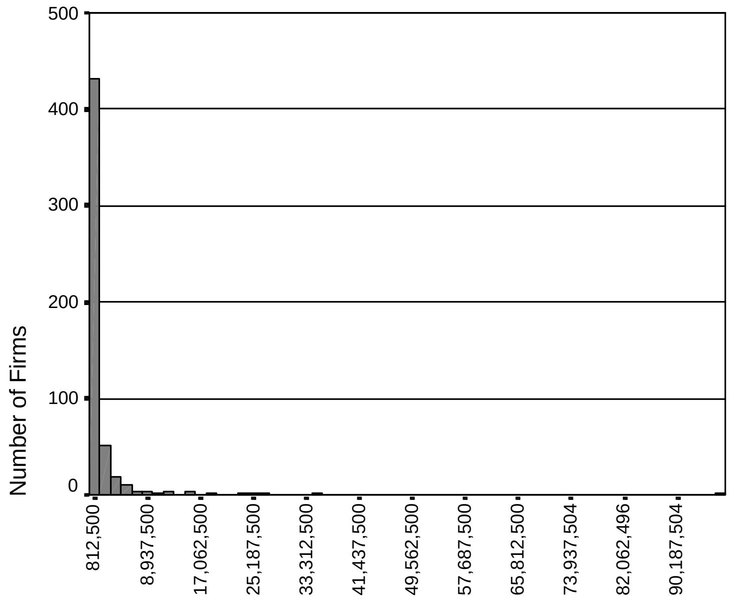

Figure 28: Total Valuation ($) Among Engineering Firms

The mean number of permits among engineering firms was approximately 1.5 permits per firm, with the median number of permits per firm equal to 1, indicating that the distribution of number of permits among engineering firms is also skewed to the left. The maximum number of permits is 10 permits, indicating the distribution of number of projects among engineers is less severely skewed than the distribution among architectural firms. Note that more than 50% of engineering firms were involved with only one project during the time period under consideration. Refer to Figure 29 for a graphical representation of the distribution of number of permits among engineering firms.

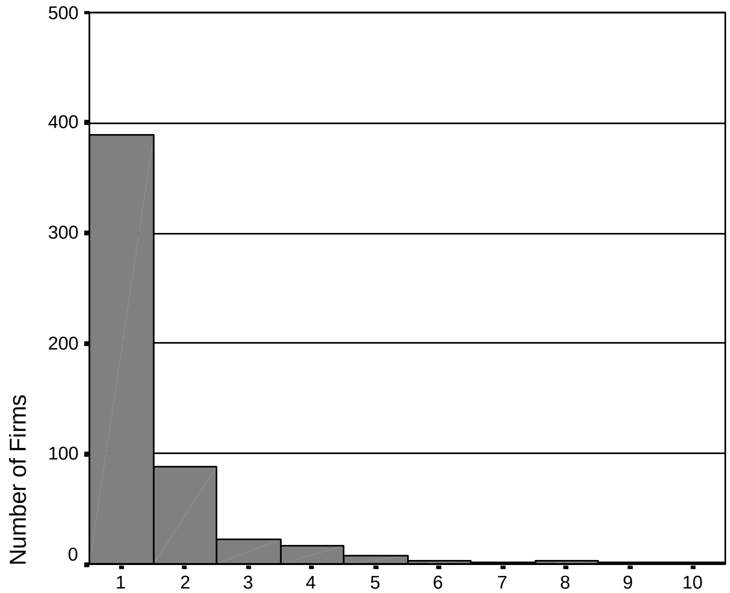

Figure 29: Number of Permits Among Engineering Firms

Sample Design Approach

Since it is likely that the populations of architectural and engineering firms differ in many ways, including distribution of firm size, it was desirable to allocate a proportion of the total sample to each of the two firm types being studied. Consequently, independent samples of size 80 were designed for both architectural and engineering firms. Within each firm type (architectural and engineering), the sample design called for stratifying by size of the firm, defined as the sum of the valuation of all projects on which the firm provided services during the time periods of interest. Firms that provided both architectural and engineering services were included in both populations.

MBSS™ was used to develop stratified sample designs under optimal allocation. Optimal allocation strives to optimize precision by allocating the sample to evenly cover the expected variability in the population. This is in contrast to proportional allocation, which allocates the sample to evenly cover the population size, e.g., based on the number of customers, as opposed to the variability between customers. The effect is that the responses of those firms who control a sizeable portion of the market are given greater weight than responses from firms who do not.

Table 1 and Table 2 show the sample designs for the architectural and engineering populations. For example, in the architectural firm sample design, the first stratum consists of 1,870 firms which had valuation less than $2,579,400. In aggregate, these 1,870 firms comprised 65% of all firms but had had a total valuation of $1,579,730,853, only about 6% of the overall valuation. By contrast, the largest 52 firms had a total valuation of $10,437,034,027, which was about 41% of the overall valuation.

Stratum	Maximum Valuation ($)	Population Size	Population Total ($)	% of Total Valuation	Planned Sample Size	Actual Sample Size	Relative Precision
1	2,579,400	1870	1,579,730,853	6%	16	23	
2	9,175,010	558	2,838,891,311	11%	16	25	
3	29,521,116	261	4,216,686,154	17%	16	15	
4	95,453,550	125	6,372,934,105	25%	16	19	
5	1,000,000,000	52	10,437,034,027	41%	16	13	
Total		2866	25,445,276,450		80	95	18.6%

Table 1: Architectural Firm Sample Design

Stratum	Maximum Valuation ($)	Population Size	Population Total ($)	% of Total Valuation	Planned Sample Size	Actual Sample Size	Relative Precision
1	400,000	210	57,583,240	7%	16	14	
2	761,500	129	72,303,178	8%	16	9	
3	1,876,360	98	109,559,324	13%	16	20	
4	4,460,000	62	170,317,119	19%	16	11	
5	200,000,000	34	458,585,744	53%	16	11	
Total		533	868,348,605		80	65	19.3%

Table 2: Engineering Firm Sample Design

Respondent Background

All quantitative interview respondents were asked a series of questions designed to learn more about their position and the firm they represent. These questions were used to classify each respondent as an architect or an engineer as well as determine the distribution of each respondent's projects among public sector clients, private sector owner-occupied clients, and private sector speculative market clients.

Figure 30 displays the distribution of respondents between architects and engineers. Note that a respondent from an architectural firm who was an engineer was reclassified as an engineer for the purposes of this study. The same is true for an architect who represented an engineering firm.

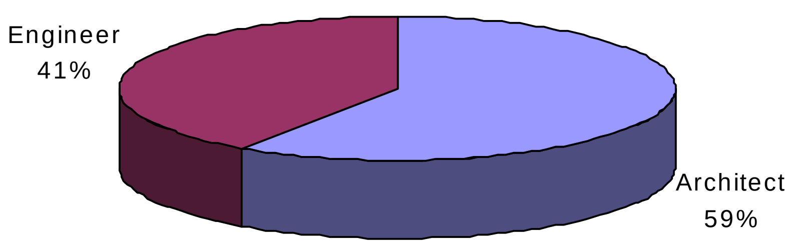

Figure 30: Distribution of Architects and Engineers Among Respondents

Figure 31 shows the distribution of the primary business of the firms who participated in the quantitative survey. For the most part, respondents were from firms that specialized in architecture, mechanical engineering, or electrical engineering. A handful of respondents represented multi-disciplinary architecture and engineering firms. A few respondents represented architecture or engineering departments within large corporations that design and build their own buildings; these respondents are categorized as Other in Figure 31.

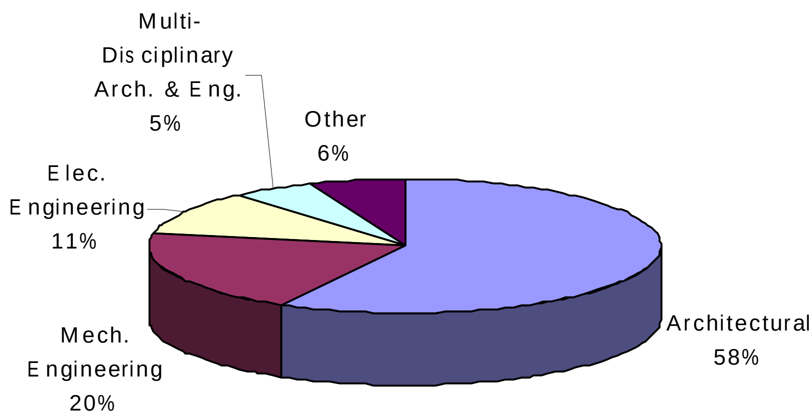

Figure 31: Distribution of Firm's Primary Business Among Respondents

To compare responses across market segments, all respondents were classified according to the sector in which the largest percentage of their projects fell. For example, if, for a given respondent, 45% of their projects were for the public sector, 35% were private sector, owner-occupied projects, and 20% were private, speculative market projects, then that respondent was classified as a public sector respondent. Only one-eighth of designers interviewed work solely on projects for one sector, while approximately 50% are involved with projects from all three sectors. Figure 32 presents the distribution of respondents among the various sectors, and Table 3 presents the breakdown between architects and engineers within each sector.

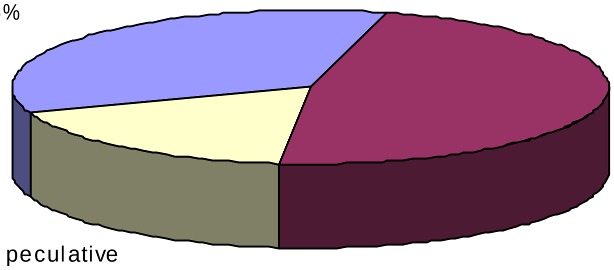

Figure 32: Distribution of Majority of Project Types

	Architects	Engineers
Public	57%	43%
Private, Owner-Occ.	55%	45%
Private, Spec.	79%	21%

Table 3: Respondent Type Within Each Sector

The Design Process

Quantitative survey respondents were asked a series of questions designed to shed light on the role of energy efficiency in the design process in non-residential new construction projects. Specifically, interviewees were asked about:

- the importance of energy efficiency considerations in the design process among the various sectors,
- methods of educating clients about energy efficiency,
- frequency of the use of optimized energy design,
- methodology utilized to determine energy savings,
- frequency of use of an energy analysis design tool,
- frequency of specification of high efficiency equipment and materials, and
- frequency of use of commissioning procedures

Energy Efficiency Considerations

Respondents were asked to indicate the importance of energy efficiency considerations for each sector they worked with, using a scale of 1 to 5, where 1 is very unimportant and 5 is very important. Table 4 shows the mean rating of importance for each sector among architects and engineers. Both architects and engineers agree energy efficiency considerations are more important in public sector projects than in private sector projects.

Designers also perceive a greater importance of energy efficiency in owner-occupied projects than in speculative market projects.

	Public Sector	Private, Owner-Occ.	Private, Spec.
Architects	4.25	4.06	3.57
Engineers	4.36	3.95	3.28

Table 4: Mean Rating of Importance of Energy Efficiency Considerations

Designers were also asked how the level of interest in energy efficiency among the various sectors has changed over the past 5 years. Figure 33 displays the change in the level of interest in energy efficiency among those who work primarily in each sector. Note that nearly 50% of those who primarily work on public sector projects indicate they have seen an increase in the level of interest among public sector clients. Also, all sectors have seen a greater increase than decrease in interest in energy efficiency.

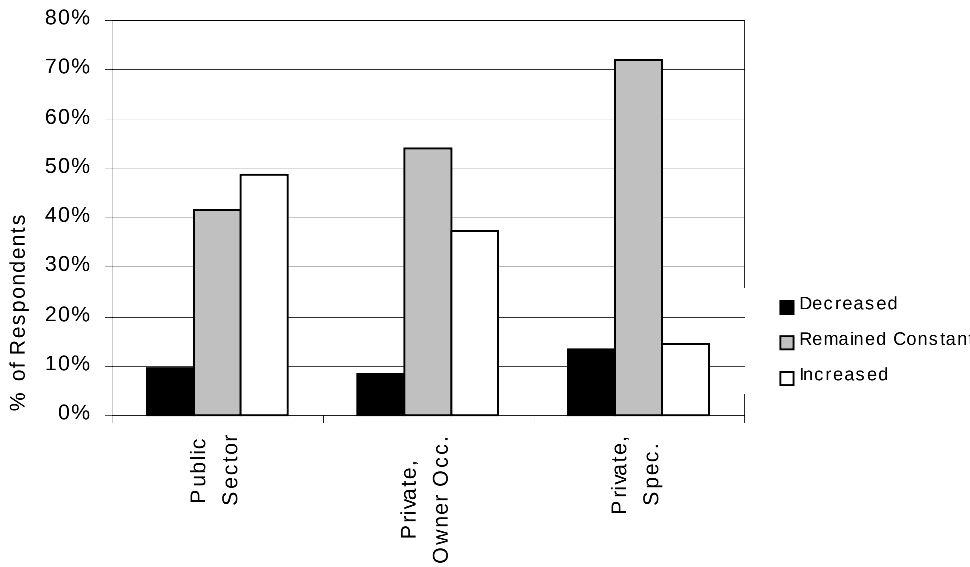

Figure 33: Change in Level of Interest in Energy Efficiency Among Those who Work Primarily in Each Sector

Educating Clients About Energy Efficiency

Interviewees were asked whether or not they attempt to educate clients about energy efficiency options that exceed Title 24 requirements. Note that this question has substantial potential for social desirability bias and responses must be interpreted accordingly. In other words, some respondents might indicate they attempt to educate their clients even if they do not because they feel that response is the “correct” answer. A full 80% of architects and nearly 90% of engineers do attempt to educate their clients about efficiency options. Figure 34 presents the percentage of respondents who work primarily in each sector who attempt to educate clients about options that exceed Title 24. Note that designers who work primarily in the public sector are significantly more likely to attempt to educate clients than those who work primarily in the private sector. Also, respondents who work primarily with private sector, owner-occupied clients are significantly more likely to educate clients than those who work primarily with private sector, speculative market clients.

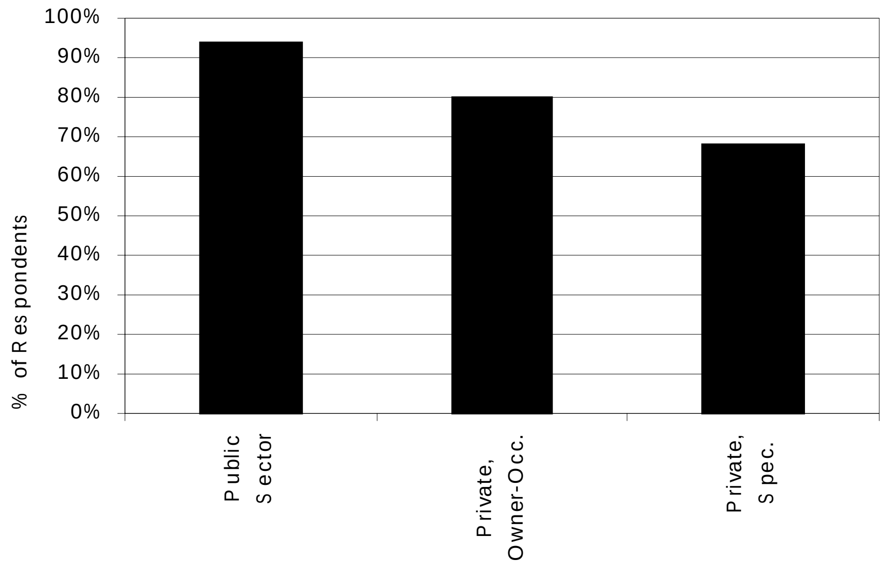

Figure 34: Percentage of Respondents who Attempt to Educate Clients About Efficiency Among Those who Work Primarily in Each Sector

Those designers who do attempt to educate clients about energy efficiency options were asked how they present the information to building owners. The majority of architects and engineers discuss operating and maintenance expenses as opposed to initial construction costs, as shown in Figure 35. As might be expected, architects also discuss comfort and aesthetic benefits associated with more efficient buildings, while engineers appear to be omitting this aspect from the discussion. Not one engineer mentioned simply relying on the architect to educate clients, even though architects are functioning as the direct link to the building owners.

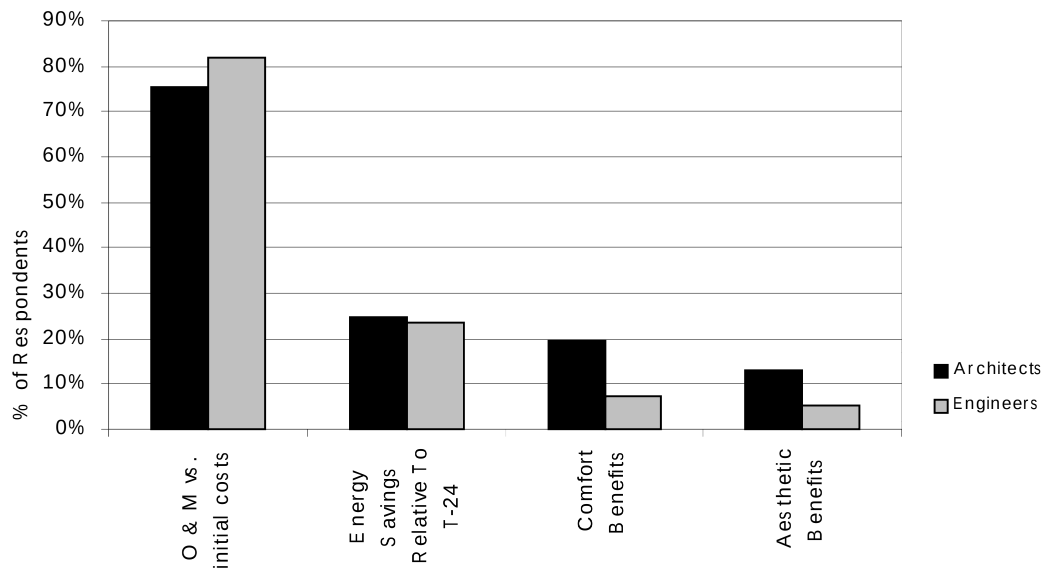

Figure 35: Methods of Educating Clients about Efficiency Among Those who Attempt to Educate Clients

Use of Energy Analysis Design Tools

Designers were asked to indicate which methods they used to determine energy savings resulting from an energy efficient building design. Figure 36 displays the percentage of respondents who utilize each method to determine energy savings. Note that engineers are significantly more likely to use calculations based on computer simulations, while architects are significantly more likely to either use rule of thumb estimates or no method at all. The most common method of determining energy savings among architects is to use rule of thumb estimates by others, and over 15% of architects use no method at all.

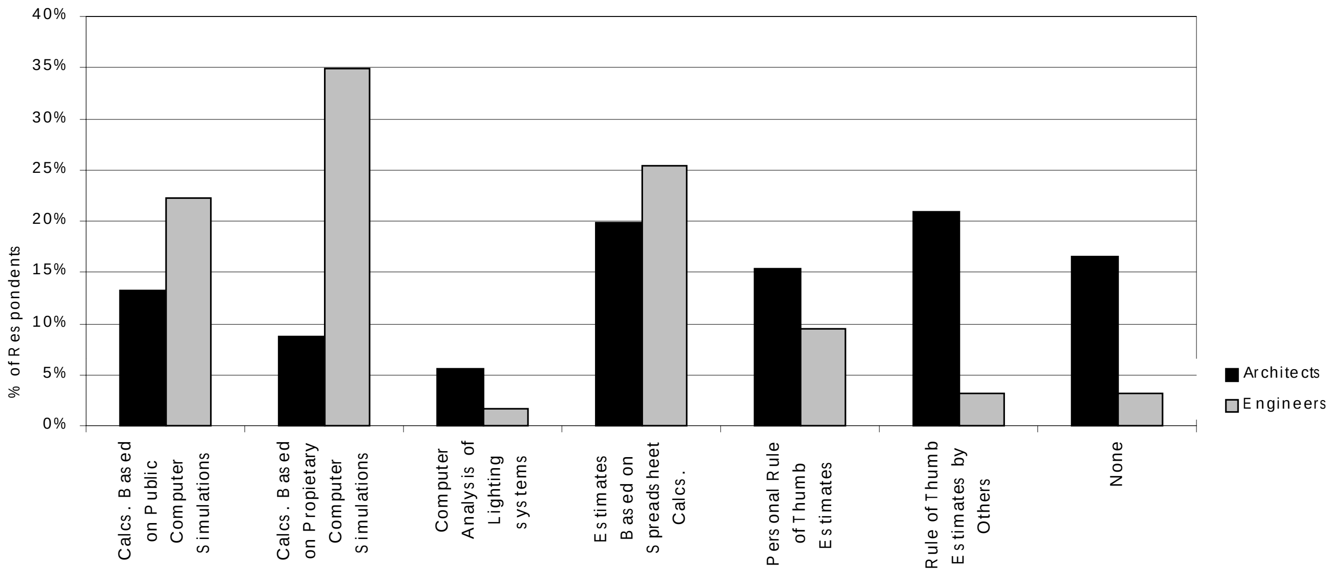

Figure 36: Methods Used to Determine Energy Savings

All respondents were asked to indicate the frequency of using an energy analysis design tool to provide energy savings estimates for clients, using a scale of 1 to 5, where 1 means never and 5 means always. Figure 37 and Figure 38 display mean ratings among architects and engineers as well as those who work primarily in each sector. As might be expected, engineers are significantly more likely to make use of such tools than are architects. Designers who work primarily in the public sector are significantly more likely to use energy analysis design tools than are those who work primarily in the private sector. Those who work primarily for private sector, speculative market clients are the least likely to make use of such tools.

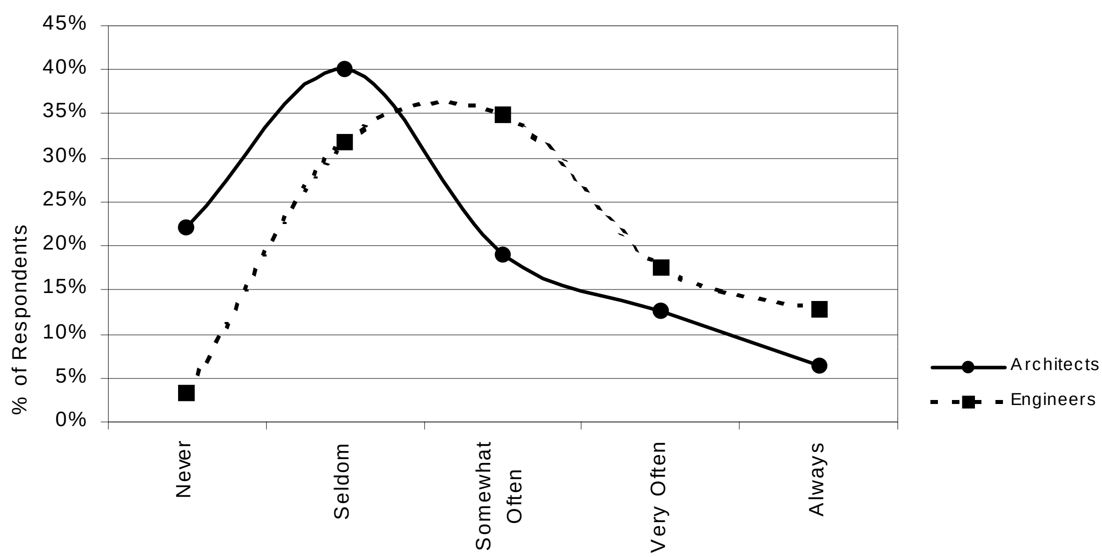

Figure 37: Frequency of Utilizing an Energy Analysis Design Tool

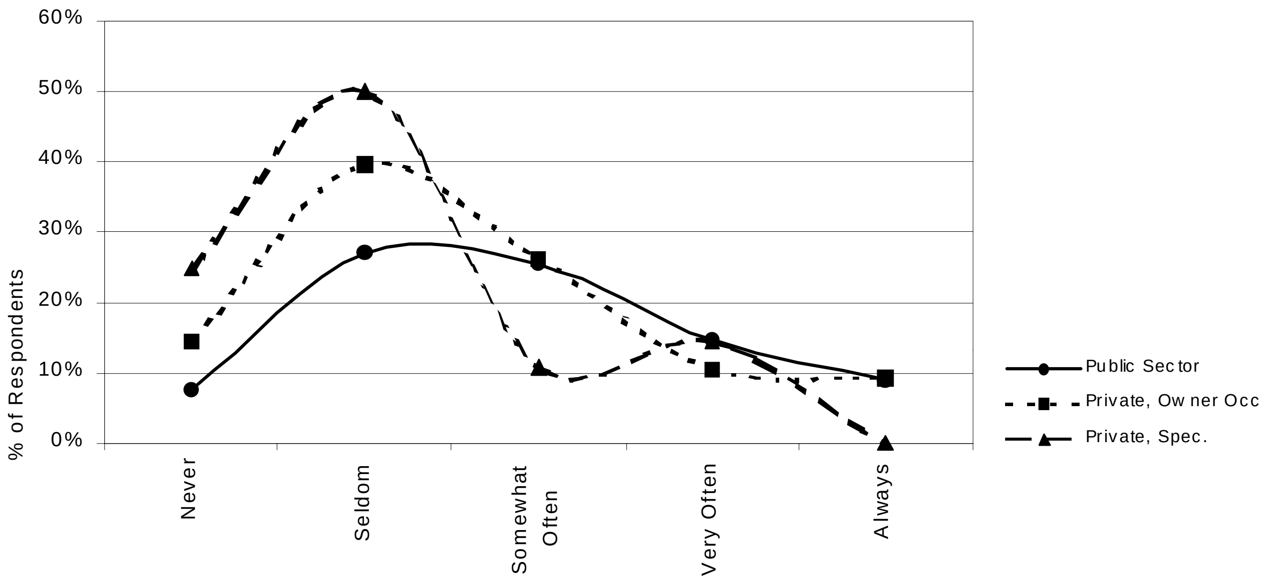

Figure 38: Frequency of Utilizing an Energy Analysis Design Tool Among Those who Work Primarily in Each Sector

Use of High and Premium Efficiency Products

All respondents were asked to indicate, using a scale of 1 to 5 where 1 means never and 5 means always, how often they specify the following equipment and materials: high performance glass, premium efficiency motors, variable frequency drives, occupancy sensors, daylighting controls, energy management systems, and high efficiency HVAC systems. Figure 39 presents the mean ratings of frequency of specifying high efficiency equipment and materials among architects and engineers. As might be expected, architects are significantly more likely to specify high performance glass and daylighting controls, while engineers are significantly more likely to specify premium efficiency motors. Surprisingly, architects and engineers are about equally likely to specify high efficiency HVAC systems.

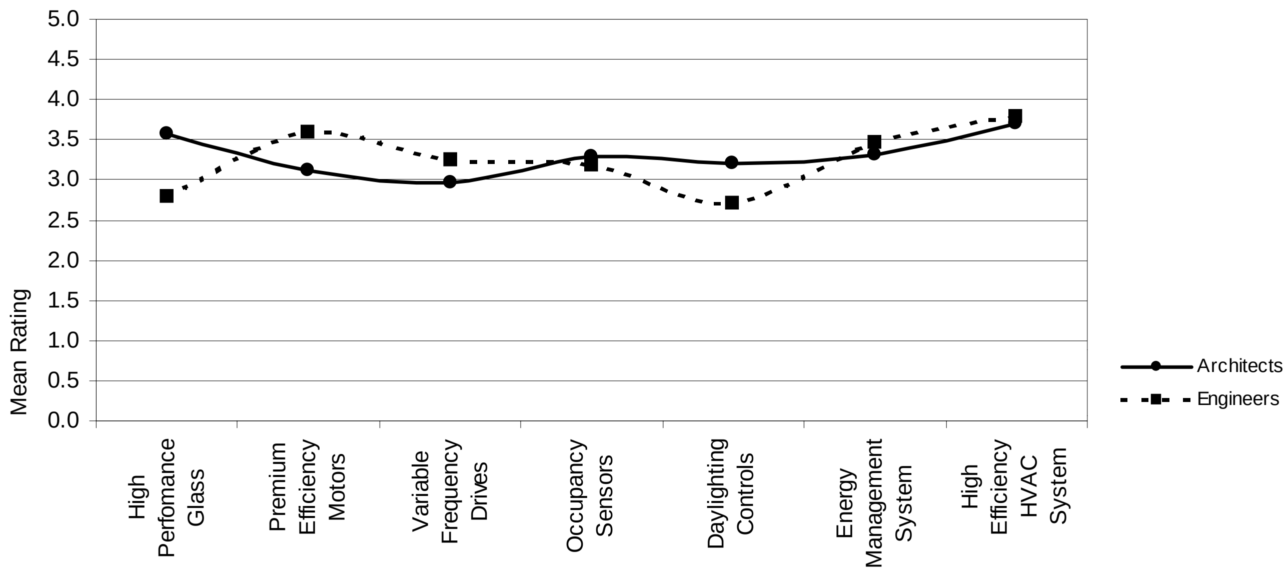

Figure 39: Frequency of Specifying High Efficiency Products

Figure 40 displays the mean ratings among those respondents who work primarily in each sector. Note that the differences among the various sectors are statistically significant for premium efficiency motors, variable frequency drives, energy management systems, and high efficiency HVAC systems. Designers who work primarily for the public sector are significantly more likely to specify the aforementioned equipment than are designers who work primarily in the private sector, while those who work primarily on private sector, speculative market projects are the least likely. Interestingly, respondents from all sectors are about equally likely to specify high performance glass, occupancy sensors, and daylighting controls.

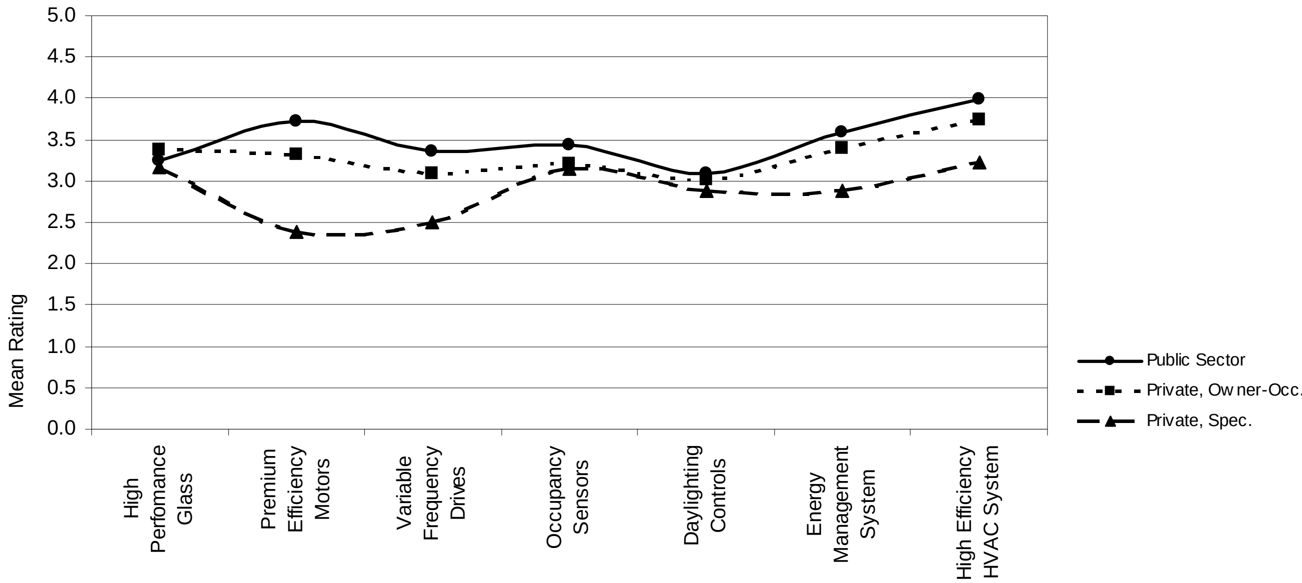

Figure 40: Frequency of Specifying High Efficiency Products Among Those who Work Primarily in Each Sector

Optimized Energy Design

All interviewees were asked what percentage of their non-residential new construction projects are completed using optimized energy design, using the following definition:

> *By "optimized energy design", we mean conscientious teamwork to create an energy efficient building by optimizing system components and interactions of the components.*

Then, respondents were asked if the use of optimized energy design increased, decreased, or remained constant over the past 5 years. Figure 41 displays the distribution of the frequency of use of optimized energy design among those who work primarily in each sector. Note that optimized energy design occurs significantly more often on public sector projects; over 20% of those who work primarily for the public sector say 80% - 100% of their projects are completed using optimized energy design.

Figure 42 presents the change in use of optimized energy design over the past 5 years among those who work primarily in each sector. The majority of respondents representing each sector indicate that the use of optimized energy design has remained constant over the past 5 years. Note, however, that a full 40% of those who work primarily on private sector, owner-occupied projects indicate the use of such design teams has increased over the past 5 years. This suggests that public sector projects initiated the use of such design teams and the trend is carrying over to the private sector. Also note that the use of optimized energy design has increased across all sectors.

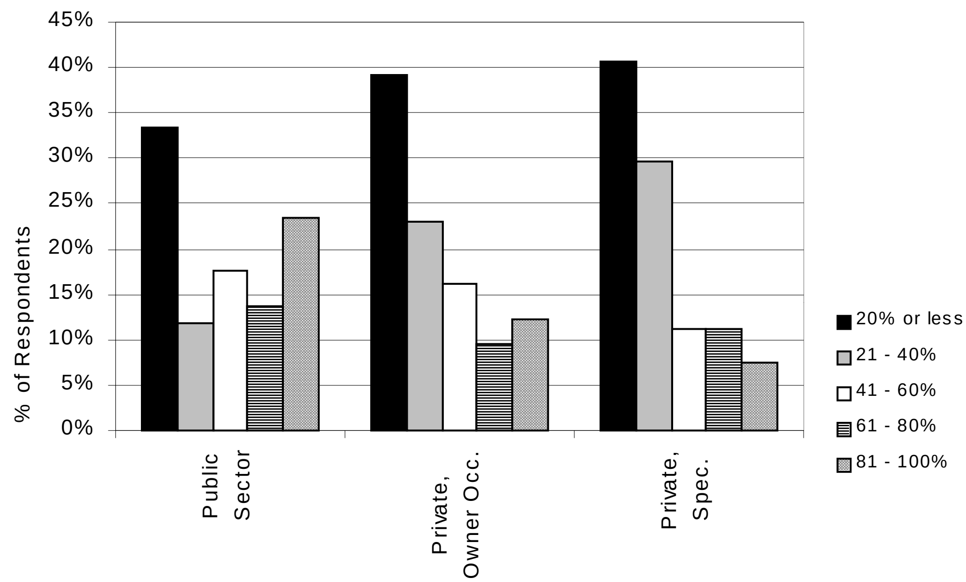

Figure 41: Frequency of Use of Optimized Energy Design Among Those who Work Primarily in Each Sector

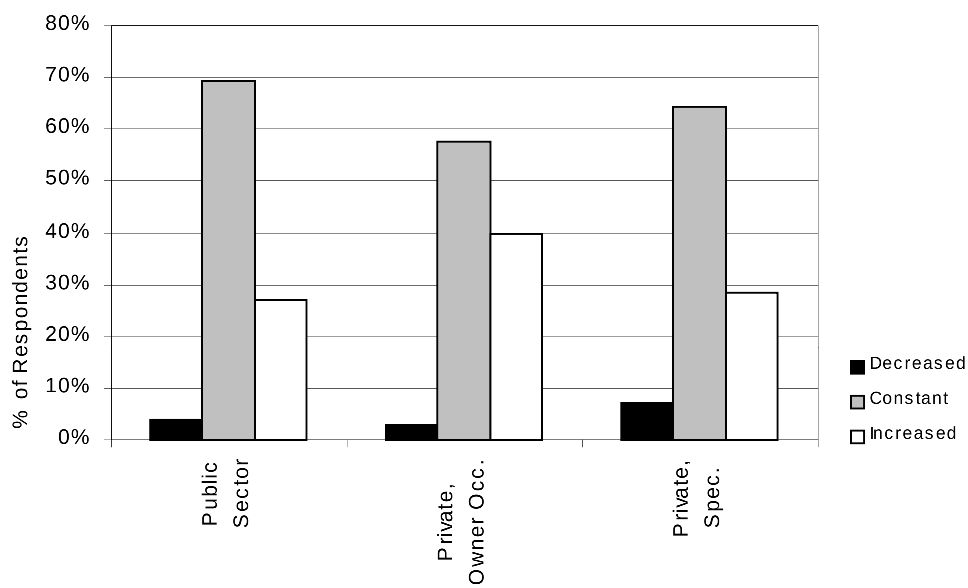

Figure 42: Change in Use of Optimized Energy Design Among Those who Work Primarily in Each Sector

Commissioning

All designers were given a list of procedures that are part of the commissioning process[8] and asked to indicate the frequency that these procedures are performed on buildings they

[8] Unlike the qualitative interviews, the definition of commissioning was not provided to respondents.

design, using a scale of 1 to 5 where 1 means never and 5 means always. Figure 43 shows the mean rating for each procedure among those who work primarily in each sector. Note that those who work primarily in the public sector are significantly more likely to provide delivery of as-built drawings, specifications, and submittals; testing of building control system operation; delivery of operations and maintenance manuals; and training of building operators. Also, those who work primarily on private sector, owner-occupied projects are significantly more likely to perform these same procedures than are those who work primarily on private sector, speculative market projects. Those who work primarily on private, speculative market projects appear to be slightly more likely to provide documentation of design intent and to incorporate commissioning requirements into the design specifications, although they do appear to be less likely to follow through on such requirements during the construction process. This is likely a function of the fact that designers of speculative buildings often only design the shell of the building and are not involved in the later phases of construction.

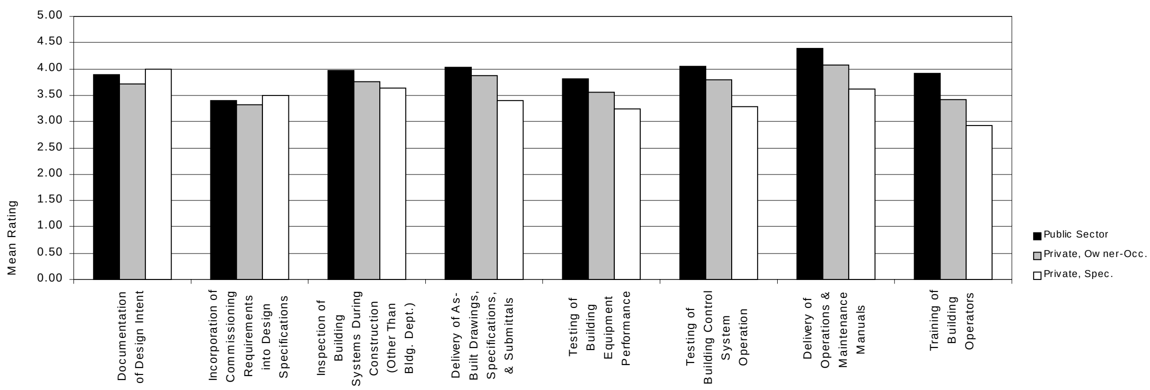

Figure 43: Mean Ratings of Frequency of Performing Commissioning Procedures Among Those who Work Primarily in Each Sector

Interestingly, when asked if commissioning occurred on their projects (after hearing a definition of commissioning) during the qualitative interviews, the majority of architects and engineers indicated that commissioning rarely, if ever, occurred. Many engineers stated during the qualitative interviews that they recommend commissioning to their clients, but most clients feel testing and balancing of systems is sufficient and opt not to follow their advice. By definition, commissioning requires the use of an independent agent. Since the above statements do not include using an independent agent, this perhaps explains the disparity between the results from the quantitative and qualitative interviews.

Energy Efficiency Information

Designers were asked a series of questions designed to learn more about sources of information for exceeding Title 24 requirements, ease of obtaining and understanding such information, as well as types of information that would be most useful for educating clients.

All interviewees were asked how well informed they were about energy efficiency options beyond Title 24 requirements, using a scale of 1 to 5 where 1 means very uninformed and 5 means very well informed. Figure 44 and Figure 45 present the mean ratings for this question. Engineers and those who work primarily in the public sector are significantly more informed about options beyond Title 24 requirements than other respondents.

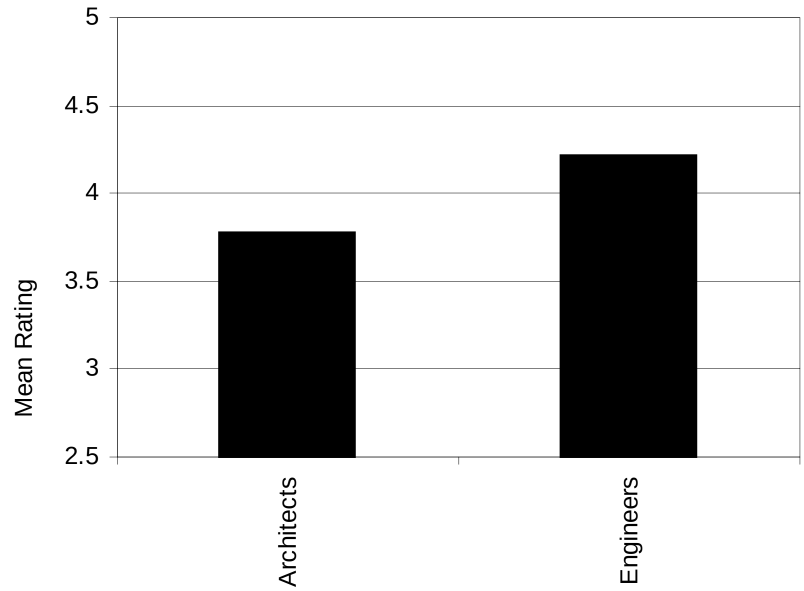

Figure 44: Mean Level of Knowledge About Options Beyond Title 24

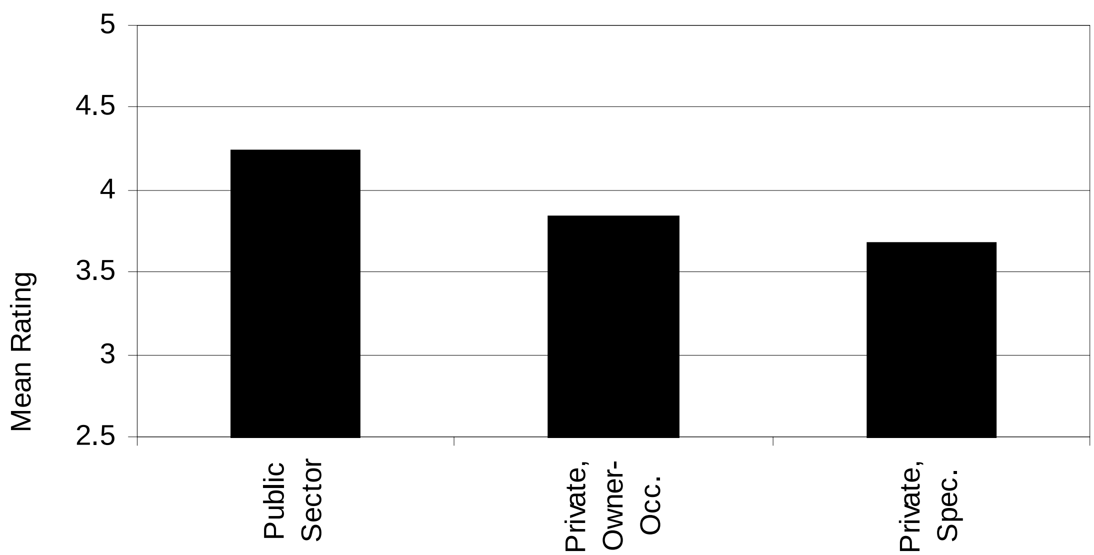

Figure 45: Mean Level of Knowledge About Options Beyond Title 24 Among Those who Work Primarily in Each Sector

Next, designers were given a list of possible sources of information for exceeding Title 24 requirements and asked to indicate their top three sources. Figure 46 displays the percentage of architects and engineers who utilize each source. Over 80% of architects indicate that mechanical engineers are one of their top sources of information. Architects are primarily relying on the engineering community to provide efficiency information while engineers obtain efficiency information from manufacturers, trade publications, energy code, and professional associations. The differences in percentages of architects and engineers utilizing the aforementioned sources are statistically significant. Interestingly, approximately 5% of architects mention their energy consultants, which were not a provided choice, as a primary source of energy efficiency information.

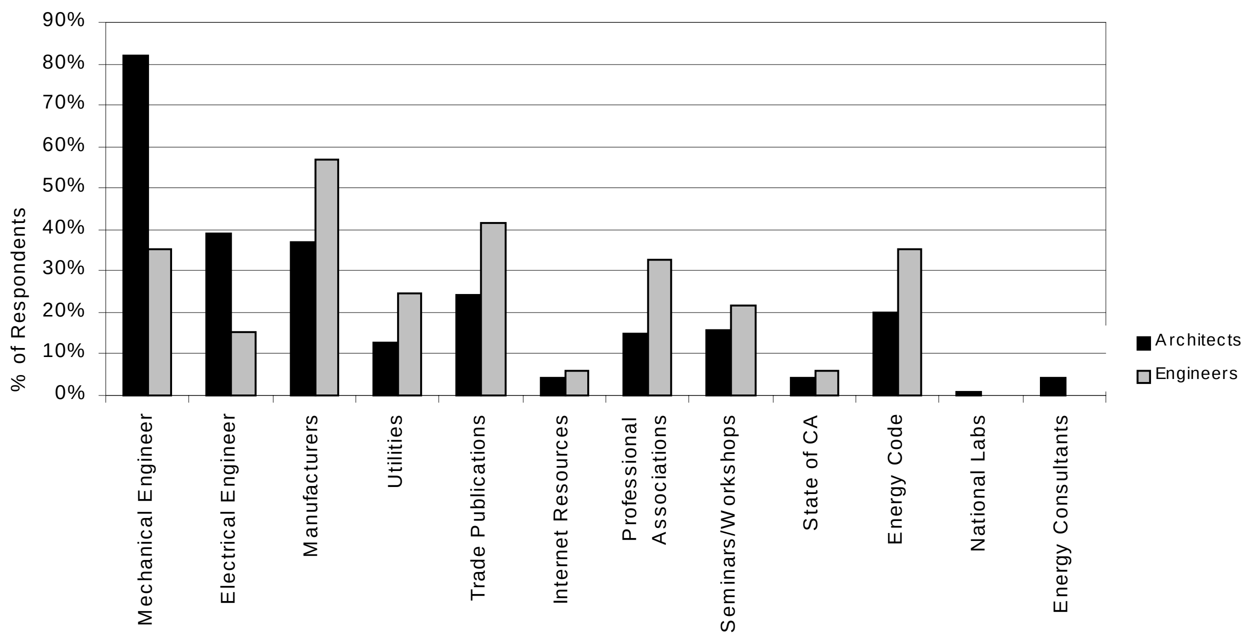

Figure 46: Sources Utilized Most Often for Information for Exceeding Title 24 Requirements

Next, all respondents were asked to rate the ease of obtaining and understanding energy efficiency information for exceeding Title 24 requirements, using a scale of 1 to 5 where 1 means very difficult and 5 means very easy. Table 5 and Table 6 present the mean ratings among architects and engineers and among those who work primarily in each sector. Statistically significant differences are shaded in gray. Engineers are significantly more likely to feel that obtaining efficiency information is easy, while there is an indication that those who work primarily in the public sector have an easier time locating such information. In terms of understanding efficiency information, engineers and those who work primarily in the public sector appear to be most likely to find it easy to understand such information, although the differences are not statistically significant. Designers who work primarily on private, speculative market projects find it easier to obtain efficiency information than those who work primarily on private, owner-occupied projects; however, they find it more difficult to understand.

	Mean Rating
Architects	3.35
Engineers	3.66
Public Sector	3.64
Private, Owner-Occ.	3.37
Private, Spec.	3.46

Table 5: Mean Ratings of Ease of Obtaining Efficiency Information

	Mean Rating
Architects	3.21
Engineers	3.52
Public Sector	3.53
Private, Owner-Occ.	3.29
Private, Spec.	3.11

Table 6: Mean Ratings of Ease of Understanding Efficiency Information

All designers were provided a list of sources and types of energy efficiency information for exceeding Title 24 requirements and asked to indicate the one source that would be the most useful for educating clients. Figure 47 presents the percentage of architects and engineers who feel each source would be the most useful for educating clients. The most common response among architects was a newsletter, while engineers most often mention a seminar. Nearly 10% of engineers indicate that no one source of information would be most useful.

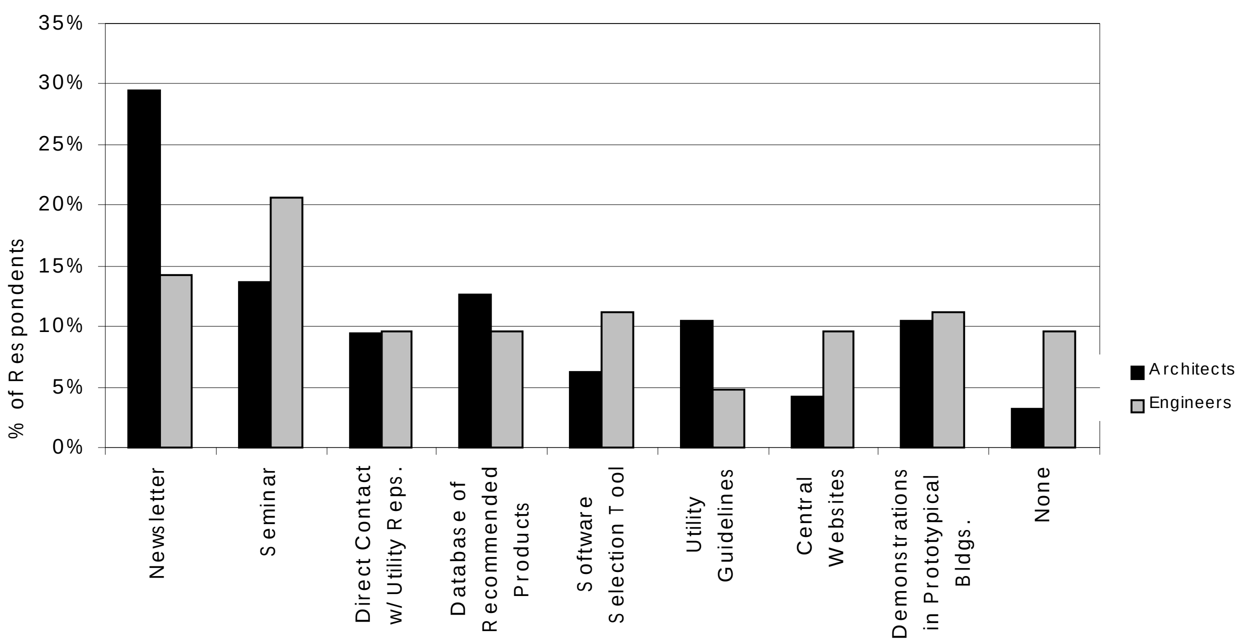

Figure 47: Sources and Types of Information Most Useful for Educating Clients

Next, respondents were provided the same list of sources and types of information and asked to indicate all sources they felt would be useful for educating clients. Figure 48 displays the percentage of architects and engineers indicating they felt the source would be useful for educating clients. Note that the second most common response among all respondents is utility-sponsored demonstrations in prototypical buildings. More than 20% of architects also mention direct contact with utility representatives, utility guidelines for specific market segments and space types as well as central websites, while engineers also feel a database of recommended products and a software selection tool for incorporating efficiency into purchase decisions would be useful.

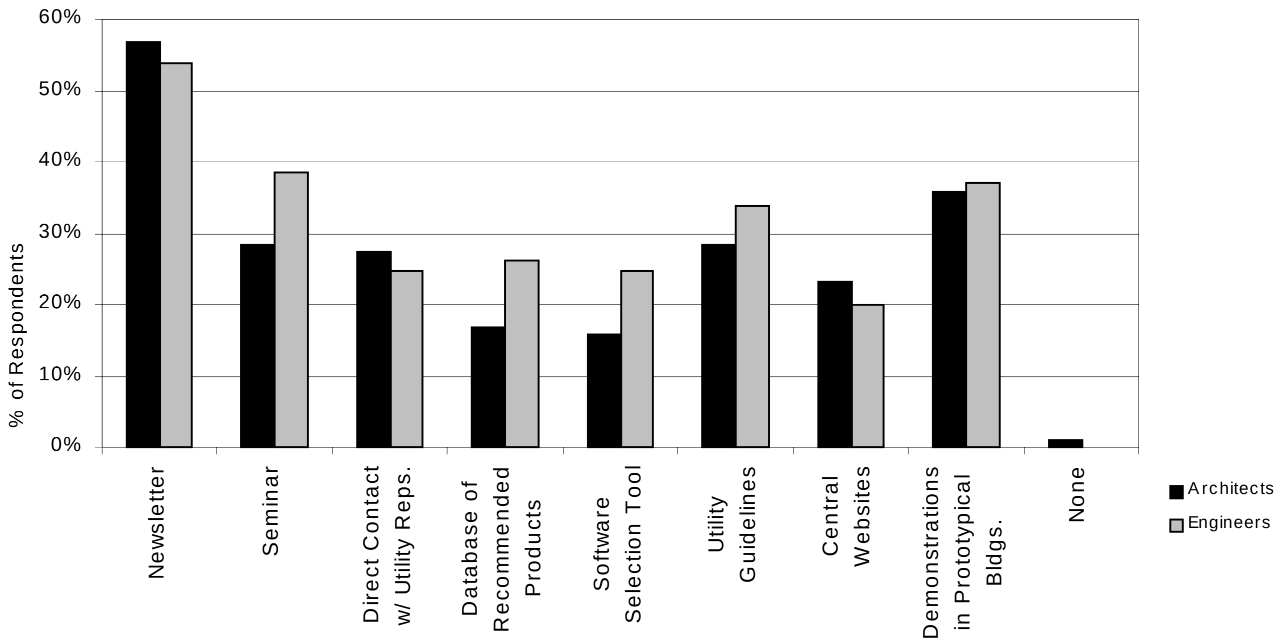

Figure 48: Sources and Types of Information Useful for Educating Clients

Decisions about Energy Efficiency

All respondents were asked a series of questions designed to determine who they perceive to have the primary responsibility for designing energy efficiency into buildings as well as who is the primary decision-maker about energy efficiency choices in non-residential new construction projects.

Interviewees were provided a list of options and asked to indicate who they believe has the primary responsibility of designing efficiency into buildings. Figure 49 presents the percentage of architects and engineers who mention each response. For the purposes of this question, it is intended that the state and federal government are considered distinct from the building owner. Note that over 50% of the architects surveyed mention that the architect has the primary responsibility of designing efficiency into buildings, while the most common response among the engineering community is the mechanical engineer. Approximately 30% of both architects and engineers believe that the owner has the primary responsibility. Interestingly, approximately 7.5% of all respondents indicate that the entire design team shares the responsibility, even though this was not on the list of provided options. Engineers appear to be slightly more likely to mention this.

Next, designers were provided the same list and asked to indicate who they believe is the primary decision-maker about energy efficiency related choices. Figure 50 displays the percentage of architects and engineers mentioning each response. Approximately half of all respondents mention the owner as the primary decision-maker. This result is not surprising since the owner is the individual who must fund such choices. More than 30% of architects believe they are the primary decision-maker while nearly 30% of engineers believe that the mechanical engineer is the decision-maker.

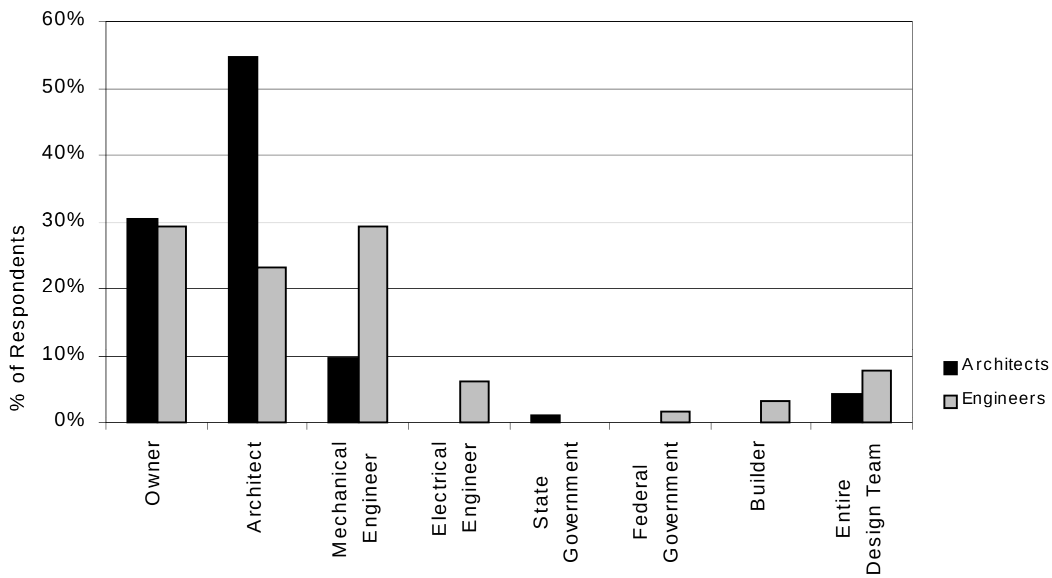

Figure 49: Primary Responsibility for Designing Energy Efficiency into Buildings

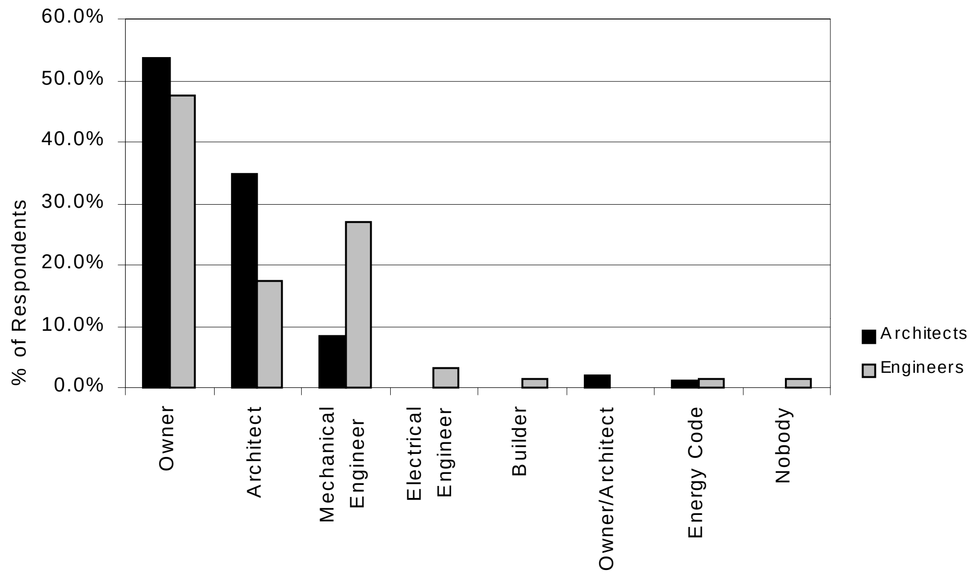

Figure 50: Primary Decision-Maker about Energy Efficiency Choices

Title 24 Requirements

All designers were asked a series of questions designed to determine what percentage of non-residential new buildings do not meet Title 24 requirements, the primary reason for the existence of new buildings which do not comply with Title 24, and whether standard design practices are driven by code or vice versa.

All designers were asked to rate their familiarity with Title 24 requirements using a scale of 1 to 4, where 1 means not at all familiar and 4 means very familiar. Along with the numerical scale, descriptions of each familiarity level were provided. Respondents who are very familiar prepare Title 24 documentation, while those who are somewhat familiar review Title 24 documentation prepared by others. A respondent who is not very familiar with Title 24 requirements know that compliance is required, but they do not prepare or review any Title 24 documentation. Those who are not at all familiar do not know what Title 24 is. Along with each numerical rating, a statement describing that level of familiarity was provided. Figure 51 displays the percentage of respondents who mention each response among architects and engineers, while Figure 52 displays this same information among those who work primarily in each sector. Architects are significantly less familiar with Title 24 requirements than are engineers. Those who are primarily involved with private sector, owner-occupied projects appear to be slightly more familiar with Title 24 than are respondents who are primarily involved with other sectors, although this result is not statistically significant.

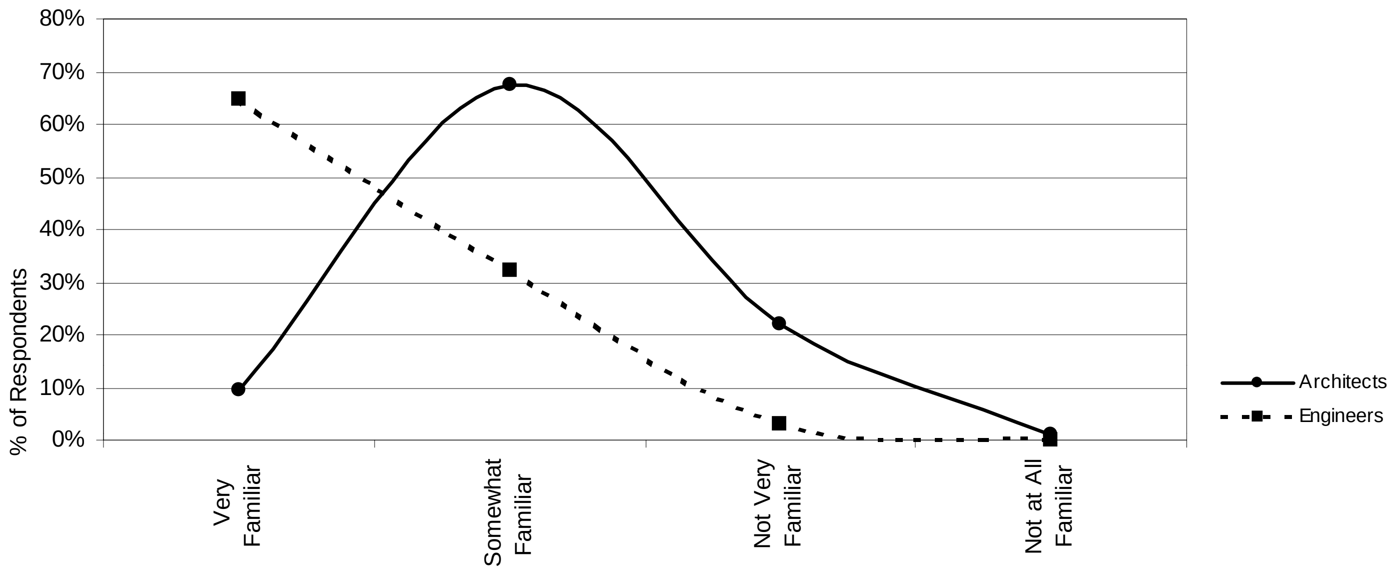

Figure 51: Familiarity with Title 24 Requirements

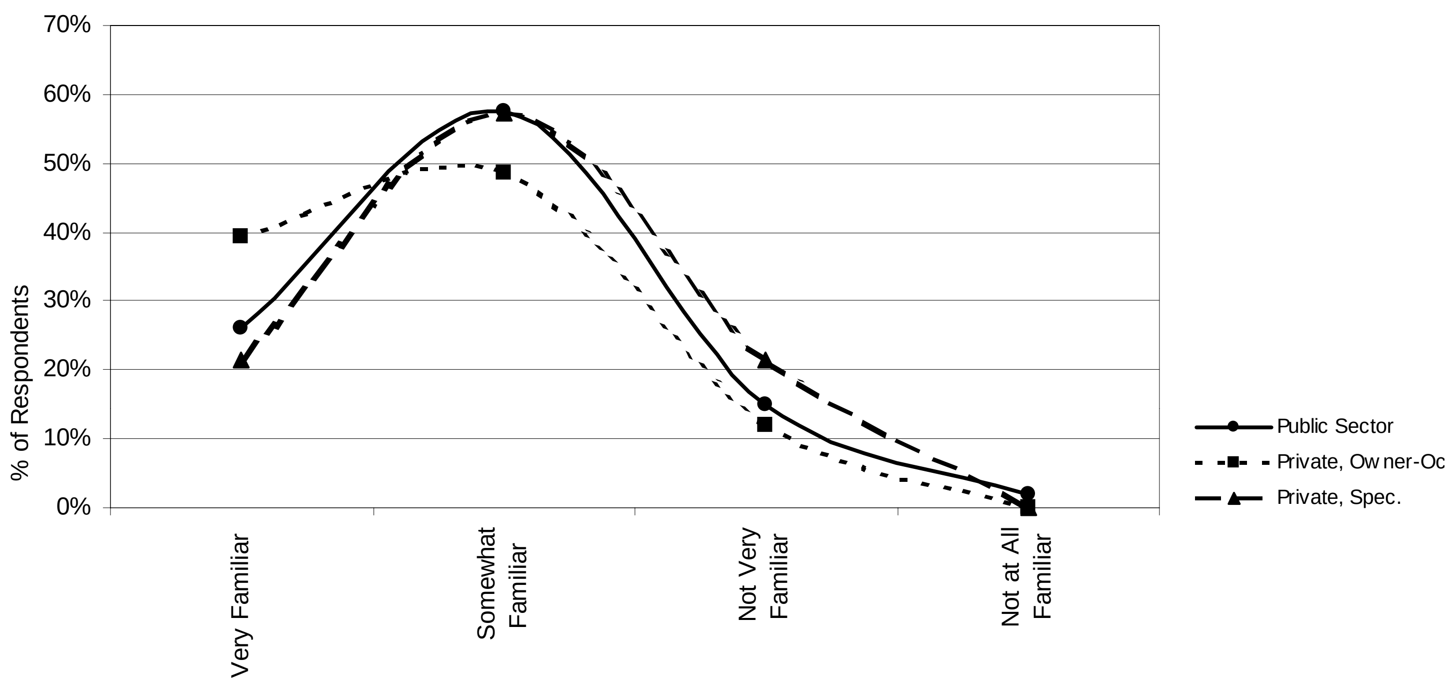

Figure 52: Familiarity with Title 24 Requirements Among Those who Work Primarily in Each Sector

Next, all designers were asked what percentage of non-residential new buildings they believed did not meet Title 24 requirements. This question was designed to ask respondents about the non-residential new construction market in general rather than buildings they personally worked on, as it was believed more meaningful results would be obtained in this fashion. Figure 53 displays distribution of the percentage of non-residential new buildings believed to not meet Title 24 requirements among all respondents and Figure 54 displays the same information by level of familiarity with Title 24 requirements. The majority of respondents believe that between 0% and 20% of non-residential new buildings do not meet Title 24 requirements. Those who were least familiar with Title 24 believe that a higher percentage of buildings fail to comply than do those who are more familiar with Title 24 requirements. Many respondents commented that they had no personal knowledge of buildings that did not comply with Title 24 requirements.

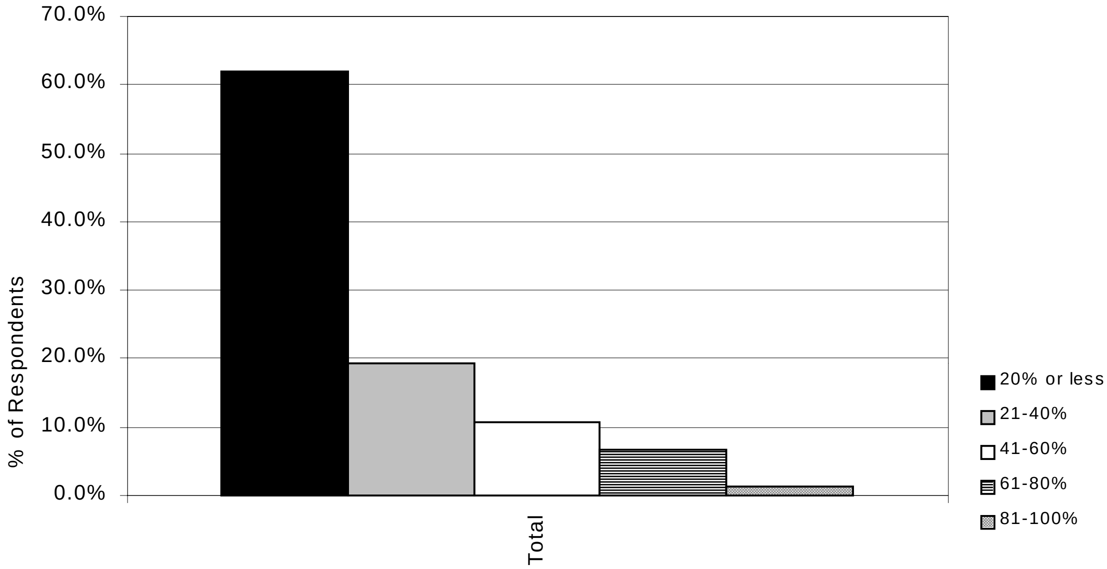

Figure 53: Percentage of Non-residential New Buildings which Respondents Believe Do Not Meet Title 24 Requirements

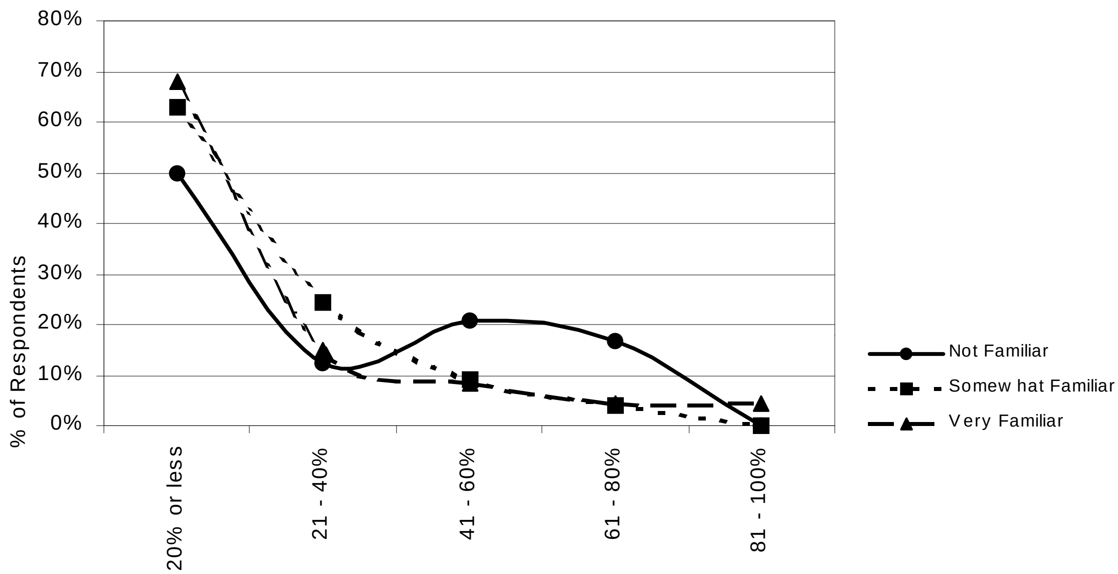

Figure 54: Percentage of Non-residential New Buildings Believed Not To Meet Title 24 By Level of Familiarity With Title 24

Then, respondents were provided a list of possible explanations and asked to indicate the primary reason for the existence of new buildings that did not comply with Title 24 requirements. Figure 55 displays the percentage of respondents mentioning each reason among architects and engineers, while Figure 56 displays the same information by level of familiarity with Title 24. The most common response among all designers is cost cutting after the initial equipment specification. Note that more than 30% of engineers believe that the primary reason for Title 24 non-compliant buildings is inconsistent Title 24 enforcement. Those who are least familiar with Title 24 are the most likely to mention inconsistent Title 24 enforcement. Designers who are very familiar with Title 24 mention inconsistent Title 24 enforcement, equipment and materials changes by the building owner, and cost-cutting after the initial equipment specification equally often. Thus, among those most familiar with Tile 24, there is no primary reason for non-compliant buildings.

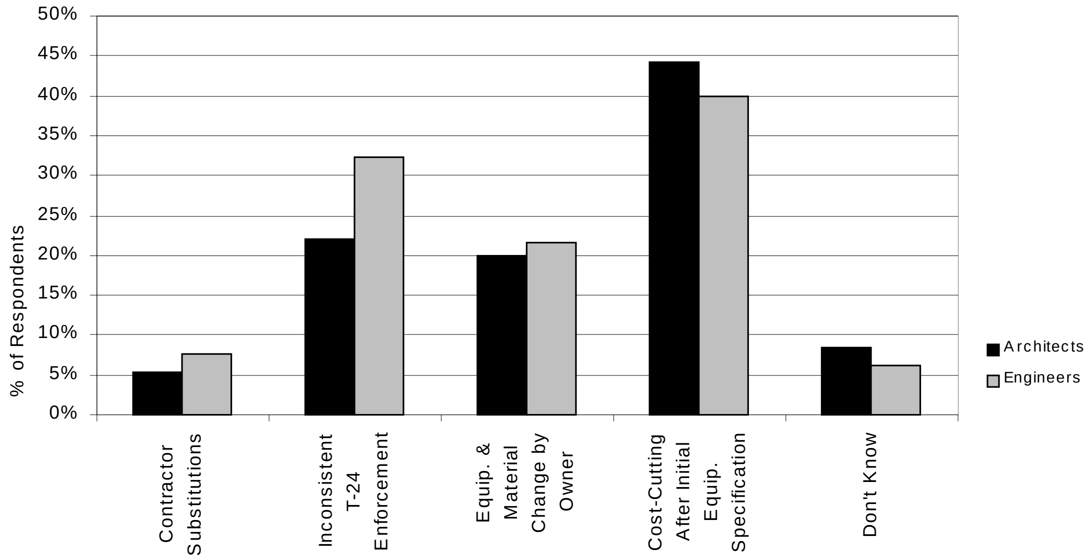

Figure 55: Primary Reason for Existence of New Buildings that Do Not Comply with Title 24 Requirements

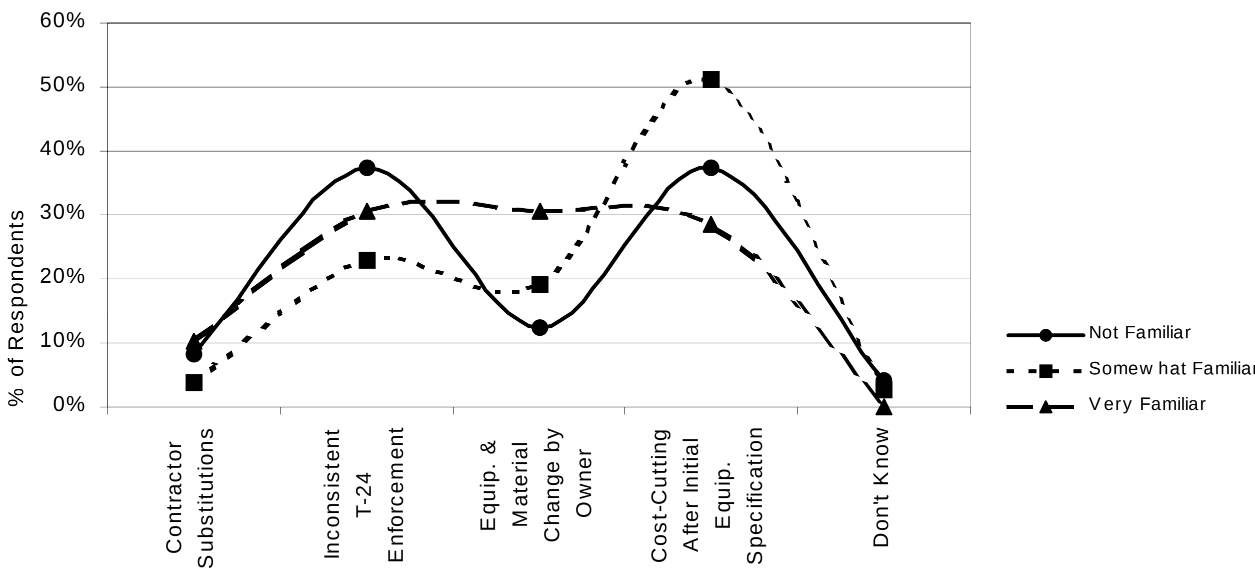

Figure 56: Primary Reason for Existence of New Buildings that Do Not Comply with Title 24 Requirements By Level of Familiarity With Title 24

All interviewees were asked if they believed standard design practice with regard to energy efficiency is driven by energy code changes or if energy code changes are driven by standard practice. Over 85% of all respondents reply that energy code changes drive standard practice.

Market Barriers

There are many motivations for NRNC projects to pursue energy efficiency designs. However, there are also many market barriers to pursuing efficient design. Two things are clear:

A rational building owner should seek to maximize his or her economic benefit from their investment in a building.

Systems are available in the marketplace that will reduce building operating costs.

The question becomes: What market barriers exist that prevent the rational building owner from purchasing the available technologies that will increase their economic benefit?

All quantitative survey respondents were asked to rate their level of agreement with two statements describing each potential barrier, using a scale of 1 to 5, where 1 means completely disagree and 5 means completely agree. Refer to the Appendix for a definition of each potential barrier along with the statements used to describe it. To determine which of the potential barriers are most prevalent in the non-residential new construction market, responses to both statements describing the barrier were summed together, and then, the mean level of agreement with each barrier was computed.

The following scheme for determining the primary barriers was derived based the mean levels of agreement with the various barriers. A mean rating for a given barrier of less than 3 indicates that designers do not perceive it as a barrier to more efficient design. A mean level of agreement of 3 to 3.5 indicates that designers perceive that potential barrier as a weak barrier, while a mean level of agreement of 3.5 or more indicates that designers perceive it as a strong barrier to energy efficient design.

Figure 57 presents the mean levels of agreement for each barrier among architects and engineers. Architects and engineers agree that the strongest barriers to efficient design in the non-residential new construction market are organizational practices, split incentives, and performance uncertainties. Both architects and engineers perceive non-externality mispricing, hidden costs, and bounded rationality as weak barriers to more efficient design. Note that architects also perceive access to financing and asymmetric information as weak barriers in the marketplace, while engineers also perceive externalities as a weak barrier.

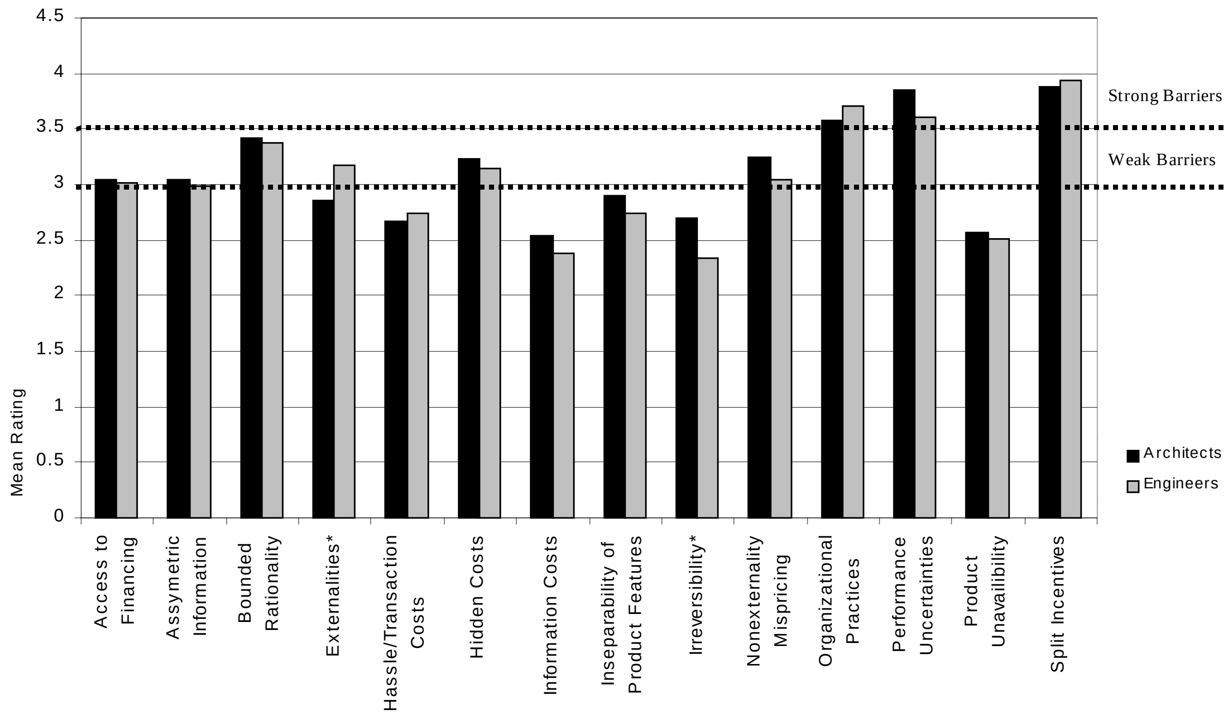

Figure 57: Mean Levels of Agreement with Barrier Statements Among Architects and Engineers[9]

Figure 58 displays the mean levels of agreement with each barrier among those who work primarily in each sector. Respondents from all sectors perceive organizational practices, performance uncertainties, and split incentives as the primary barriers to more efficient design practice. Those who work primarily in the private sector also perceive bounded rationality as a primary barrier to energy efficiency. Respondents from all sectors perceive hidden costs and non-externality mispricing as weak barriers to efficient design practices. Respondents who work primarily in the public sector or on private sector, speculative market projects also perceive access to financing as a weak barrier. Those who work primarily on private sector, owner-occupied projects perceive asymmetric information as a weak barrier to energy efficient design. The mean level of agreement among designers who work primarily in the public sector is consistently lower than the rating among those who work primarily in the private sector. Also, respondents who work primarily in the public sector do not perceive information costs, irreversibility, or product unavailability as barriers to more efficient design practices, as their mean ratings for these barriers are less than 2.5.

[9] An asterisk next to the barrier name indicates that the difference between architects and engineers is statistically significant.

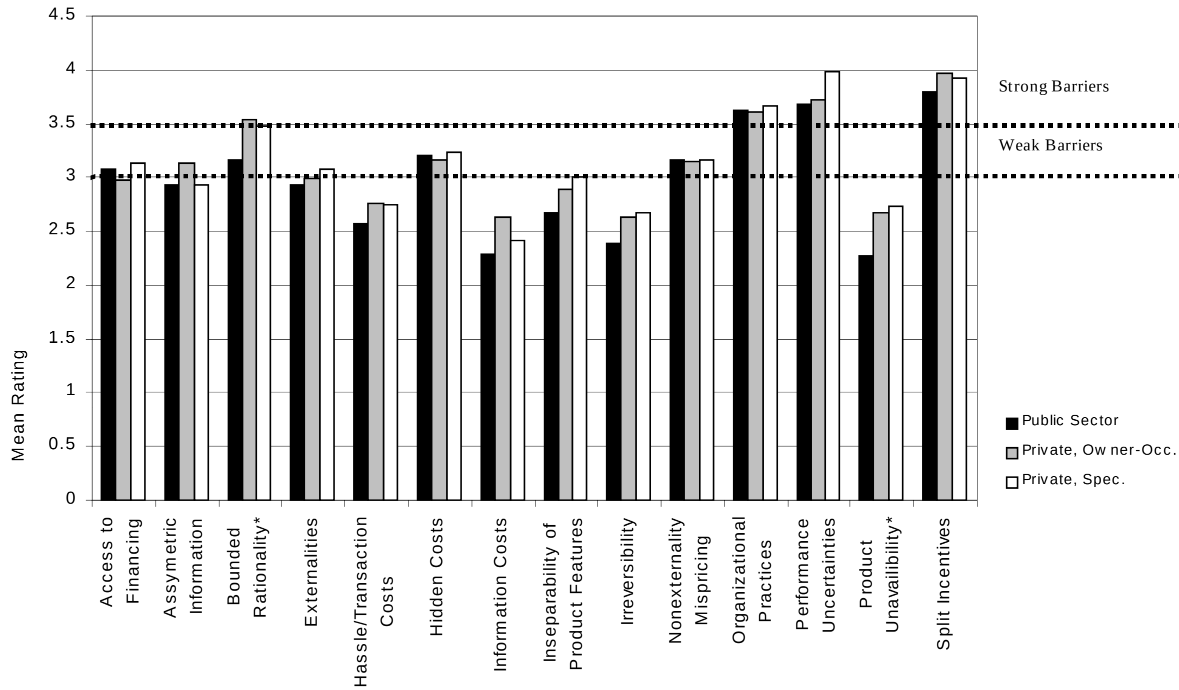

Figure 58: Mean Levels of Agreement with Barrier Statement Among Those who Work Primarily in Each Sector[10]

[10] An asterisk next to the barrier name indicates that the difference between architects and engineers is statistically significant.

5. The Buildings

In this chapter, we will look at the energy efficiency of actual buildings. We will seek to answer the following questions:

- What is the energy efficiency in the various market segments?
- How has the market evolved over time?
- What are the differences in efficiency between public and private buildings?
- What are the differences in efficiency between owner-occupied and speculative buildings?
- What has been the impact of past utility-sponsored programs?
- Where are the unrealized efficiency gains in each segment of the market?
- What is the current baseline for non-residential new construction practice?

Ultimately, of course, the energy efficiency of buildings is determined by their physical characteristics. Knowledge about physical characteristics is essential for strengthening energy codes and developing design guidelines. Once we have looked at efficiency, we will turn to the underlying physical characteristics. We will summarize the most relevant physical characteristics and we will compare some of them to our baseline.

Overview of Findings

Because of the length and complexity of this chapter, we will provide a brief preview of the principle findings.

- The energy-efficiency programs of the utilities have had relatively low penetration in the nonresidential new construction market. Our data indicate that about 15% of the new construction projects in our four building types participated in these programs.
- The energy efficiency of buildings has generally been stable over the years we are studying. However, there has been an improvement in cooling efficiency.
- In our segments, 75% to 90% of all new building exceed Title 24 requirements. Schools exceed the requirements by the widest margin.
- Over 10% of schools and 2-3% of other buildings are using about half of the energy they would be using if they were built exactly to Title 24 requirements. 20% to 40% of the buildings are using about 70% of the energy they would be using if they were built exactly to Title 24 requirements.
- On average, public sector buildings are more efficient relative to Title 24 than private owner-occupied buildings; these in turn are more efficient than speculative buildings. But the distribution of energy efficiency is very similar. In other words, there is much more variation within these sectors than between the sectors.
- Lighting directly accounts for about three-fourths of the savings relative to Title 24. There is evidence that the interactive effects of lighting on cooling and fan loads accounts for much of the added savings. In other words, the

buildings that have lighting power densities substantially below Title 24 requirements seem to be the same buildings that are much more energy efficient than our Title 24 baseline.

- Perhaps because of the interactive effects of lighting, most building are using less energy for cooling than they would be if they had been built exactly to Title 24 requirements.
- About 70% of the buildings have cooling systems that seem to be appropriately sized.
- Cooling systems seem to have grown more efficient over this period, for a variety of reasons.

Methodology

In this section we will lay the foundation for the analysis used throughout this chapter. We will discuss:

- The use of energy simulation to control for differences between buildings
- Our target population and the sample data
- The use of the borrowed data
- The penetration of the utility's energy efficiency programs and the validity of pooling sample data including both participants and nonparticipants
- Trends in energy efficiency over the period of our data and the implications for pooling the data from the prior samples with the most recent sample
- A summary of the subsamples chosen for each type of analysis

Energy Simulations

In order to examine the energy efficiency an individual building or a set of buildings, we will compare (a) the <u>as-built</u> energy consumption of the building or buildings and (b) the <u>baseline</u> energy consumption of the same building or buildings. The baseline energy consumption for each building is defined to be the energy consumption of the building as if all of the equipment was specified to be minimally compliant with Title 24 and the building was operated on the schedule found during the on-site survey.[11]

Consider a modern office building. To understand its energy efficiency, we need to consider the level of lighting, how the waste heat from the lighting fixtures is removed, how the windows are orientated, the reflection and convection of the glazing, the type, size and efficiency of the air conditioning, etc. Moreover we have to think of the building as a system of zones - each with their own characteristics and subsystems, each interacting with one another.

11 This comparison is not an appropriate way to determine the degree of compliance of specific buildings with Title 24. Our analysis uses actual schedules rather than the default Title 24 operating schedules. And our simulations use the area category method for each building regardless of the Title 24 compliance path actually elected Nevertheless, the baseline does provide a general indication of the relative efficiency of buildings in specific NRNC market segments. Since our comparisons are all based on ratios, we feel it is appropriate to draw general conclusions about the energy efficiency of groups of buildings.

With energy simulation we can represent all of these systems and subsystems and combine their individual efficiencies and interactions to determine the efficiency of the building as a whole. The whole-building efficiency is measured by comparing the simulated annual energy of the office as we have found it to what the annual energy would have been if it had been built according to the Title 24 specifications. In effect, we have reduced the complex building down to two numbers – the as-built energy and the baseline energy.

Now suppose we want to describe the energy efficiency in the office market segment. The office segment contains a wide variety of buildings ranging from glass and steel skyscrapers to one-story wood frame buildings. It is not very meaningful to discuss the average roof U-value or the average EER of the air conditioning across the office market segment. In fact it is virtually impossible to summarize the relevant characteristics of these diverse buildings in a meaningful way.

Fortunately, through simulation, we can define the collective efficiency of the buildings in the office market very simply – by comparing the following two quantities:[12]

- The total simulated annual energy of the buildings in the office market segment as they have been built, and
- The total simulated annual energy of the buildings in the office market segment if they had been built to the baseline conditions.

Suppose, for example, that the as-built electricity use is found to be 90 million kWh per year and the baseline use is found to be 100 million kWh per year. Then we say that the energy ratio is 0.90 in this market segment, or equivalently, that this collection of buildings is 10% more efficient than the baseline.

With this approach, we can compare the energy efficiency of one market segment to another, even though it contains vastly different buildings. For example we can compare the energy efficiency of the office segment with the public assembly segment which includes theaters and museums. Moreover we can compare buildings in the public sector – e.g., city halls, fire stations and schools – with buildings in the private sector – offices and retail.

This approach offers several key advantages. It helps us:

- Systematically record the relevant physical characteristics of a specific building
- Look at the physical characteristics of the building as a system
- Consider the often complex interactions between the many elements of the building
- Reduce the diverse physical characteristics down to a few meaningful numbers, e.g., the simulated annual energy consumption of the building
- Combine information across different buildings by comparing each individual building to a fixed, common baseline

[12] Of course we can't simulate the total energy for all buildings in the market, but we can estimate the total from a statistical sample of buildings.

- Make meaningfully comparisons between various market segments despite the differences in the types of buildings in the segments.

Population Characteristics and Sample Sizes

The target population of this study is new construction in California in the office, retail, schools and public assembly sectors during the period 1994 through 1998. We defined the population using a listing of new construction projects obtained from F. W. Dodge. The database seeks to list all new construction projects that are valued over $200,000 and are expected to start within 60 days. The data include renovations and expansions as well as entirely new buildings.[13]

Table 7 shows that the population contains almost 400 million square feet of construction in almost 14,000 projects. These projects are estimated to use a total of 6,295,012,727 MWh of electricity per year. As expected, the office and retail sectors are much larger than the school and public assemply sectors.

As shown in Table 7, our sample consists of 667 new construction projects. 148 of these sites were 1998 projects audited specifically for the present study. To expand the database, we borrowed 519 audits from the following four prior studies:

- 1994 SCE and PGE joint NRNC program evaluation
- 1995 SDGE NRNC program evaluation
- 1996 SCE NRNC program evaluation
- 1996 PGE NRNC program evaluation

All of the samples were stratified by building type. The program evaluation samples were stratified to provide a representative sample of program participants and a sample of nonparticipants matching the participants in terms of square footage and building type. In preparing the data for our analysis, we have created new case weights to properly project the sample sites up to our target population. These case weights adjust for differences between our sample and the population in terms of program participation, building type and square footage. For example, the case weights adjust for the fact that schools represent 25% of the sample projects but only 16% of the projects in the population.

	Office	Public Assembly	Retail	School	Total
Number in Population	6,259	1,567	3,690	2,179	13,697
Percentage of Total Population	46%	11%	27%	16%	
Total Floor Area (SF, in thousands)	184,192	27,422	132,543	54,889	399,046
Percentage of Total Floor Area	46%	7%	33%	14%	
Total Energy (mWh)	2,847,697	401,301	2,562,884	483,131	6,295,012,727
Percentage of Total Energy	45%	6%	41%	8%	
Sample Size	231	105	162	169	667
Percentage of Sample	35%	16%	24%	25%	

Table 7: Population Characteristics by Building Type

[13] The data is thought to cover over 95% of all projects that are competitively bid.

Ownership Sectors

One of our goals is to compare the characteristics of buildings in three ownership sectors – public, owner occupied, and speculative. Table 8 shows the corresponding population characteristics and sample sizes.[14] The owner occupied sector accounts for 45% of the projects, 52% of the floor area, and 60% of the energy use. The public and speculative sectors are about equal.

	Public	Owner Occupied	Speculative
Number in Population	3,811	5,564	3,056
Percentage of Total Population	31%	45%	25%
Total Floor Area (SF)	88,731,001	194,626,132	87,373,506
Percentage of Total Floor Area	24%	52%	24%
Total Energy (kWh)	1,038,851,362	3,506,916,795	1,263,886,014
Percentage of Total Energy	18%	60%	22%
Sample Size	217	299	124
Percentage of Sample	34%	47%	19%

Table 8: Population Characteristics by Owner

Use of Borrowed Data

As indicated above, our sample consists of new data and data borrowed from four prior evaluation studies of energy efficiency programs serving the new construction market.

We had several concerns about combining these samples. We considered:

- The appropriateness of combining samples collected over a several year period, especially if there are significant changes in the market over the period,
- The practice in the secondary studies of using separate sample designs for program participants and nonparticipants, thereby over-representing the participants and potentially providing a distorted picture of the general population,
- The practice in the secondary studies of matching the sample of nonparticipants to the sample of program participants, possibly providing a biased sample of the building types occurring in the NRNC market, and
- The difference in the building types represented in the secondary samples and the primary sample.
- The desire to describe the baseline status of the NRNC market both with and without the energy efficiency programs offered by the utilities.

In carrying out our analysis, we have sought to take full advantage of these extensive data while minimizing bias arising from the use of data collected in past project with different

[14] We did not know the ownership type for 30 sites from the 1995 San Diego evaluation so these 30 sites were excluded from the sample. The population was adjusted accordingly.

objectives. Fortunately, the studies had much in common. The same principle contractors carried out most of these studies. Although there was gradual improvement in tools and techniques, the sampling and auditing methods were generally consistent across almost all of the studies.[15] Moreover we have been able to run new DOE-2 as-built and baseline simulations for all of the sites using the current modeling software.

However, there were some significant differences between the new audits and the prior studies. In the current sample, we excluded participants in utility energy-efficiency programs to the extent possible. By contrast, the prior samples included both participants and nonparticipants in about equal numbers. Moreover, the current sample was restricted to four building types – office, retail, schools and public assembly – in order to stretch our limited resources. In the prior studies, the nonparticipant samples were designed to match the types of buildings found among the program participants. So the borrowed data represent almost all building types whereas our new audits tend to give us greater depth in the four selected building types

We have taken several steps to minimize bias arising from the use of the combined data. We assembled all of these data into a consistent integrated database describing almost 1,000 buildings. We calculated new weights by building type and size for both the participants and nonparticipant buildings in the prior samples. The new weights reflect the NRNC population in each year and the saturation of program participants in the population of NRNC projects. This should go far to reduce any bias due to the original sample designs.

We have also tried to select the most appropriate subsets of the data for the various comparisons. For example we restricted the comparisons of participants and nonparticipants to the 1994 and 1996 data since participants were excluded from the 1998 sample. Similarly in looking for trends between the 1994, 1996 and 1998 studies, we restricted the analysis to nonparticipants in the four building types targeted in the 1998 sample. We have also been cautious to combine the data from different years only to the extent that it is justified. These issues will be addressed in more detail in the subsequent sections.

Program Penetration

In much of the work to follow, we will include both program participants and nonparticipants in the analysis. We feel this is appropriate because:

- Program participants represent only about 8% of the buildings and 15% of the floor space and energy usage in the population, and
- Program participants are only slightly more efficient than nonparticipants.

This section will provide more detailed information.

---

[15] All of these studies with the exception of the SDG&E impact evaluation were carried out by RLW Analytics and Architectural Engineering Corporation. About 30 of the audits were borrowed from the 1995 SDG&E impact evaluation which was carried out by Regional Economic Research, Inc. Aspen was the auditing subcontractor for the 1994 study and used somewhat different auditing procedures than the subsequent studies.

As previously noted, in the 1994 and 1996 NRNC impact studies the sample was designed to capture an approximately equal number of participant and nonparticipant buildings. The actual population of buildings contains a much smaller percentage of participants. However, the weights were calculated to adjust for the overrepresentation of participants in the sample. Therefore, when the participants and nonparticipant s are combined in the analysis, the weights accurately represent the number of buildings in the Dodge population for each given year. A thorough description of this weighting procedure is contained in the appendix to this report.

Table 9 shows the population characteristics by program participation.[16] The table contains the estimated number of sites in the population, [17] the total floor area, and the total energy. All of these results have been obtained by using the case weights to extrapolate the sample to the population. Table 9 shows that the participants make up 8% of the total number of buildings in the population, and about 15% of the floor space and energy usage in the population. In other words, program participants are a small proportion of the population.

The table also shows the number of sites in the sample. As expected the participants comprise about one-half of the 1994 and 1996 samples. The estimated percentage of participants in the population is approximately 8 percent, while the percentage of participants in the sample was approximately 49 percent. These numbers show that the weights do indeed adjust for the overrepresentation of the participants in the population.

	Participant	**Non-Participant**
Number in Population	806	9,858
Percentage of Total Population	8%	92%
Total Floor Area (SF)	50,486,818	290,532,418
Percentage of Total Floor Area	15%	85%
Total Energy (kWh)	833,240,992	4,559,116,932
Percentage of Total Energy	15%	85%
Sample Size	242	250
Percentage of Sample	49%	51%

Table 9: Population Characteristics by Participation

Table 10 looks at participants and nonparticipants within each of the four building types. The number of participants in the sample is much lower than the number of participants in the population. Again this shows that the prior impact evaluation samples were deliberately balanced by participant status, and the weights adjusted for this overrepresentation. The highest program penetration is in the public assembly sector, where the participants comprise 22% of the population and use 25% of the energy.

[16] The analysis is restricted to offices, retail, schools and public assembly. Other building types in the 1994-96 samples are excluded.

[17] This is estimated as the sum of the case weights for the sample sites from the 1994 and 1996 samples. The 1998 sample was excluded since it was restricted to nonparticipants.

	Office		Public Assembly		Retail		School	
	Participant	Non-Participant	Participant	Non-Participant	Participant	Non-Participant	Participant	Non-Participant
Number in Population	287	4,766	222	805	136	2,617	161	1,669
Percentage of Total	6%	94%	22%	78%	5%	95%	9%	91%
Total Floor Area (SF)	17,606,788	129,269,893	4,339,542	13,787,772	9,189,606	99,157,286	4,534,320	34,819,041
Total Floor Area	12%	88%	24%	76%	8%	92%	12%	88%
Total Energy (kWh)	267,478,766	1,975,135,508	54,216,449	165,982,383	257,524,311	1,853,732,957	42,683,940	290,245,053
Percentage of Total Energy	12%	88%	25%	75%	12%	88%	13%	87%
Sample Size	90	90	35	23	53	64	64	73
Percentage of Sample	50%	50%	60%	40%	45%	55%	47%	53%

Table 10: Population Characteristics by Participation and Building Type

Figure 59 shows the overall energy ratios by program participation for the whole building, lighting, cooling, and fans. We found small but consistent differences between the energy ratios for the program participants compared to the nonparticipants. Figure 59 shows that, as a whole, the nonparticipants have about 11% less energy use than baseline, whereas the participants have about 17% less energy use than baseline. So relative to baseline, the participants use about 6% less energy than the nonparticipants. The largest average difference between participants and nonparticipants is in cooling, but the difference was still only 10%.

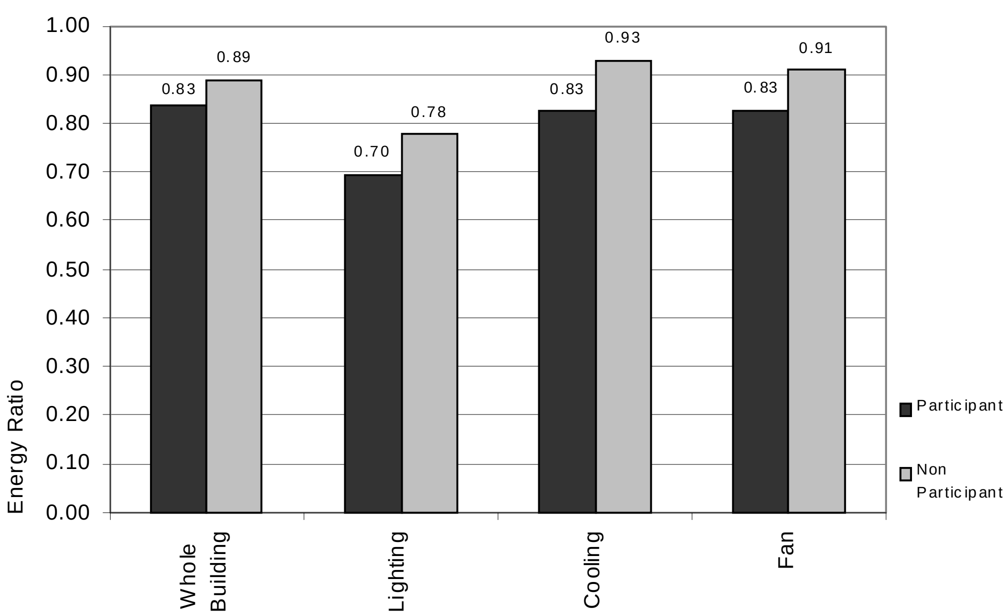

Figure 59: Overall Energy Ratio by Utility Program Participation

The points below summarize the preceding discussion:

- The weights adjust for the overrepresentation of participants in the sample;
- Participants, on average, make up less than 10% of the targeted building population in 1994 and 1996;
- Only relatively small differences exist between participant and nonparticipant energy ratios for all end uses.

Therefore, it was decided that it would be appropriate to pool the sample of participants and nonparticipants for the analyses. Given the relatively small program penetration and the relatively small difference between program participants and nonparticipants, we believe similar results would be obtained if we had chosen to delete the participants from our analysis.

Trends Over Time

To the extent possible we want to utilize data from all years. In this section we will show that there has been little change in energy efficiency over the time spanned by our sample data. The exception is in the cooling end use, where we see a trend to increased efficiency. In the case of cooling we will limit our analysis to the 1998 sample, but otherwise we will use data from 1994, 1996 and 1998.

Another issue in drawing comparisons over time is that only nonparticipant buildings were sampled in 1998. So in order to maintain a consistent sample across the years, the program participants from the 1994 and 1996 samples were eliminated from the time trend analyses.

Figure 60 shows the overall ratio by year for the whole building and major end uses. A trend is readily apparent in cooling. The energy ratio for cooling has significantly decreased from 1994 to 1996, and also from 1996 to 1998. Since the intent of this study was to determine the current baseline for new construction practices, it was decided that data should not be included in the analyses if it was no longer applicable to current practice. In the case of cooling, the samples across the years were found to be fundamentally different. Therefore the cooling data was not pooled across years.

Figure 60 shows no trend in the whole building, lighting, or fan energy ratio. Therefore, with the exception of cooling, the data from all three years will be pooled to form the largest possible sample.

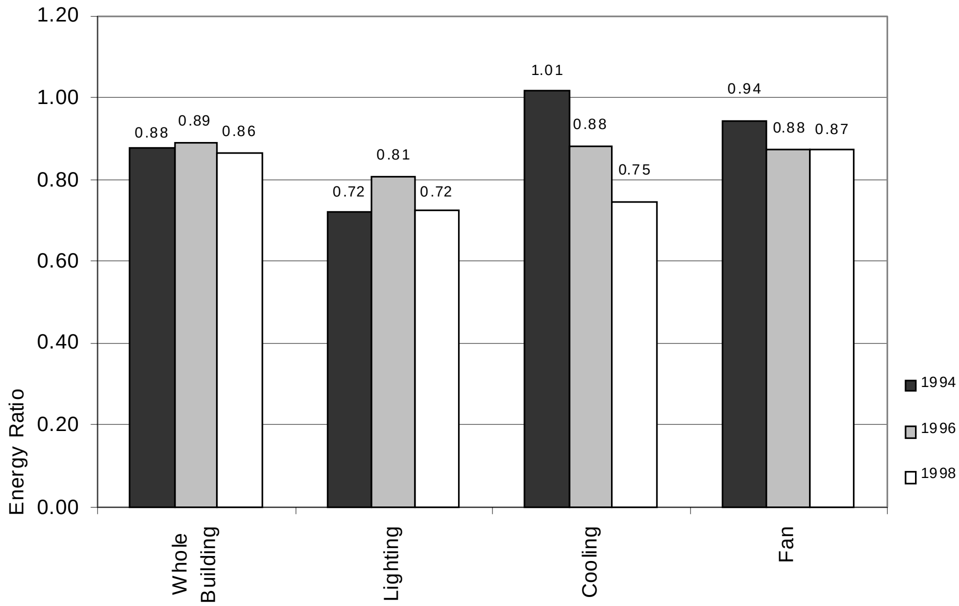

Figure 60: Overall Energy Ratio by Year

Subsample Used in Each Type of Analysis

As indicated in the prior discussion, we have sought to carefully choose the part of our sample used in each type of analysis. The following table summarizes our approach. For the analysis of energy efficiency by building type, we have used all 667 sample points. When we compare ownership sectors – public, private owner occupied, and speculative – we have dropped the sample sites from the 1995 SDG&E impact evaluation because we do not know the ownership status of these sites.

In comparing participants to nonparticipants, we have dropped the 1998 sample since it was restricted to nonparticipants. In looking at time trends, we excluded the program participants because we wanted to compare the 1994, 1996 and 1998 data. We dropped the 1995 SDG&E sites from the time comparisons because that part of the sample was small and was out of phase with the rest of the sample. Finally, when we analyzed cooling results by building type and ownership, we restricted the analysis to the 1998 sample because of the trend in cooling efficiency.

	1994		1995		1996		1998	
Type of Analysis:	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Total Number in Sample**
Building Type	130	124	17	10	112	126	148	667
Ownership Type	130	124	0	0	112	126	148	640
Participant vs. Non-Participant	130	124	17	10	112	126	0	519
Time Trends	0	124	0	0	0	126	148	398

End Use Energy Efficiency

With the proceeding groundwork, we can begin to analyze the sample data. This section starts by describing the average energy efficiency of buildings in the NRNC market, in total and by end use. To simplify this initial analysis, we will consider all four building types taken together. We will show that about three-fourths of the savings are due directly to lighting, and the remaining savings are about equally divided between cooling and fans. Much of the cooling and fan savings appear to be due to the interactive effects of the lower lighting loads. Based on this background, subsequent sections will focus on these three end uses: lighting, cooling and fans.

Figure 61 shows the energy ratios for the total-building energy use and for all end uses. Figure 61 shows that at the whole building level, the average energy ratio is 0.88. In other words, taken together these buildings are consuming 12% less energy than they would have been had they been built to the baseline assumptions.

Figure 61 also shows the average overall energy ratio for each of the major end uses. The lighting results indicate that the buildings are consuming 24% less electricity than the baseline. Both cooling and fan[18] end uses are also below baseline. By contrast, the buildings are consuming twice as much electricity for heating as the baseline.[19]

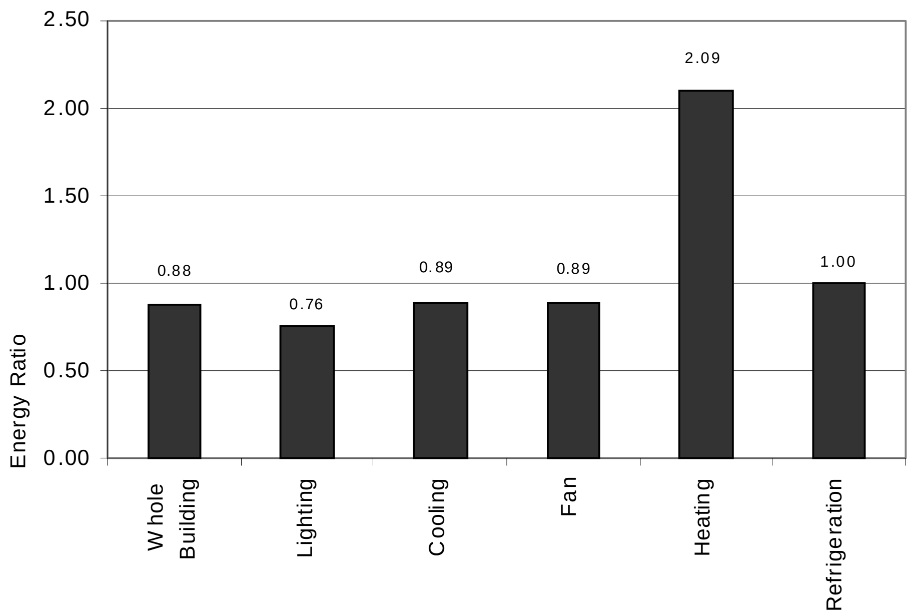

Figure 61: Average Overall Energy Ratio

Another way to look at this information is to consider the energy savings in each of the end uses as a percentage of the whole-building baseline electricity use. The energy savings have been calculated as (a) / (b) where:

[18] We use the term fans to refer to ventilation systems that supply and recycle air in building spaces.

[19] The heating end use in this report refers to electric heating only. Fuels other than electricity were not analyzed.

(a) is the baseline end-use energy use minus the as built end-use energy use, and

(b) is the baseline whole-building energy use.

Table 11 shows these results. The table shows that lighting represents 9.5% savings relative to baseline. Cooling and fans each account for 1.7% and 1.8% savings respectively. Table 11 shows that the increase in energy used for heating is only 0.7% of the whole-building baseline use.

The data shown are the results of "whole-building" simulations, which account for the interactive effects of changes in building characteristics across all affected end-uses. For example, buildings with lighting energy ratios less than one will also show cooling energy ratios less than one, even if the cooling system efficiency characteristics remain unchanged. Reductions in lighting energy results in reduced lighting heat gain to the building, thus reducing the cooling energy required to remove this heat. Similarly, the heating energy will increase in response to decreased lighting loads.

Between the as-built and baseline simulation runs, the cooling system capacity is adjusted in response to changes in all building characteristics that affect cooling system size, such as lighting loads and glazing characteristics. Similarly, the fan system size is adjusted in response to the change in the cooling system size, since smaller cooling systems require smaller fans. Reductions in cooling and fan system size result in reduced cooling and fan energy, even if the efficiency characteristics of these systems are unchanged. The simulation models suggest that much of the cooling and fan savings are, in fact, due to the interactive effects of reduced lighting loads.[20]

Figure 62 illustrates the end use savings as a percentage of total savings. About 73% of the total savings below the baseline is in the lighting end use. The remaining savings are in fans and cooling due to the indirect impact of reduced lighting loads.

We will focus the remainder of the analysis on the whole-building energy and these three end uses. The results will be presented at the whole building level, and then broken down into the three end uses.

End Use	Savings as a % of Whole Building Baseline kWh
Heating	-0.7%
Cooling	1.7%
Lighting	9.5%
Fan	1.8%
Whole Building	12.2%

Table 11: Percentage of Energy Savings by End Use

[20] Parametric runs are needed to isolate interactive effects. This type of simulation had been done for the 1994 and 1996 impact evaluation studies but was not done for the new 1998 sample sites. Therefore we did not isolate interactive effects systematically.

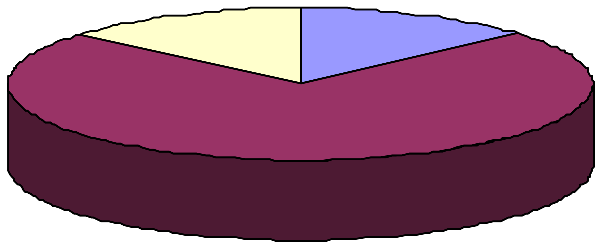

Figure 62: Energy Savings by End Use

Participant vs. Nonparticipant

The primary objectives of utility program offerings in the non-residential new construction arena have been to achieve increased levels of energy efficiency in new buildings. The programs' main methods have been to provide:

- Information to design professionals
- Financial incentives to building owners.

The primary feature of the utility-sponsored programs has been to offer financial incentives for the installation of efficient equipment. These incentives have been calculated on both a prescriptive and overall performance basis. The prescriptive incentives essentially use a "price list" of rebates for the installation of equipment of a particular efficiency level. The performance-based incentives use building energy simulations to compare overall building performance to a baseline, usually a percentage below building code requirements.

There is strong evidence that the utility programs have increased the level of efficiency in the buildings that participated in the programs. There is also some evidence that suggests that these programs have had longer-term effects on design practice.[21] The following section on participant vs. nonparticipant efficiencies attempts to explore the differences that may exist between these buildings.

Figure 63 shows participant and nonparticipant energy ratios. The participants consume less energy relative to baseline than nonparticipants. Figure 63 shows that, as a whole, the nonparticipants have about 11% less energy use than baseline, whereas the participants have about 17% less energy use than baseline. So relative to baseline, the participants use about 6% less energy than the nonparticipants. However this should not be taken as an estimate of the net savings of the utility programs since it does not adjust for free ridership or spillover.

[21] The PY1996 NRNC impact evaluation studies for PG&E and SCE, prepared by RLW Analytics and AEC, present evidence and quantitative estimates of spillover in the NRNC market.

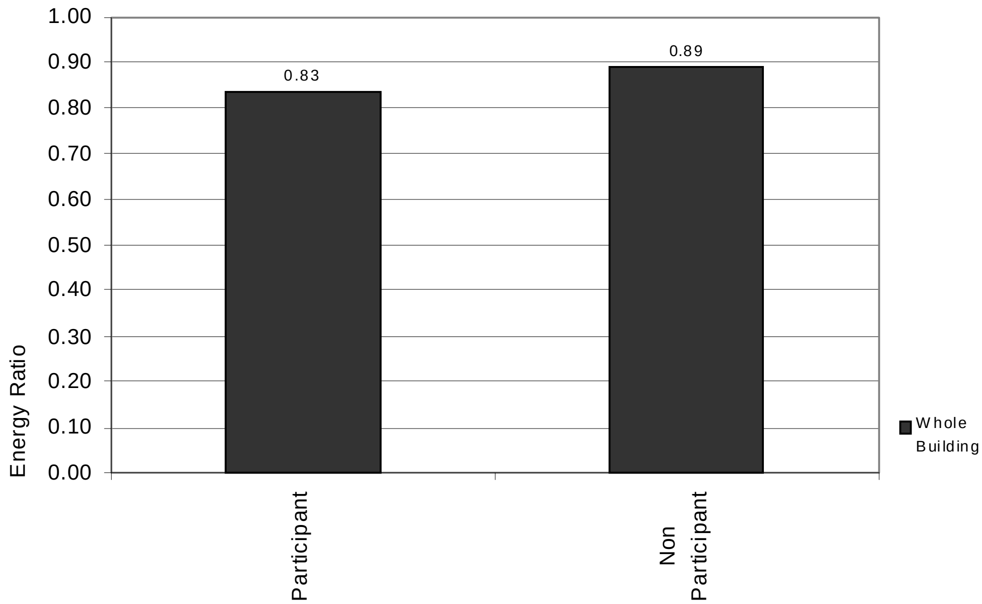

Figure 63: Average Whole Building Energy Ratio

Table 12 shows the sample size, the percentage of sites better than baseline, the average value of the energy ratio, and the error bounds associated with each value. A 90% confidence interval can be calculated by adding and subtracting the error bound from the average value. In the case of participants, for example, we can state with 90% certainty that on average, participants use between 0.81 and 0.85 as much energy as baseline. The table also indicates that more than 88% of participants have an energy ratio lower than baseline.

Program Participation	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Participant	259	88.3%	0.83	0.02
Non Participant	260	81.5%	0.89	0.02

Table 12: Whole Building Energy Ratio by Utility Program Participation

Figure 64 shows the distribution of the whole building energy ratio for individual buildings classified by program participation. This shows, for example, that about 8% of the participant buildings have an energy ratio of about 0.5. In other words, about 8% of the participant buildings use about 50% of the energy that they would have used if they had been built exactly to Title 24 requirements. By contrast, about 5% of the nonparticipant buildings used about 50% of the energy expected per the baseline. The main point is this: although participants as a whole were somewhat more efficient than nonparticipants, both participants and nonparticipants alike included energy-efficient buildings.

The construction of Figure 64 requires further explanation. The data show the estimated percentage of buildings in the population with energy ratio in each interval centered at the value labeled on the x-axis. For example, the percentages above the number 0.50 represent the fraction of buildings with an energy ratio between 0.40 and 0.60. Table 13 gives the interval associated with each value shown in Figure 64. So a more precise statement is that about 8% of the participant buildings used between 40% and 60% of the energy expected per the baseline. All of the graphs in this chapter use the same convention of using the midpoint of the relevant range as the label shown on the x-axis.

The dashed vertical line on the graph represents 1.00, or a building built exactly to baseline conditions. Those buildings to the left of the dashed line use less energy than baseline and those to the right use more energy than baseline.

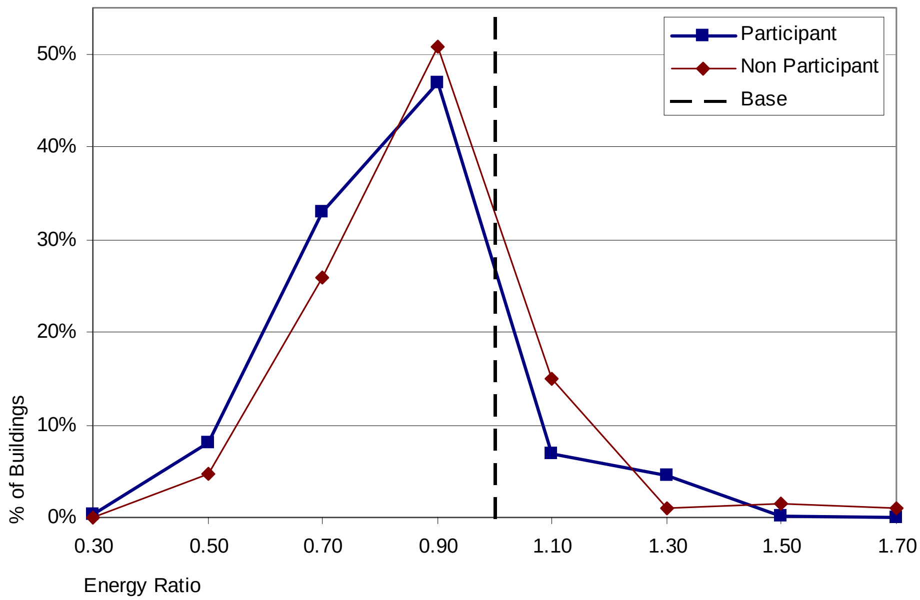

Figure 64: Whole Building Energy Ratio by Utility Program Participation[22]

Midpoint	Range of Values
0.30	0.20-0.40
0.50	0.40-0.60
0.70	0.60-0.80
0.90	0.80-1.00
1.10	1.00-1.20
1.30	1.20-1.40
1.50	1.40-1.60
1.70	1.60-1.80

Table 13: Intervals for the X-axis Values

[22] One site with a whole building energy ratio of 2.4 is not included in this graph.

Figure 65 shows the distribution of the EUI (Energy Use Intensity in kWh/sf/yr). The chart shows, for example, that about 27% of the participants and 25% of the nonparticipants have an EUI between 8 and 12 kWh/sf/yr. The main point of Figure 65 is that the EUIs are highly variable between buildings and are generally similar among both participants and nonparticipants.[23]

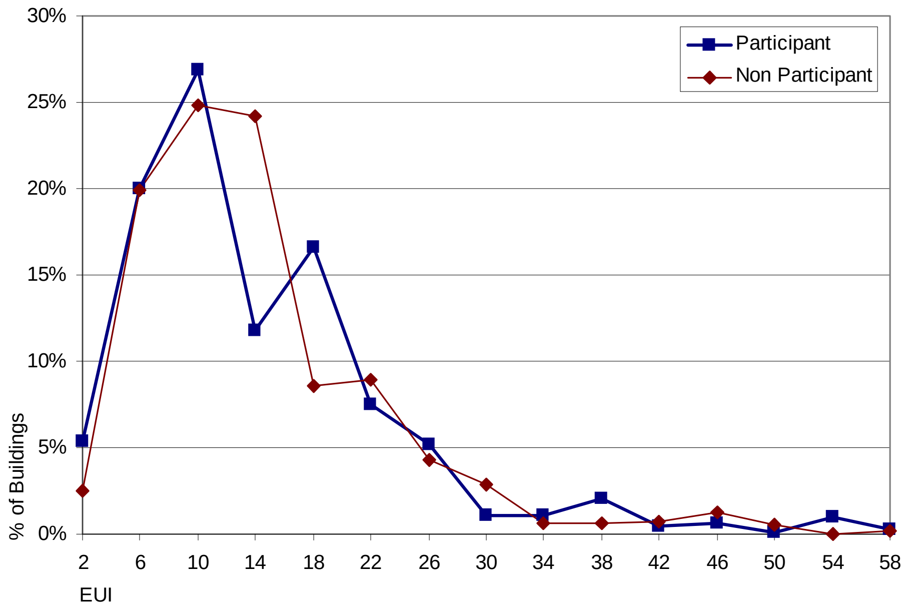

Figure 65: EUI Distribution by Utility Program Participation

Time Trends

The NRNC market is slow to change. A typical project may take from one to three years from the time the building is designed until it is built and occupied. Furthermore, designers are motivated to standardize their plans and specifications, repeating system designs and choices of equipment that have worked well in previous projects. Change is gradual at the whole building level, as individual systems evolve and as designers experiment with newer design options. All of this combines to produce a slow rate of change in NRNC practices. It is not uncommon for a major design change, such as the use of T-8 lamps and electronic ballasts replacing the older T-12 lamps and magnetic ballasts, to take more than ten years to become standard practice.

During that change, some segments of the market, some designers, and some owners will adopt early, and others will change only slowly. There may even be regional differences in the rates of adoption, especially for technologies that are climate dependent or which are introduced by one company. Understanding and measuring the rates of change and

23 The difference between the EUI charts and the energy ratio charts that the energy ratio is comparing as-built energy use to baseline energy use. The EUI charts only are looking at as-built conditions, but not comparing those results to baseline. In general, if the term 'ratio' is used to refer to a chart, then it is the as-built energy use relative to baseline energy use. If the chart presents only the distribution of the parameter without 'ratio', then the data is only summarizing the as-built conditions in the parameters' respective units.

the patterns of change in the NRNC market requires a sustained effort to track a large number of techniques, technologies and market segments.

Through our on-site data collection, we are able to gain insight on the technologies that are being used, and how prevalent they are in the population. The advantage of the biannual studies is that the rates of adoption can be compared across years if there is a statistical control in place that accounts for the differences that emerge in the new construction market over time. The method we are using to analyze the data allows for these comparisons.

Our results from this study confirm the fact that the market is slow to change. When we compared the NRNC datasets from the 1994-1996 NRNC impact studies and the 1998 baseline study, only cooling showed a significant trend toward higher efficiency units.

This section breaks the efficiency data down by year. This cross-sectional analysis by year excludes participants because only nonparticipants were included in the 1998 sample. The 30 sites from San Diego 1995 were also excluded from this analysis to concentrate on the three years of major data collection, namely1994, 1996, and 1998. 398 buildings in our sample met these criteria and were included in the following analysis. The same set of buildings will be used in the analyses of the trends presented later in this chapter.

Figure 66 shows the average whole building energy use relative to baseline by year for program nonparticipants. The differences are not statistically significant, indicating that there is no trend.

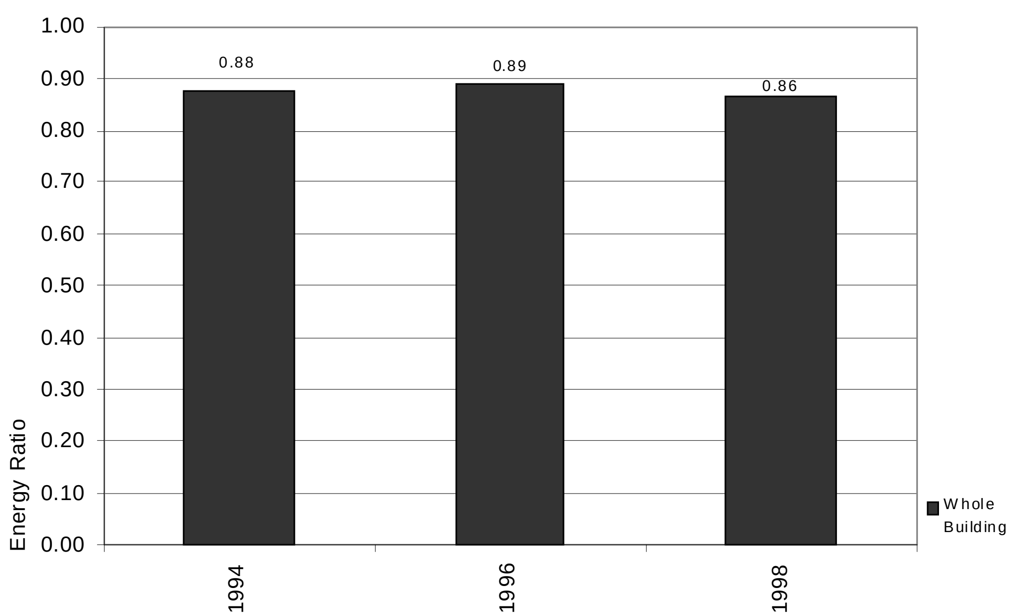

Figure 66: Average Whole Building Energy Ratio by Year

Year	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
1994	124	77.7%	0.88	0.03
1996	126	82.5%	0.89	0.03
1998	148	83.5%	0.86	0.07

Table 14: Average Whole Building Energy Ratio by Year

Figure 67 shows the distribution of the energy ratio by year. The graph shows that a majority of the buildings are being built more efficient than baseline. In fact, for all three years of data, over three-quarters of the sites in the population were consuming less energy relative to baseline. The high proportion of the inefficient sites are from the 1994 studies, indicating that over the course of the last few years, the market may slowly be reducing these poor sites. But, approximately 10% of the sites in the 1998 study are less efficient than baseline, indicating that there is still room for improvement.

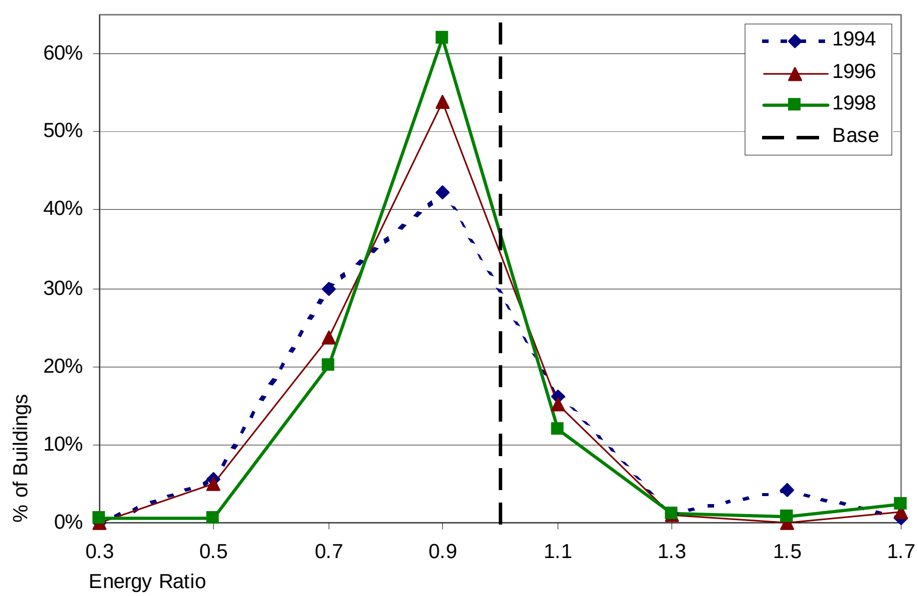

Figure 67: Whole Building Energy Ratio Distribution by Year

Figure 68 shows the distribution of EUI by year. There does not seem to be any trends over time for EUI.

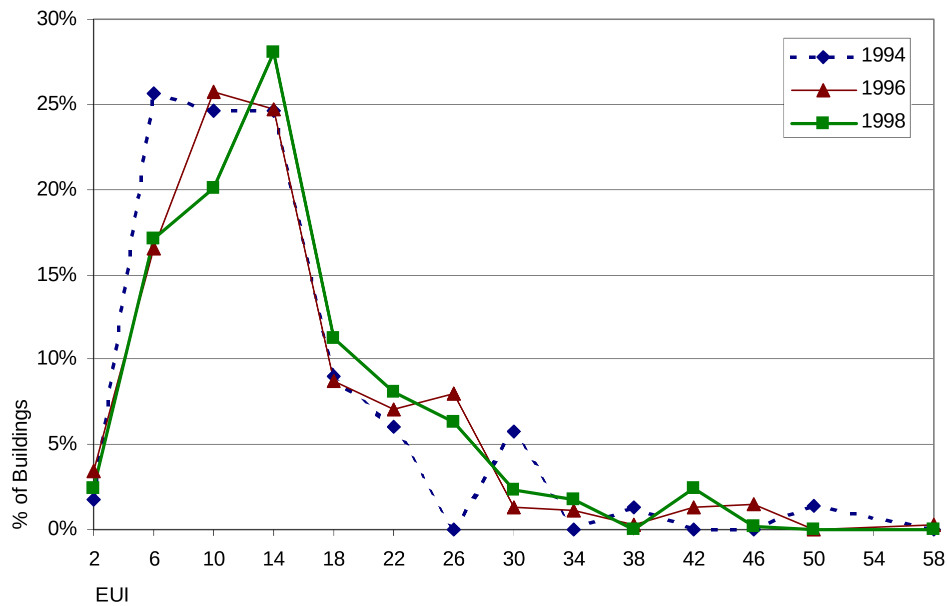

Figure 68: EUI Distribution by Year

Building Type

Figure 69 shows the average energy ratio by building type. On average, schools consume the least amount of energy relative to baseline, and the three other building types almost the same. Table 15 shows the corresponding statistics.

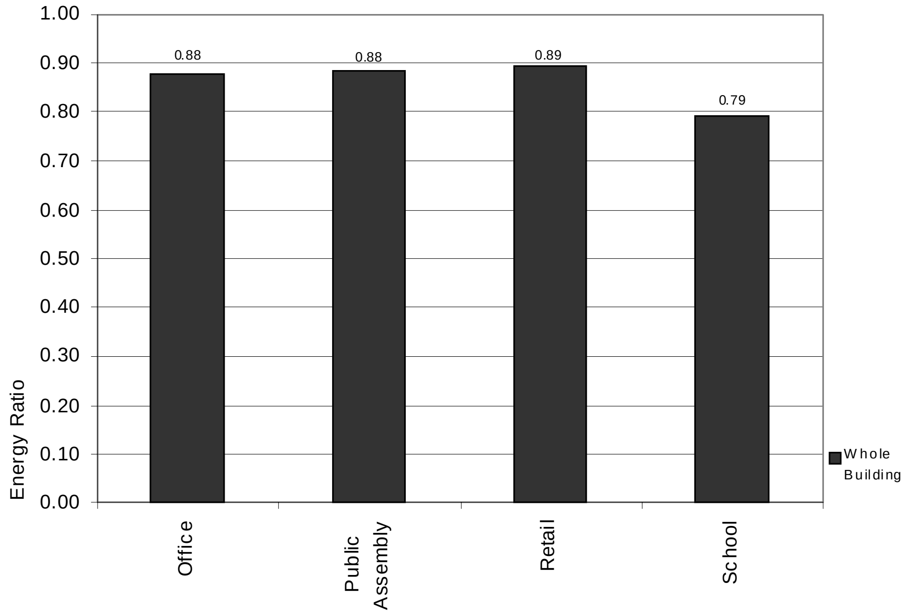

Figure 69: Average Whole Building Energy Ratio by Building Type

Building Type	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Office	231	84.8%	0.88	0.03
Public Assembly	105	77.1%	0.88	0.04
Retail	162	75.3%	0.89	0.03
School	169	90.6%	0.79	0.03

Table 15: Whole Building Energy Ratio by Building Type

Figure 70 shows the range of the whole building energy ratio values for individual buildings. These results are shown for each building type. The main point is that the vast majority of the buildings meet or exceed Title 24 within each of these market segments. More generally, the variation within the buildings in each segment is far greater than the variation between the segments.

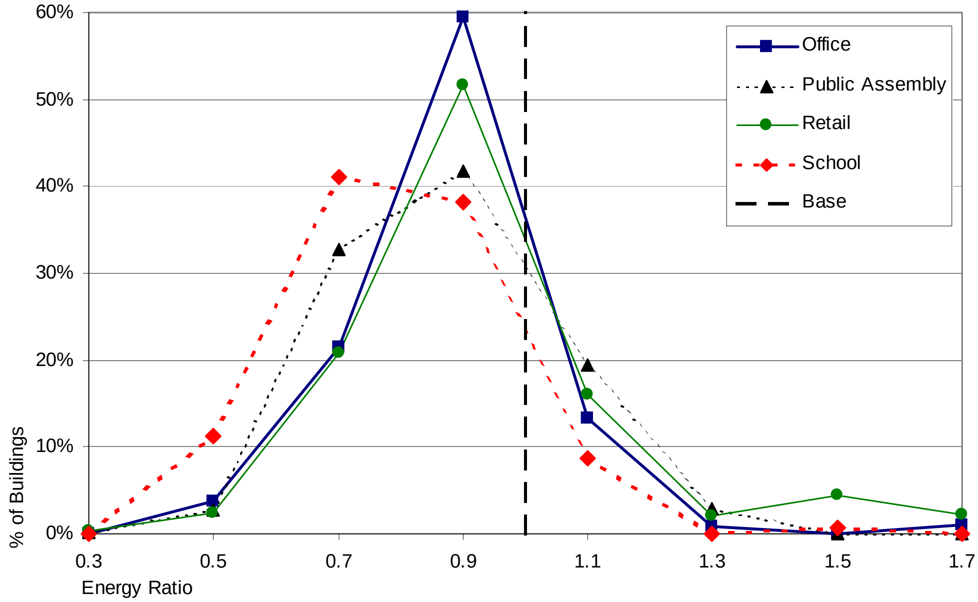

Figure 70: Whole Building Energy Ratio Distribution by Building Type

Figure 71 shows the average EUI by building type. Retail has the highest average whole-building EUI and schools the lowest average whole-building EUI. Figure 71 also shows the EUIs for the major end uses. This shows that the higher EUI in the retail segments is due to higher lighting loads. The lighting EUI for the retail segment is approximately 100% greater than the EUIs for the other three building types. Retail sites have a higher installed LPD (lighting power density in Watts/sf) as shown later. In addition, on average, the annual hours of operation for the retail segment are greater than for the remaining three segments.

The heating EUI considers only those buildings with some type of electric heating and does not consider gas heating which is outside the scope of this study. As the graph indicates, the heating EUI is negligible. The EUIs for the 'other' category includes all electrical energy consumed by miscellaneous "plug loads", exterior lighting, and exterior miscellaneous loads.

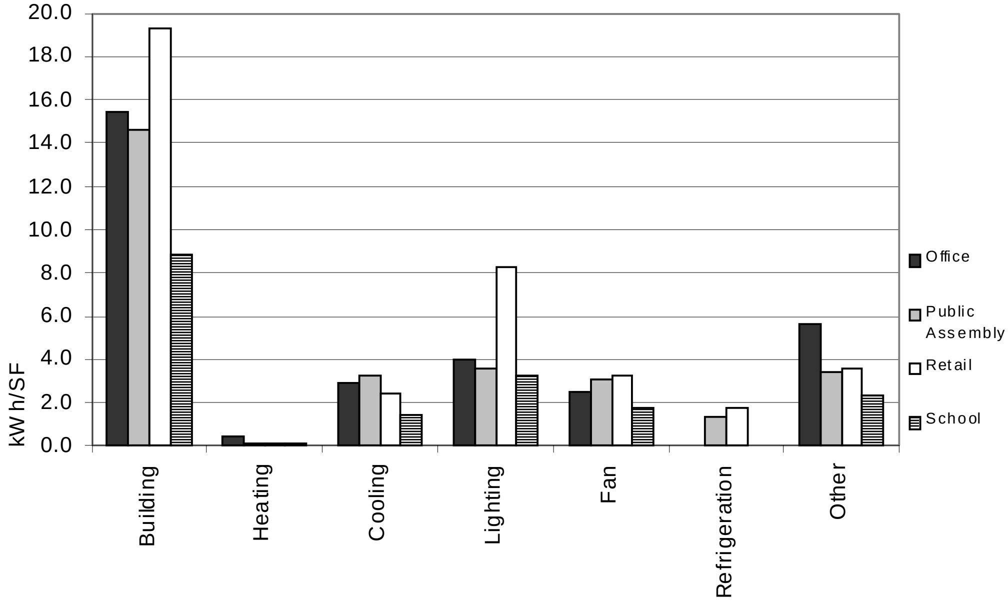

Figure 71: Average EUI for All End Uses by Building Type

Figure 72 shows the distribution of EUI by building type. The chart indicates that the majority of the buildings have an EUI between 1 and 12 kWh/sf. Schools and public assembly tend to have low EUIs, indicating that they consume less energy per square foot on an annual basis than the other types. This is largely due to the fact that these buildings have fewer operating hours than the other building types.

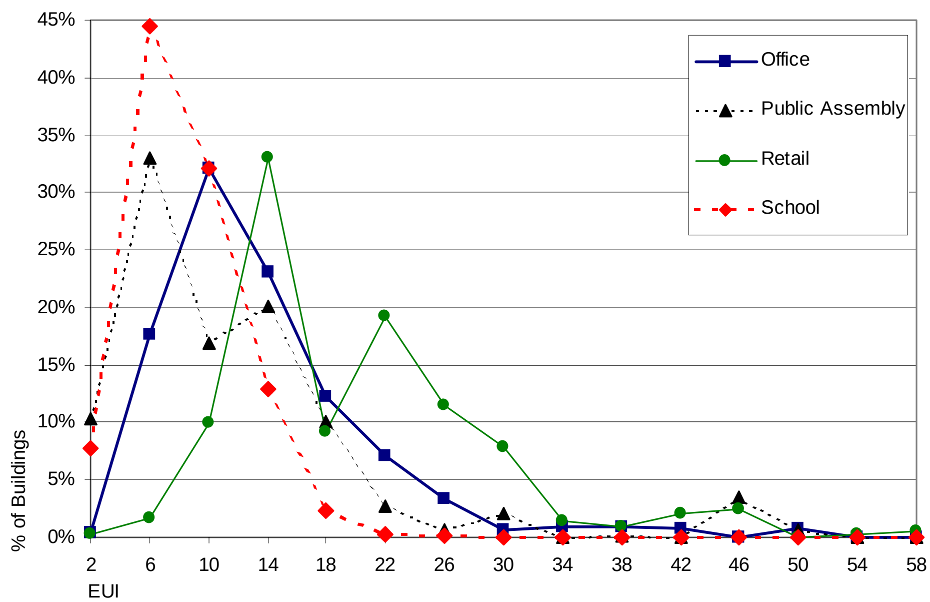

Figure 72: EUI Distribution by Building Type

Ownership Type

The following cross-sectional analysis looks at the differences between ownership types. The three ownership types explored in this analysis are public, owner occupied, and speculative development. Public buildings are typically buildings owned and operated by federal, state, or local governments. These buildings tend to be office buildings, public assembly space, and specialized uses such as police and fire stations. Owner occupied buildings are funded and constructed by private organizations for private use. Speculative development describes construction practice that speculates needs in the building market. Developers construct new buildings with the prospect of selling or leasing the building for profit.

Figure 73 shows the whole building energy ratio by ownership. The average energy ratio for public buildings is higher than both owner occupied and speculative private development. Taken together, public sector buildings are using 16% less energy than baseline, owner-occupied buildings 13% less than baseline, and speculative 8% less than baseline. Figure 73 shows that 86% of the public buildings are better than baseline, 83% of the owner-occupied buildings are better than baseline, and 75% of the speculative buildings are better than baseline.

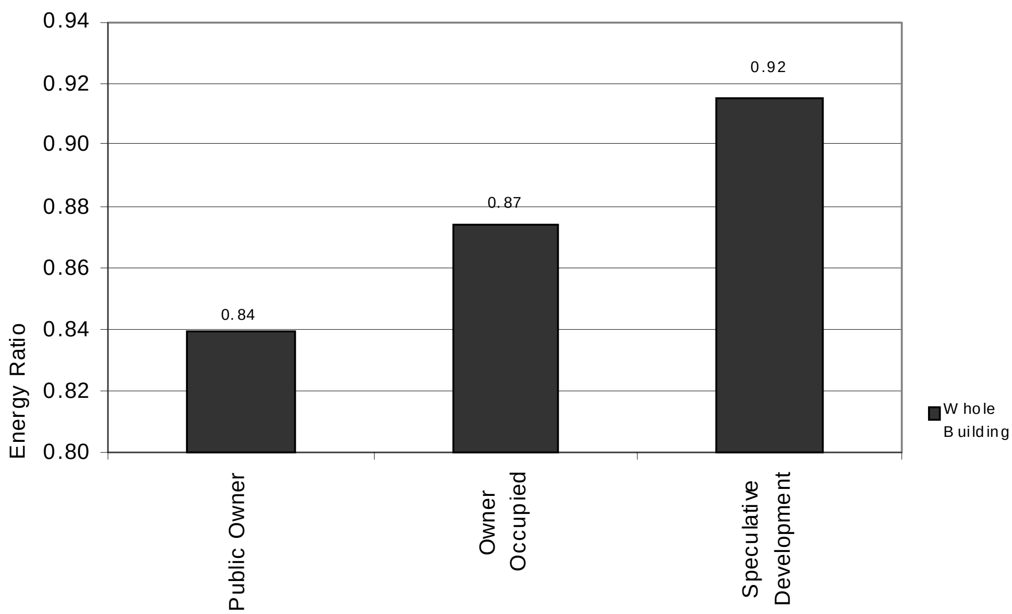

Figure 73: Whole Building Energy Ratio by Ownership

Ownership	**Sample Size**	**Sites Better Than Baseline**	**Average Value**	**Error Bound**
Public	217	85.6%	0.84	0.04
Owner Occupie	299	82.7%	0.87	0.03
Speculative	124	74.9%	0.92	0.04

Table 16: Whole Building Energy Ratio by Ownership

Figure 74 shows the range of the whole building energy ratio by ownership. As usual, there is much overlap in the distributions. It can be seen that virtually all of the buildings with very poor energy ratios are speculative.

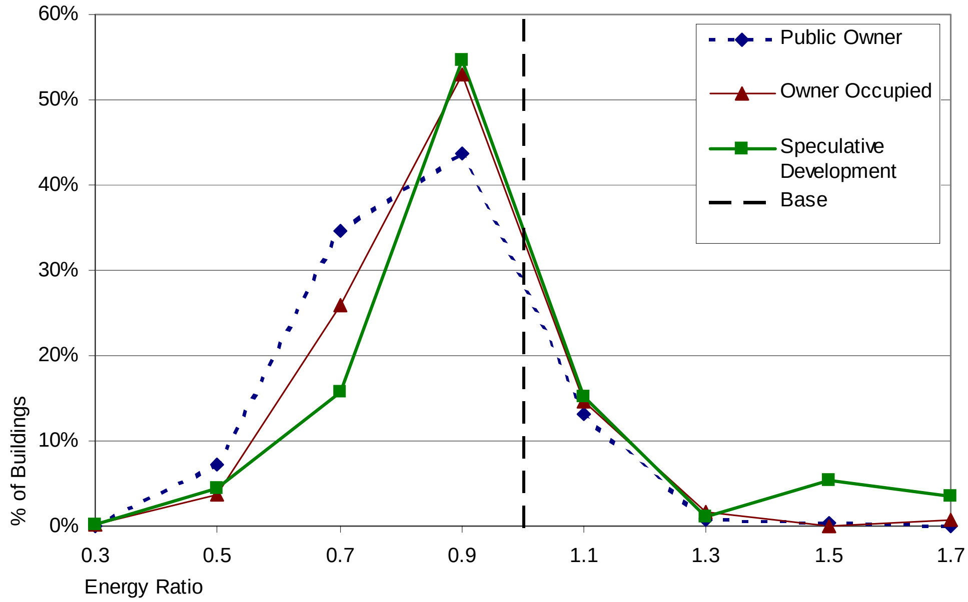

Figure 74: Whole Building Energy Ratio Distribution by Ownership

Figure 75 looks at the overall whole building energy ratio for offices by ownership. Only offices were broken down into ownership types since only this building type had enough diversity in each ownership sector. Interestingly, there was virtually no difference in average efficiency by ownership sector within the office building type.

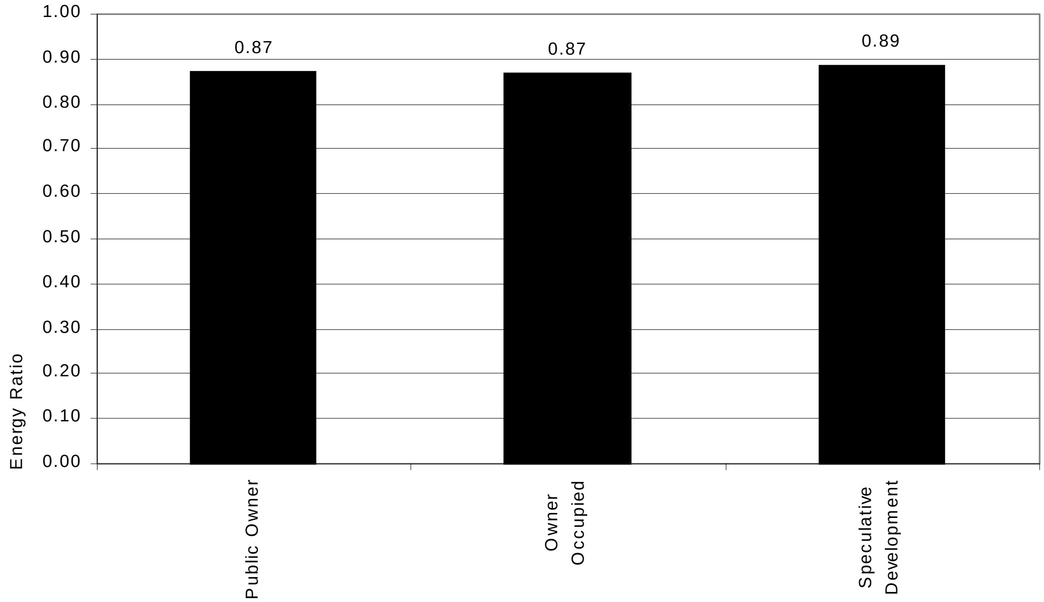

Figure 75: Average Office Whole Building Energy Ratio by Ownership

Figure 76 shows the EUI for private and public buildings. It is likely that the differences are due to the different building types in the public sector and private sector populations, i.e. the public sector consists of many schools that were found to have low EUIs, while the private sector contains very few schools.

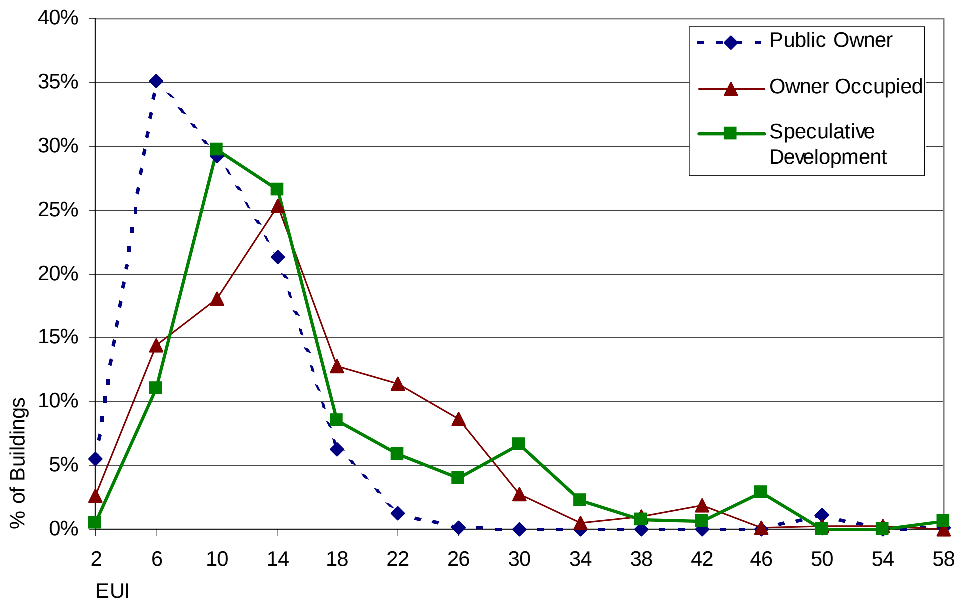

Figure 76: EUI Distribution by Ownership

Lighting

We have seen that lighting directly accounts for about three-fourths of the overall energy savings in the NRNC market. This section provides more information about lighting efficiency. Lighting is commonly measured in watts per square foot of lighted area[24]. The term lighting power density (LPD) is used describe this measurement and will be referred to throughout this section.

The LPD can be reduced by either efficient lighting equipment or reduced lighting levels. To reduce lighting energy further, lighting controls can be installed that reduce the load by dimming the lights if daylight levels are high or completely turning the lights off when the space is not in use.

An energy-efficient lighting system consists of technology aimed at reducing peak demand and electrical energy consumption. T-8 fluorescent lamps with electronic ballasts account for the majority of these systems. Low lighting energy ratios are probably the result of increased market penetration of the T8/electronic ballast lighting technologies, but that conclusion can not be drawn explicitly from our data.

Increasingly, technologies such as occupancy sensors, daylighting controls, energy management controls, light emitting diodes (LED), and compact fluorescent lamps are becoming more common practice because of their potential to save energy and their reduced cost.

Figure 77 shows the distribution of LPDs by all buildings combined. The majority of buildings are in the 1.0-1.8 watts per square foot range.

[24] Note that the lighting energy may include measurement error due to the potential for undercounting lighting fixtures during the on-site audits. This could have led to a systematic underestimate of the lighting watts in the data used for this study. However, an independent verification study would be required to determine whether this occurred. See the recommendations for further research in Chapter 6.

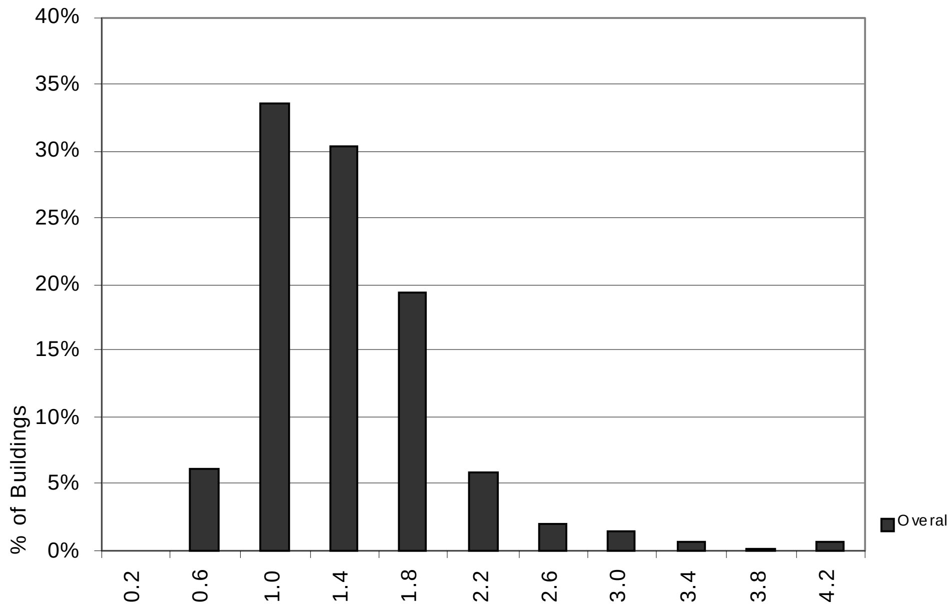

Figure 77: Overall LPD Distribution

Participant vs. Nonparticipant

Figure 78 shows the average lighting energy ratio by program participation. Once again, the participants are much lower on average than nonparticipants. An interesting finding in this section is that participants, on average, are consuming approximately 70% of the lighting baseline energy, for a savings of approximately 30 percent. Nonparticipants, on average, are consuming approximately 78% of the lighting baseline energy, for a savings of approximately 22 percent. The average energy ratio of nonparticipants for lighting is not drastically different than that of participants.

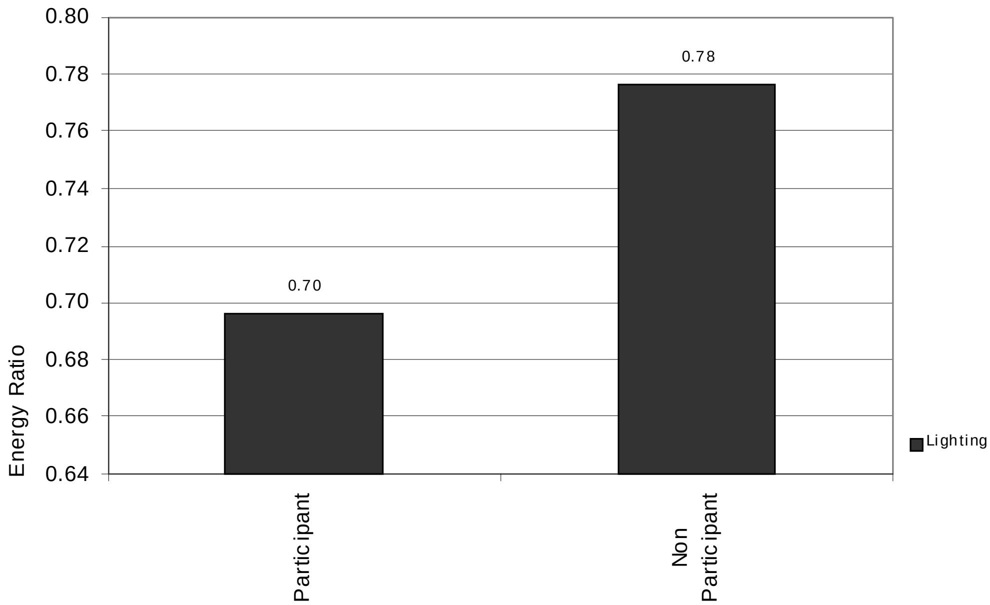

Figure 78: Average Lighting Energy Ratio by Utility Program Participation

Program Participation	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Participant	259	86.9%	0.70	0.03
Non Participant	260	79.5%	0.78	0.05

Table 17: Lighting Energy Ratio by Utility Program Participation

Figure 79 shows the lighting energy ratio of individual buildings classified by program participation. The lighting energy ratio is defined as:

$$\frac{[LPD \times \text{Square Footage} \times \text{Annual Hours}]_{\text{As Built}}}{[LPD \times \text{Square Footage} \times \text{Annual Hours}]_{\text{Baseline}}}$$

The square footage and the annual hours of operation for each building drop out of the equation because they are the same in both the as-built and baseline cases. As a result, the lighting energy ratio is equal to the ratio between the as-built and baseline lighting power densities (LPDs). It is clear that the participants have systematically lower lighting energy ratios than the nonparticipants. The majority of the inefficient buildings on the chart are the nonparticipants.

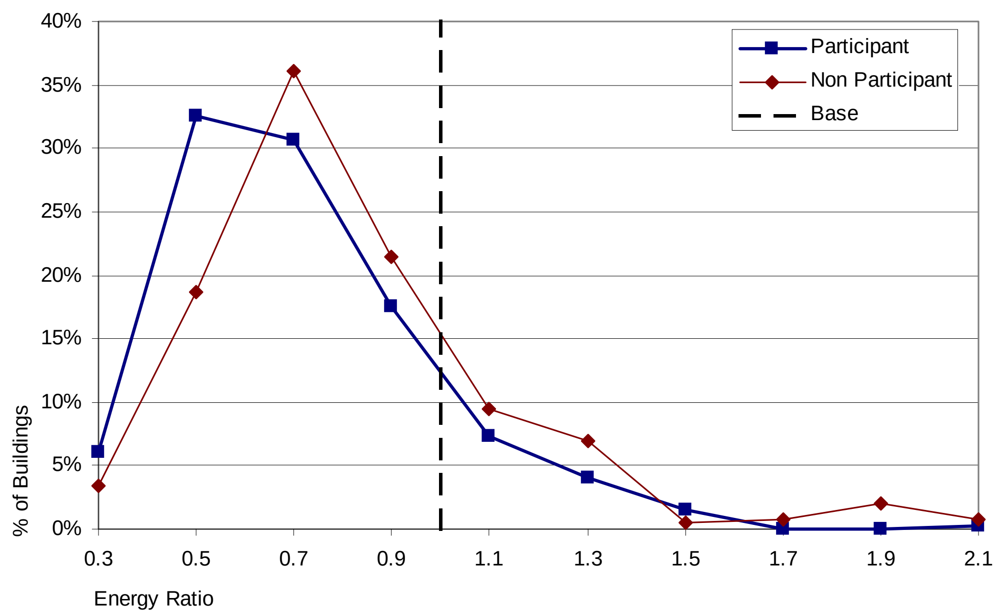

Figure 79: Lighting Energy Ratio Distribution by Utility Program Participation

Figure 80 shows the distribution of the actual LPDs among buildings classed as participants and nonparticipants. As we would expect, buildings that participated tended to have lower LPDs than the nonparticipants, but as always there is a substantial overlap in the distributions.

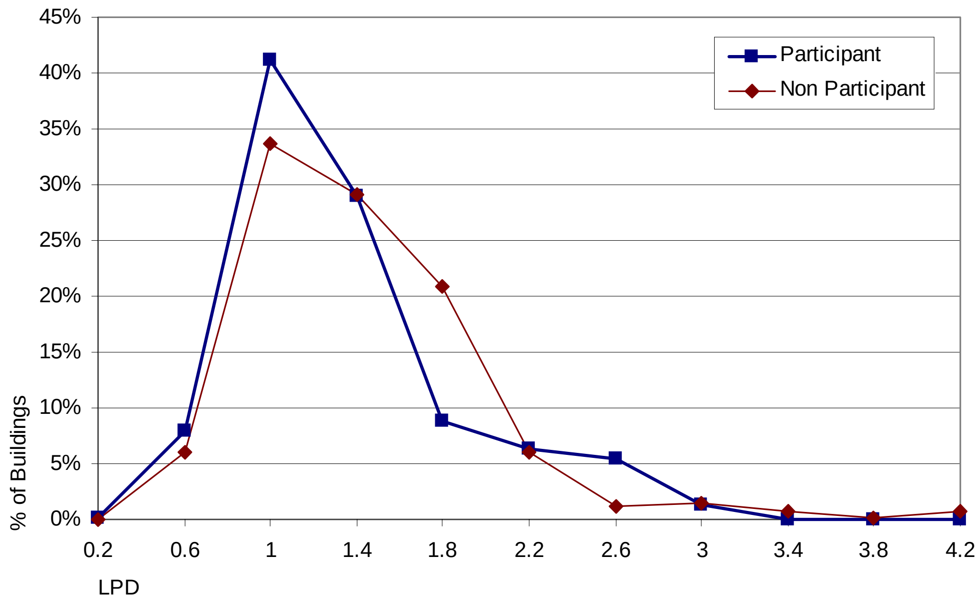

Figure 80: LPD Distribution by Utility Program Participation

Time Trends

In this section we will look for trends in lighting over time. Figure 81 shows the average lighting energy ratio by year. There are no apparent trends between the years, since the energy ratio increases from 1994 to 1996, then decreases from 1996 to 1998. Although the 1996 average lighting energy ratio for nonparticipants were slightly higher than the other two years, the difference is not statistically significant.

Figure 81 shows that there has been some increase in the proportion of sites that are better than baseline. Figure 81 shows the lighting energy ratio of individual buildings classified by year. It is hard to see any meaningful trend.

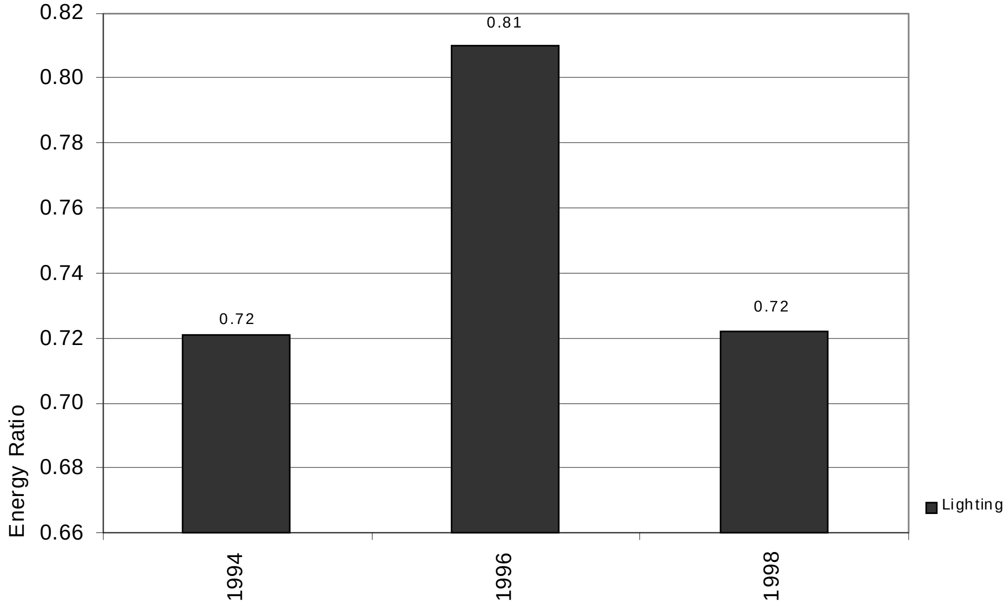

Figure 81: Average Lighting Energy Ratio by Year

Year	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
1994	124	78.5%	0.72	0.06
1996	126	79.7%	0.81	0.06
1998	148	84.2%	0.72	0.05

Table 18: Lighting Energy Ratio by Year

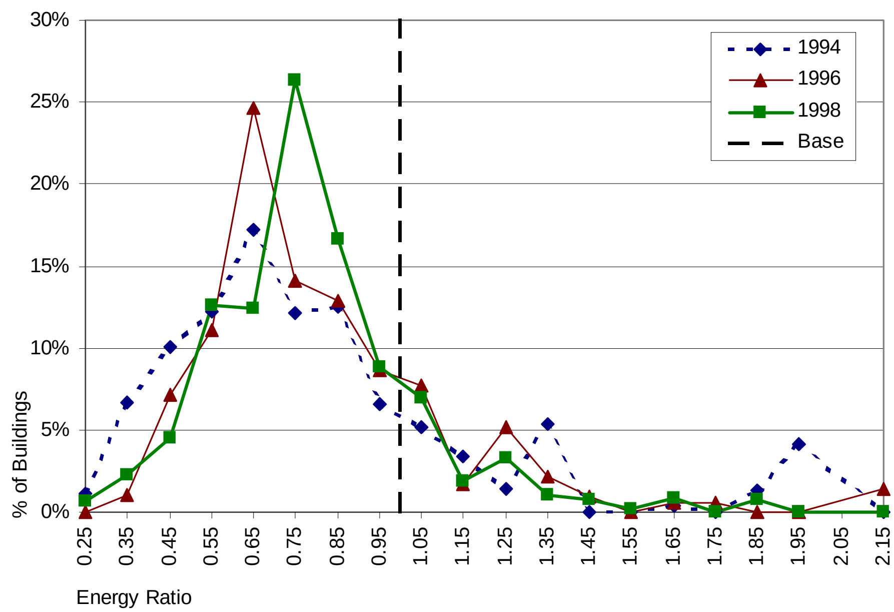

Figure 82: Lighting Energy Ratio Distribution by Year

Figure 83 shows the distribution of LPD by year. Notice that even in 1998, there are some buildings that have a LPD that falls above the typical range of 0.8 to 2.

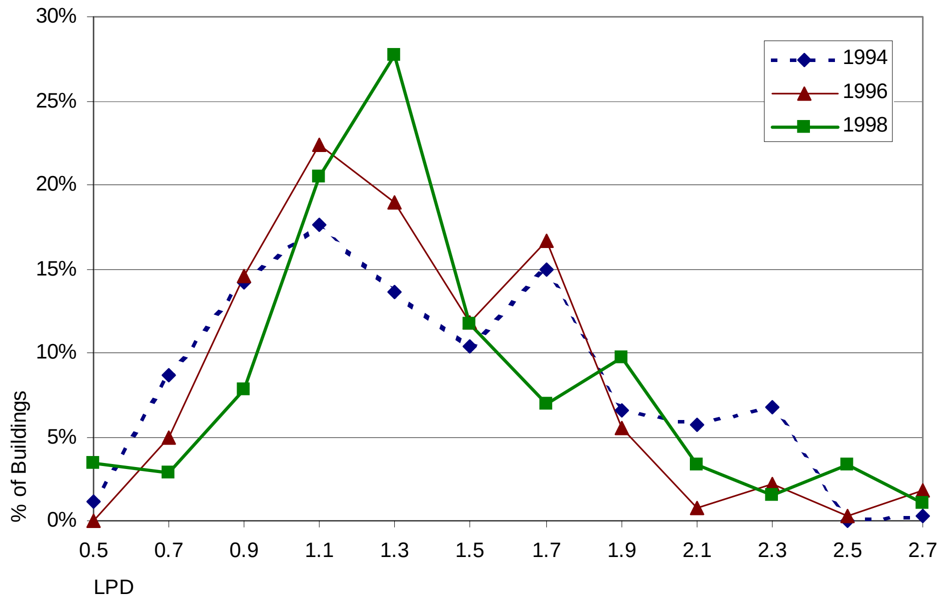

Figure 83: LPD Distribution by Year

Figure 84 shows the percentage of buildings with various types of lighting controls. The number of occupancy sensors being installed has decreased significantly from 1994. 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.

The decrease in occupancy sensors is partially offset by the increase in stepped dimming daylight controls in 1998. Stepped dimming daylight controls are an emerging technology that uses a lighting lumen sensor to detect the amount of natural light that is penetrating the room. The sensor responds to the amount of natural light by turning on/off, or dimming the lights in the room. The stepped sensor controls lighting levels by stepping down the lumen output of the fixture, similar to the popular 3-way incandescent lamp. The fact that almost 10% of the 1998 sites have this control, is a tremendous increase over previous years, in which less than 1% of the buildings installed this type of control.

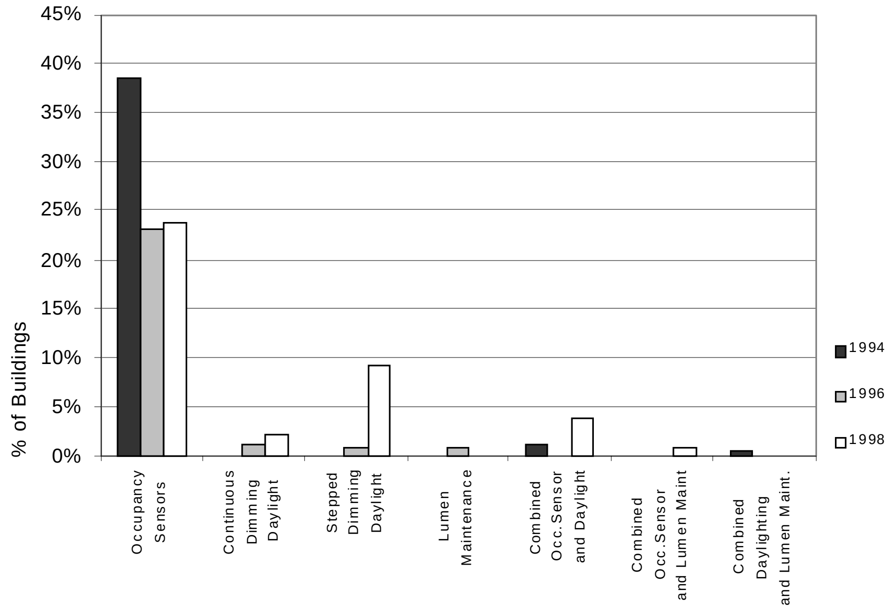

Figure 84: Percentage of Buildings with Lighting Controls

Figure 85 shows the percentage of buildings with daylighting sensors by year. There has been a significant increase in the percentage of buildings that have daylight sensors over the three years. All the lighting sensor types in Figure 84, except occupancy sensors, represent various daylighting control strategies and were used to develop the totals shown in Figure 85. The data indicates that the market is moving more toward increased utilization of daylighting sensors.

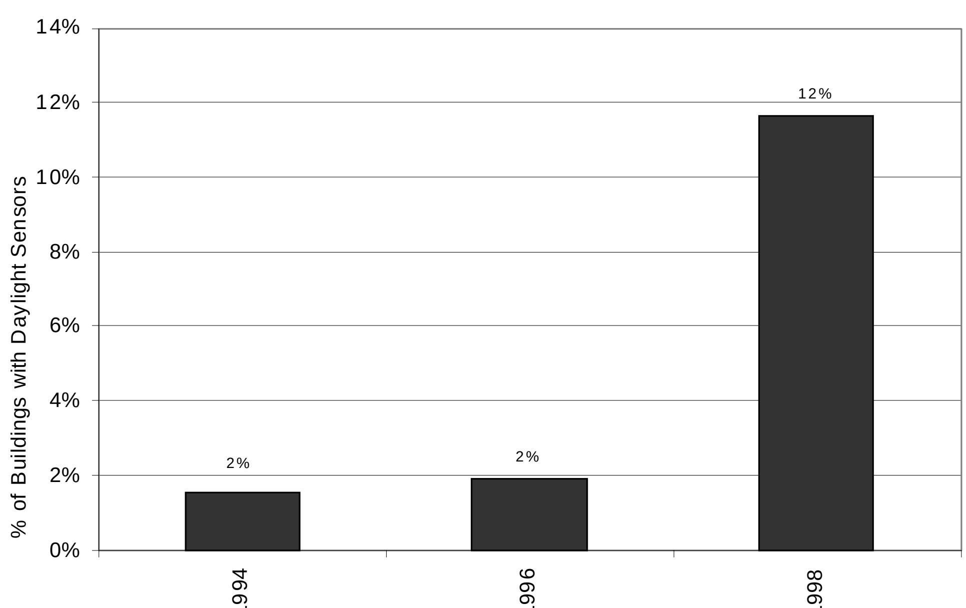

Figure 85: Percentage of Buildings with Daylight Sensors by Year

Building Type

Figure 86 shows the average lighting energy ratio by building type. The graph shows that schools are consuming, on average, less energy than the other building types relative to baseline. Conversely, retail has the highest average energy ratio of the four buildings at 0.80.

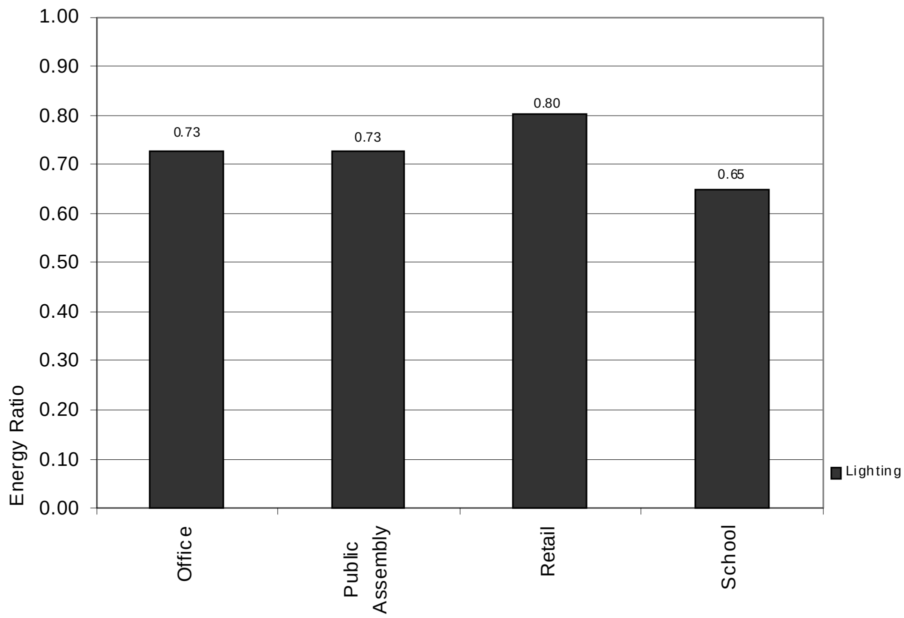

Figure 86: Average Lighting Energy Ratio by Building Type

Table 19 shows that retail also has the fewest sites better than the baseline. Nevertheless, even in the retail sector, about 73% of the sites are better than the baseline.

Building Type	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Office	231	82.6%	0.73	0.04
Public Assembly	105	78.6%	0.73	0.09
Retail	162	72.7%	0.80	0.06
School	169	90.3%	0.65	0.05

Table 19: Lighting Energy Ratio by Building Type

Figure 87 shows the range of lighting energy relative to the baseline energy use by building type. Once again the graph shows the majority of buildings fall below baseline lighting energy use. The figure shows retail buildings having the highest probability of using more energy than the baseline[25]. An interesting finding here is that a little more than half of the buildings in the school and public assembly segments have an energy

[25] Site 94S1750, a performing arts theatre, is the outlier. This site from the 1994 study had stage lighting included in the lighting counts. The fixtures have been removed from the database.

ratio that is between 0.20 to 0.60. This indicates that for those two building types, the majority of the sites use much less energy relative to baseline.

The results indicate that there is a large potential in all building types for the baseline to be pushed up to a higher level of efficiency since the majority of the sites are consuming less lighting energy relative to baseline[26]. Another finding unique to lighting is that there is a large number of sites that have lighting that is substantially lower than baseline. This can be seen in the chart below, since the majority of the sites fall between 0.4 to 0.8, rather than in the range that is just below baseline, 0.8 to 1.0.

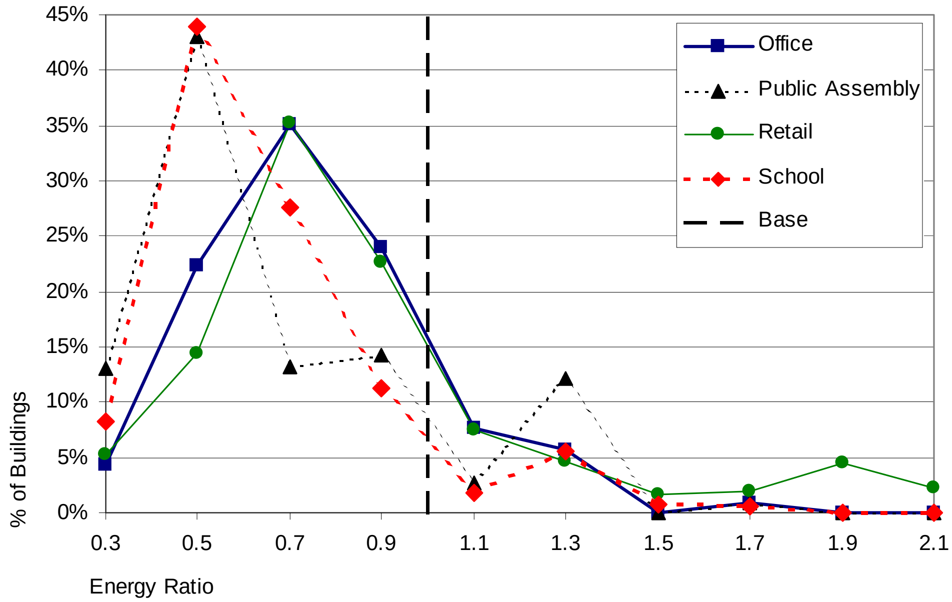

Figure 87: Lighting Energy Ratio Distribution by Building Type

Figure 88 shows the average lighting power density by building type. We would expect retail to have the highest lighting power density because of the need to have higher lumen levels for showing merchandise.[27]

[26]The 1995 Title 24 lighting standards have been exceeded for a high percentage of the surveyed buildings. The Title 24 standards are being updated in 1999 which will have the effect of lowering the LPDs in future buildings below the level (1995 Title 24) required for compliance during the period of this study.

[27] Display case lighting is excluded from the lighting energy.

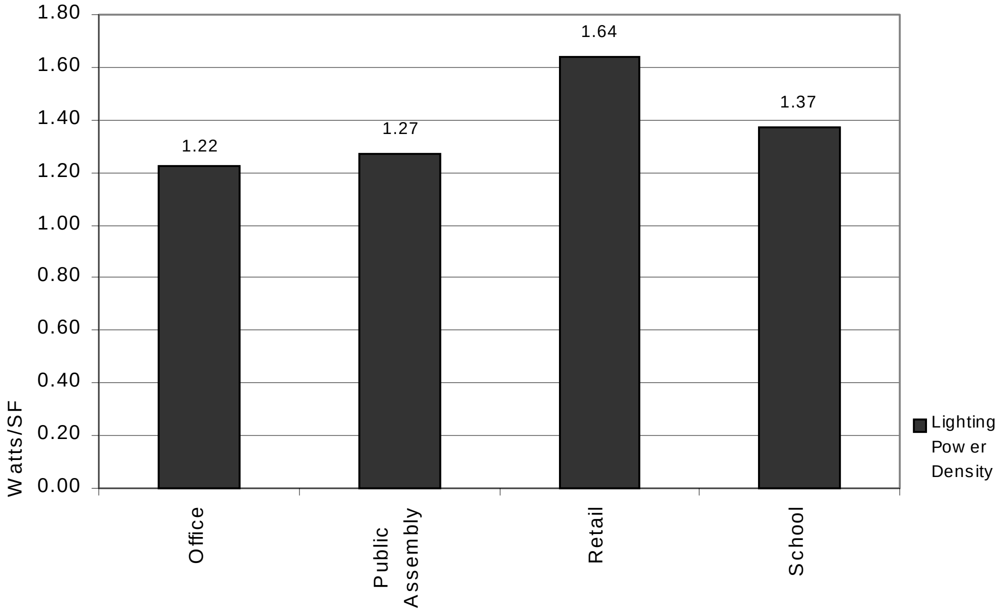

Figure 88: Average Lighting Power Densities by Building Type

Figure 89 shows the distribution of lighting power densities by building type. Here we see that retail sites tend to have higher LPDs. The majority of sites of all types have LPDs between 0.8 to 2.0.

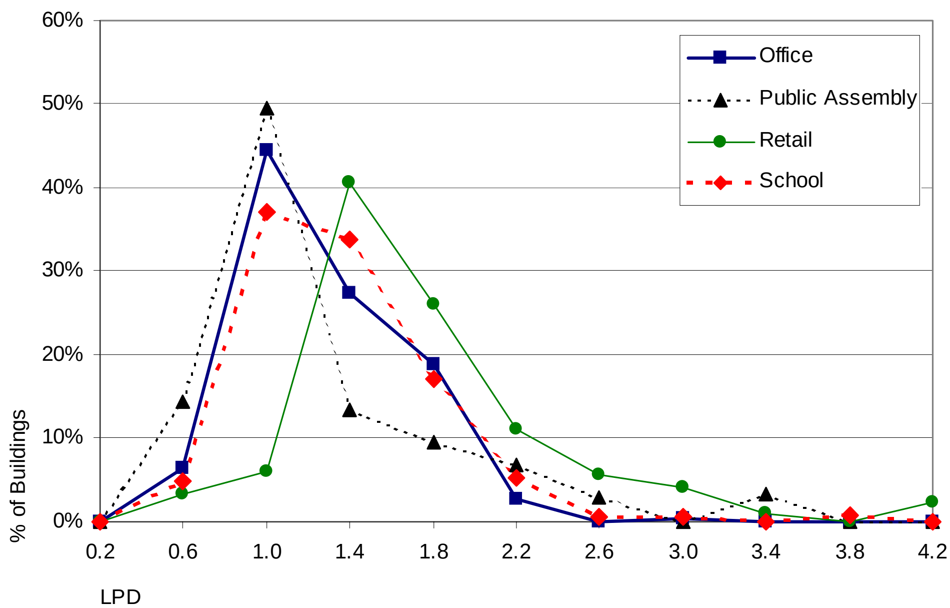

Figure 89: LPD Distribution by Building Type

In Figure 90 different lighting control types are graphed by building type. The vertical axis represents the percentage of the total lighting connected load to which each control type is connected. We see that occupancy sensors control 30% of the lighting load in schools and nearly 25% in offices. A small percentage of retail buildings use stepped daylighting controls.

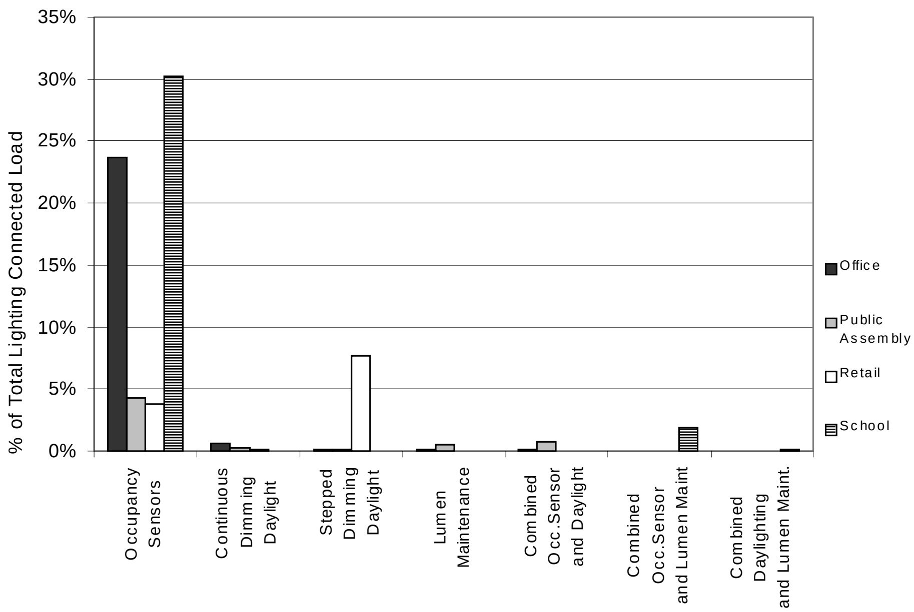

Figure 90: Lighting Control Types by Building Type

Ownership Type

This section provides information on lighting based on ownership of the building, i.e. publicly owned, privately owned, or speculative development. The trend among ownership types that surfaced for the whole building energy ratio continues for lighting. On average, the public owners are more efficient than the owner occupied buildings, which are more efficient than the speculative developments. Figure 91 shows the average lighting energy ratio of each sector

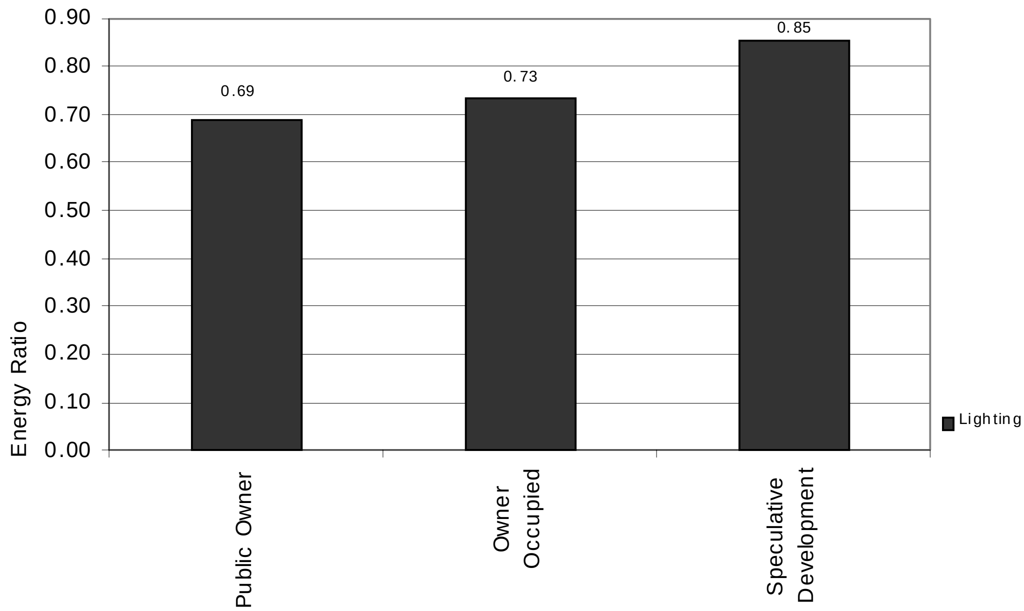

Figure 91: Average Lighting Energy Ratio by Ownership

Table 20 shows the detailed information on the lighting energy ratio broken out by ownership. As expected speculative development has the highest average value and the most buildings using more lighting energy than baseline, although their energy savings are still approximately 15% under baseline.

Ownership	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Public	217	84.6%	0.69	0.04
Owner Occupied	299	82.1%	0.73	0.05
Speculative	124	72.9%	0.85	0.07

Table 20: Lighting Energy Ratio by Ownership

Figure 92 shows the range of the lighting energy ratio broken out by ownership. The average value for owner occupied buildings is significantly lower than that of speculative development. Notice that the lower energy ratio ranges have the highest percentage of public buildings, and the highest energy ratio ranges have the highest percentage of speculative development buildings. About 10% of the speculative buildings are using about twice as much lighting as allowed.

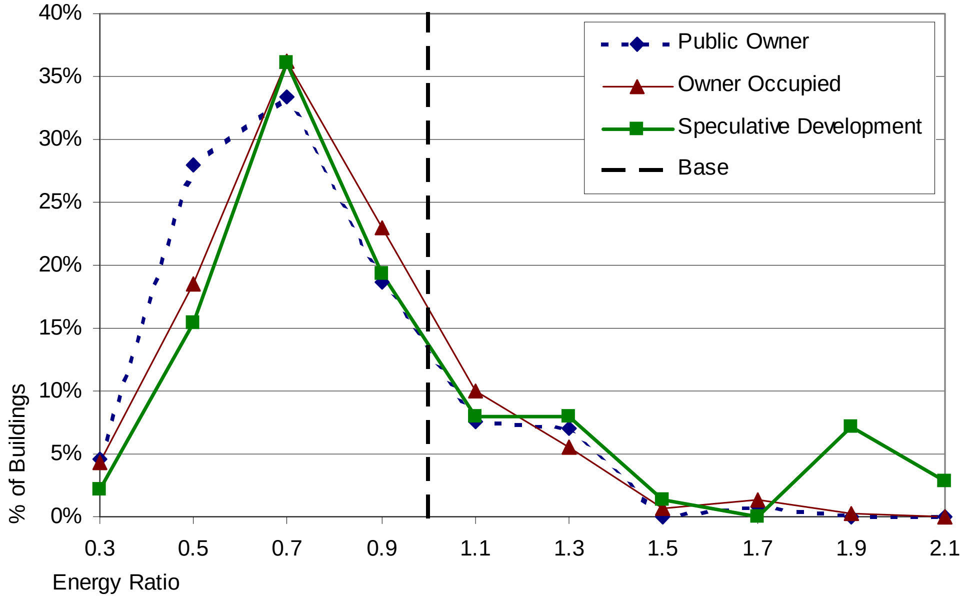

Figure 92: Lighting Energy Ratio Distribution by Ownership

The distribution of lighting power density is shown in Figure 93 . The range of actual LDPs is comparable to the range of the lighting energy ratios shown in Figure 93.

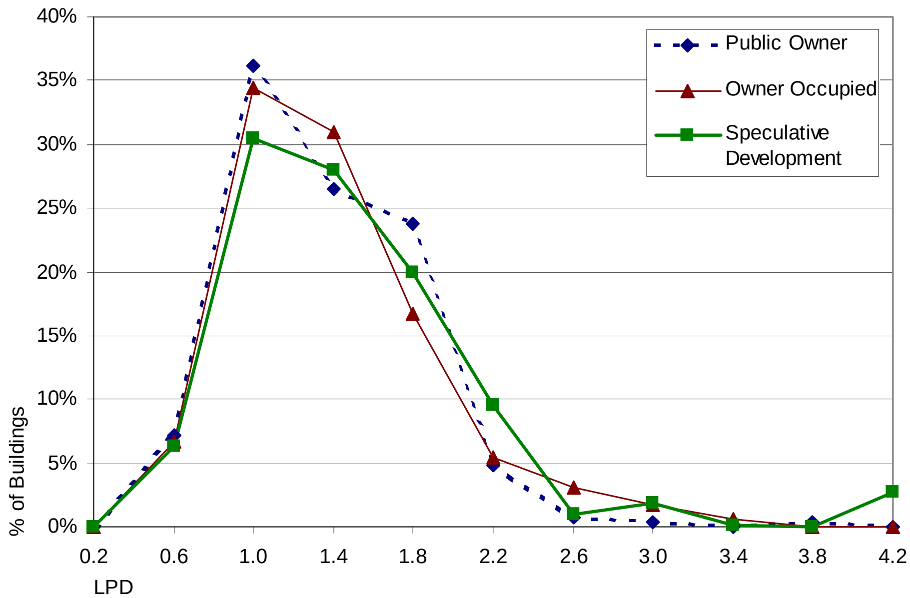

Figure 93: LPD Distribution by Ownership

Cooling

This section provides information on cooling energy efficiency. As discussed earlier in this report, much of the cooling savings are due to the adjustment in cooling loads and capacity in response to lower lighting loads and more efficient envelope measures. Another possible reason for the cooling savings is the installation of higher efficiency units, although this appears to have had a much smaller impact on cooling savings than the interactive effects with lighting[28].

Our main measure of the overall cooling efficiency of the building is the cooling energy ratio – the ratio between the cooling energy of the buildings as built and the cooling energy they would have used if they had been built just in compliance with Title 24. As discussed earlier, the cooling energy ratios reflect both the direct effect of cooling efficiency and the indirect effect of more efficient lighting. The cooling energy ratios, along with the average efficiencies of packaged/split systems and built-up systems are reported in this section. Cooling systems can be categorized into two basic types, packaged/split systems and built-up systems. Packaged/split systems, by far the most common of the two, are rated in efficiency using Energy Efficiency Ratio (EER), while built-up systems are conventionally rated in kW/ton.

In packaged/split systems, the higher the EER, the more efficient the cooling unit. In built-up systems, increased efficiencies are characterized by lower kW/ton values for the chiller. In order to calculate the overall cooling energy consistently, the energy efficiency of packaged/split systems and built-up systems were expressed in the same units, EER, and were weighted based on the size of the unit. The efficiency measured in kW/ton was converted to EER using a mathematical transformation.[29] If a site had a mixture of cooling types, the built-up system efficiencies were converted to EER and weighted with the relevant packaged systems to develop an overall EER for the site.

Participant vs. Nonparticipant

Figure 94 compares the overall cooling energy ratios for participants and nonparticipants. Participants are using about 17% less energy for cooling than baseline, whereas nonparticipants are using about 7% less energy than baseline. So, relative to the baseline, participants are using about 10% less energy than nonparticipants for cooling.

[28] No attempt has been made to measure the isolated effects of changes in cooling efficiencies in this study. Refer to the future research projects section of this report for more information on potential projects.

[29] kW/ton = 12 / EER or equivalently EER = 12 / (kW/ton)

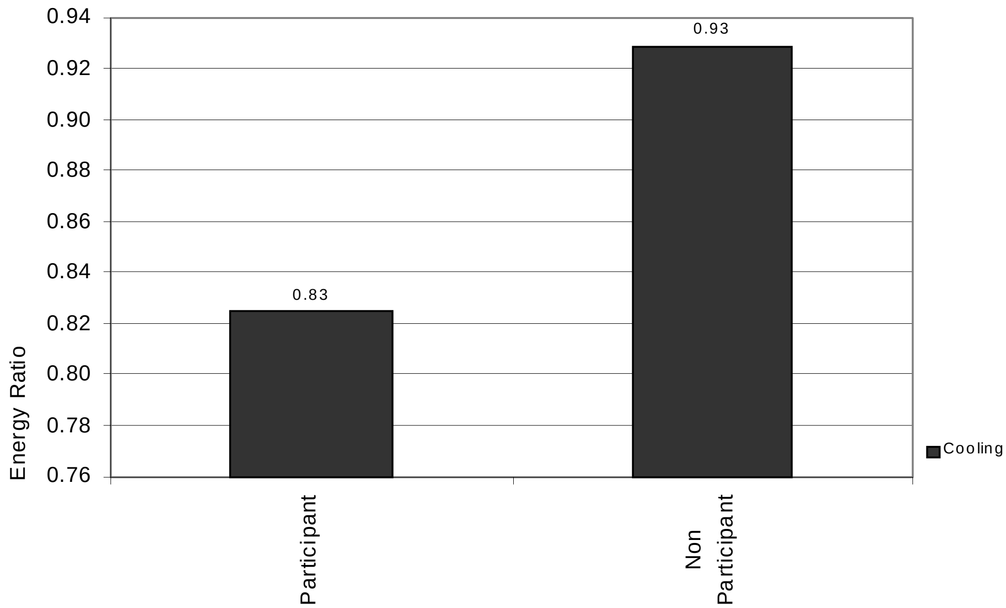

Figure 94: Average Cooling Energy Ratio by Utility Program Participation

Table 21 shows the detailed information. This table tells us that although the average energy ratio for participants is significantly lower than nonparticipants, about 73% to 74% of both participants and nonparticipants are better than baseline.

Program Participation	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Participant	251	72.7%	0.83	0.05
Non Participant	242	73.9%	0.93	0.04

Table 21: Cooling Energy Use Relative to Baseline by Program Participation

Figure 95 shows the distribution of the cooling energy ratio by program participation. Almost 50% of the nonparticipants have a cooling energy ratio in the interval 0.8 to 1.0, indicating that they are only slightly better than baseline. About 35% of the participants are in this interval. As usual, the distributions of participants and nonparticipants are quite similar.

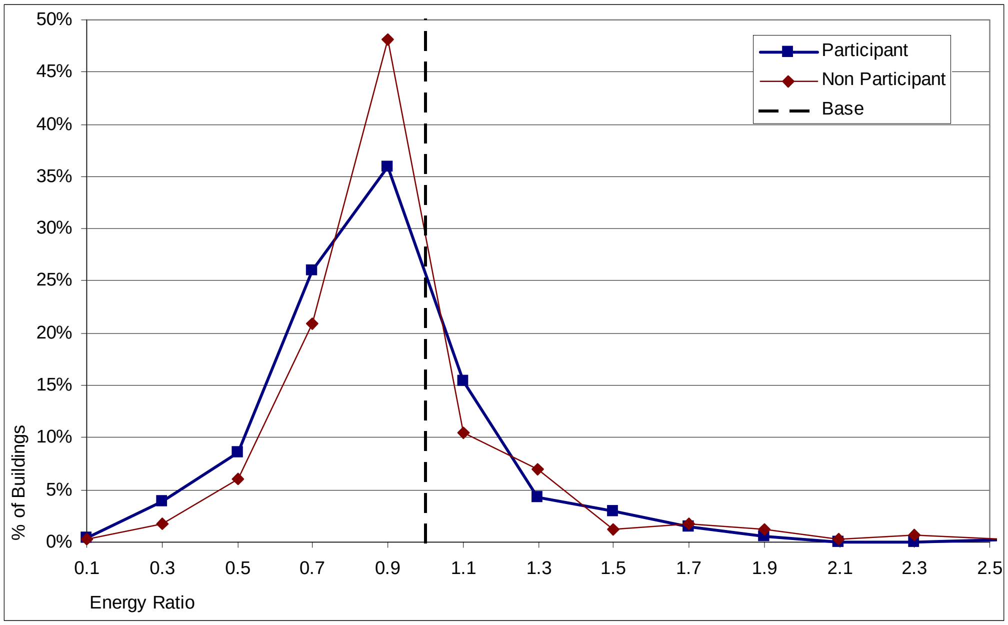

Figure 95: Cooling Energy Ratio Distribution by Utility Program Participation

The cooling sizing ratio is an important indicator of how well the cooling system has been matched to each building. The cooling sizing ratio is defined as the as-built cooling capacity of the system divided by the peak cooling load that is placed on the cooling system. Thus, if the cooling sizing ratio is 1.1, the capacity of the cooling system is 10% greater than the highest cooling load placed on the system.[30] A properly sized cooling system generally has a sizing ratio slightly greater than one to allow for expansion and to provide a small amount of redundancy. Some variation is expected due to differences in peak occupancy and internal loads from building to building. As a rule of thumb, we will consider a system to be undersized if the sizing ratio is below 0.7 and oversized if it is greater than 1.3.

Figure 96 shows the cooling sizing ratio by participation. The majority of participants and nonparticipants have a cooling sizing ratio that fall into the range between 0.7 to 1.3 – indicating that they were appropriately sized. The cooling systems appear to be undersized for about 15% of the participants and 15% of the nonparticipants.[31] Similarly, the cooling systems seem to be oversize for about 15% of the participants and about 10% of the nonparticipants. The majority of the sites that are oversized are schools and office buildings. These results indicate that the cooling systems are appropriately sized to match the actual lighting and envelope loads of about 70% of the buildings.

[30] This is determined from the DOE-2 simulations using typical meteorological year (TMY) weather data that attempts to reflect the usual day to day variation in weather conditions.

[31] We have estimated the percentage with a sizing ratio less than 0.7 as the sum of the percentages associated with 0.3 and 0.5 and one-half the percentage associated with 0.7.

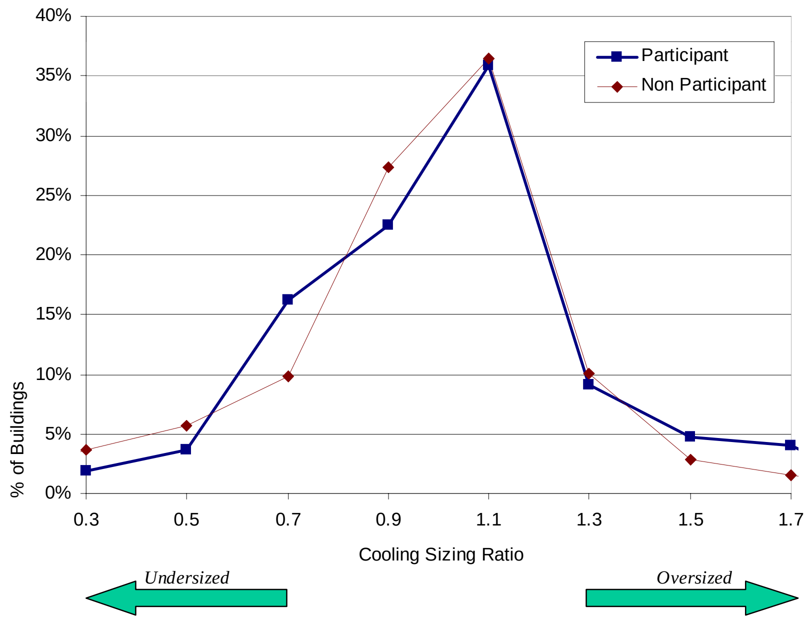

Figure 96: Cooling Sizing Ratio Distribution by Utility Program Participation

Time Trends

Figure 97 shows the average cooling energy ratio by year. A definite trend over time can be seen in this graph. Due to the fact that no significant trends over time were found in the lighting levels, it is believed that the improved cooling energy ratio is attributable to improvements in cooling system efficiency and envelope characteristics. Standard packaged systems were found to have higher average efficiencies in 1998 than in the other two years. Moreover, there seems to have been an increase in the proportion of the cooling load served by more efficient built-up systems relative to packaged systems.

Figure 97 shows that the 1998 buildings are 13% more efficient in cooling than buildings constructed in 1996, and 26% more efficient than those constructed in 1994. These are substantial improvements.

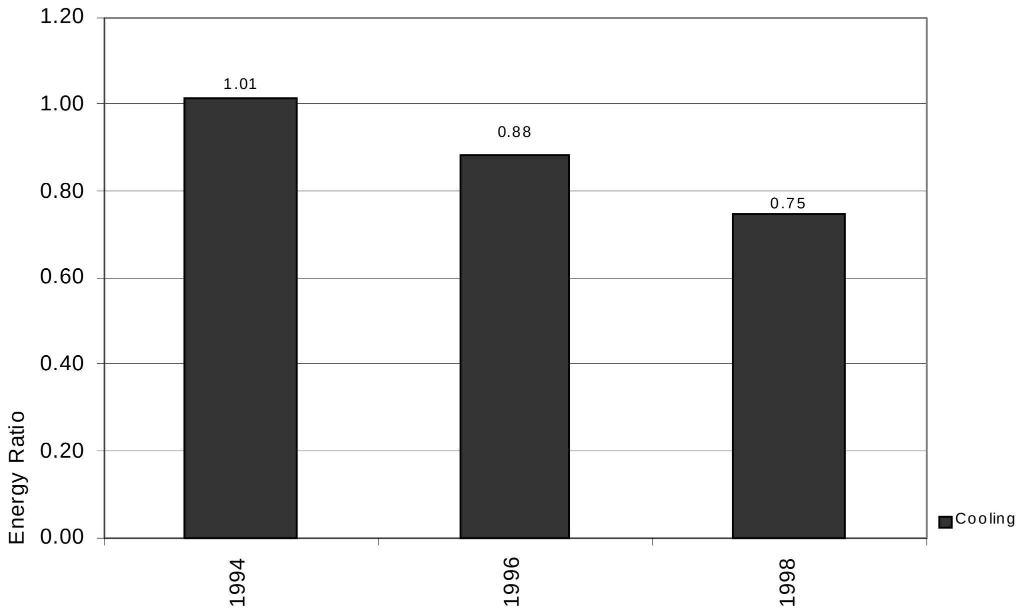

Figure 97: Average Cooling Energy Ratio by Year

Figure 97 shows the overall cooling energy ratio by year. The difference between years is statistically significant between all three years, indicating that there has indeed been a measured shift in the efficiency levels. The percentage of sites better than baseline has increased accordingly. Figure 98 shows the distribution of the cooling energy ratio for each of the three years.

Year	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
1994	111	62.5%	1.01	0.07
1996	121	79.8%	0.88	0.03
1998	144	80.8%	0.75	0.09

Table 22: Cooling Energy Ratio by Year

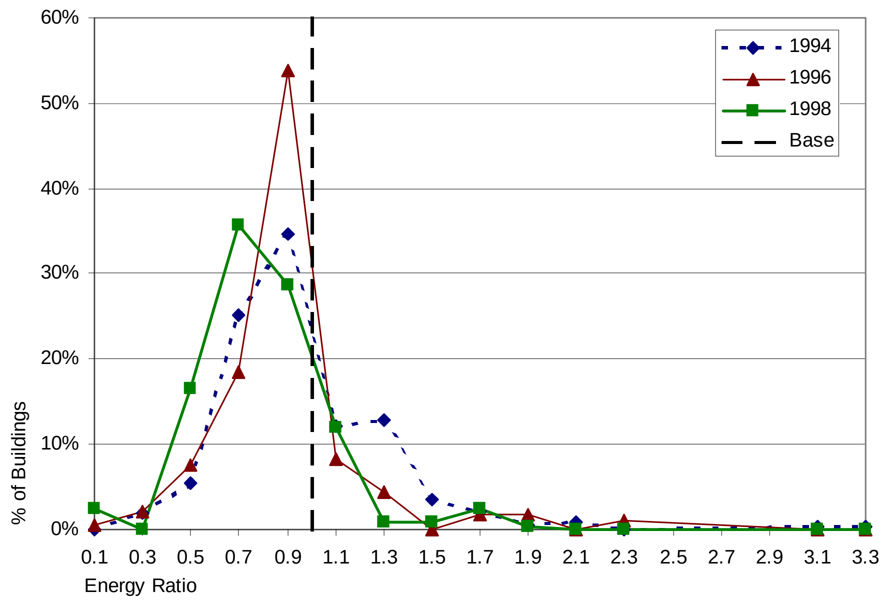

Figure 98: Cooling Energy Ratio Distribution by Year

Three factors might be causing the decrease in cooling energy ratios:

- An increased use of built up systems relative to packaged systems,
- An increased efficiency in packaged systems, and
- An increased efficiency in built up systems.

We will investigate each of these factors in turn. Figure 99 shows the percentage of the total conditioned floor area that is served by the packaged and built up systems. The graph shows no sign of a trend but there were more packaged systems in 1998 than in prior years.

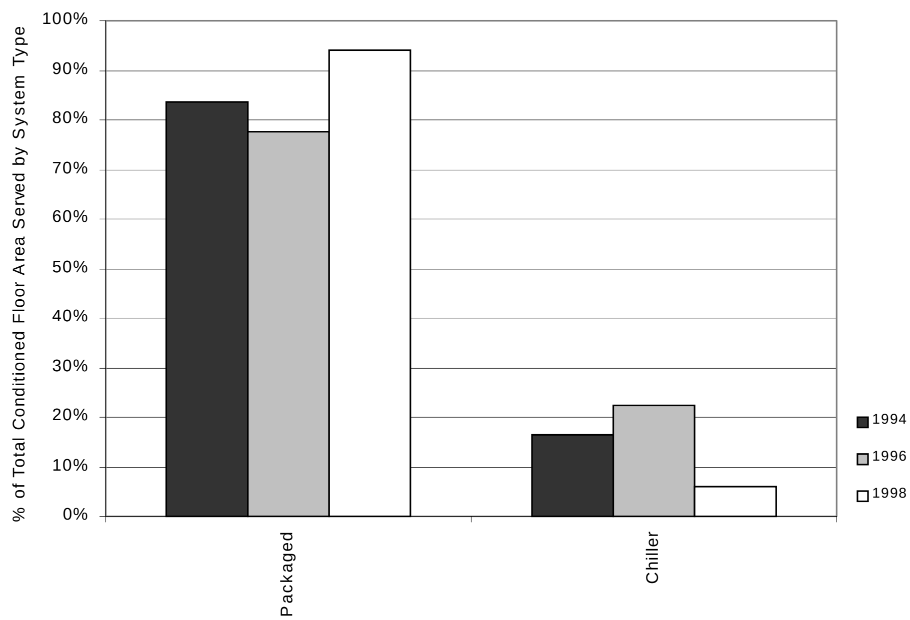

Figure 99: Percentage of Total Floor Area Served by System Type

Packaged Cooling Systems

To look at the overall efficiency of these systems, we analyzed the average EER. The higher the EER, the more efficient the unit. Figure 100 shows the results of this analysis. The 1998 systems are about 8% more efficient than in 1996 and 9.6% more efficient than in 1994. So improved efficiency of packaged units explains part but not all of the improvement in the overall cooling energy ratios.

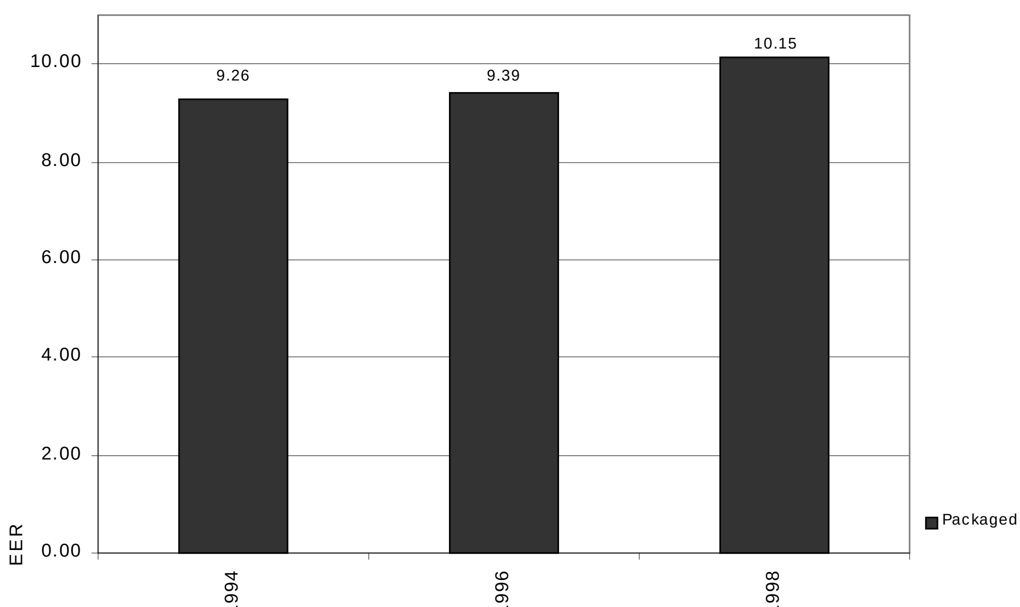

Figure 100: Average Packaged System Efficiencies (EER) by Year

We can also look more closely at the various types of packaged units. Table 23 contains the descriptions of the size and types of packaged units. Figure 101 shows the breakdown of system types within those buildings with packaged systems. Notice that small, medium and large type A systems account for the majority of the population of packaged/split systems.

TYPE OF SYSTEM	DESCRIPTION
A	Single Package Rooftop AC, Single Package Rooftop Heat Pump, Split System AC, Split System Heat Pump, or Dual Fuel Heat Pump, without evaporative condenser
B	Any units of type A, with evaporative condenser.
C	Packaged Terminal AC, Packaged Terminal HP, Window/Wall AC Unit, Window/Wall HP Unit
D	Water Loop Heat Pump
	* = Size of System, range in tons
Small Medium Large Extra Large	0 < ton <= 5.4 5.4 < ton <= 11.25 11.25 < ton <= 63.3 ton > 63.3

Table 23: Types of Packaged System Cooling Efficiencies

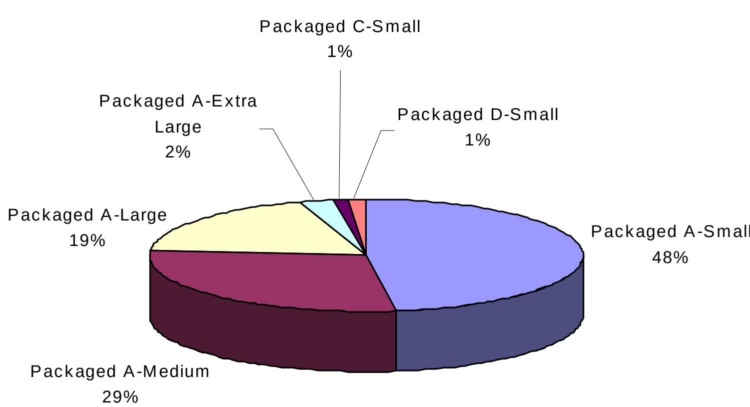

Figure 101: Distribution of Packaged System Types in Buildings with Packaged Systems

Figure 102 shows the year to year changes in the percentage of the total conditioned floor area that is served by different types of packaged systems. The percentage of the total conditioned floor area that is served by the small, medium and large packaged systems has fallen between 1994 and 1998. Conversely, the use of extra large systems has increased dramatically over this period, reaching a saturation of about 12% by 1998.

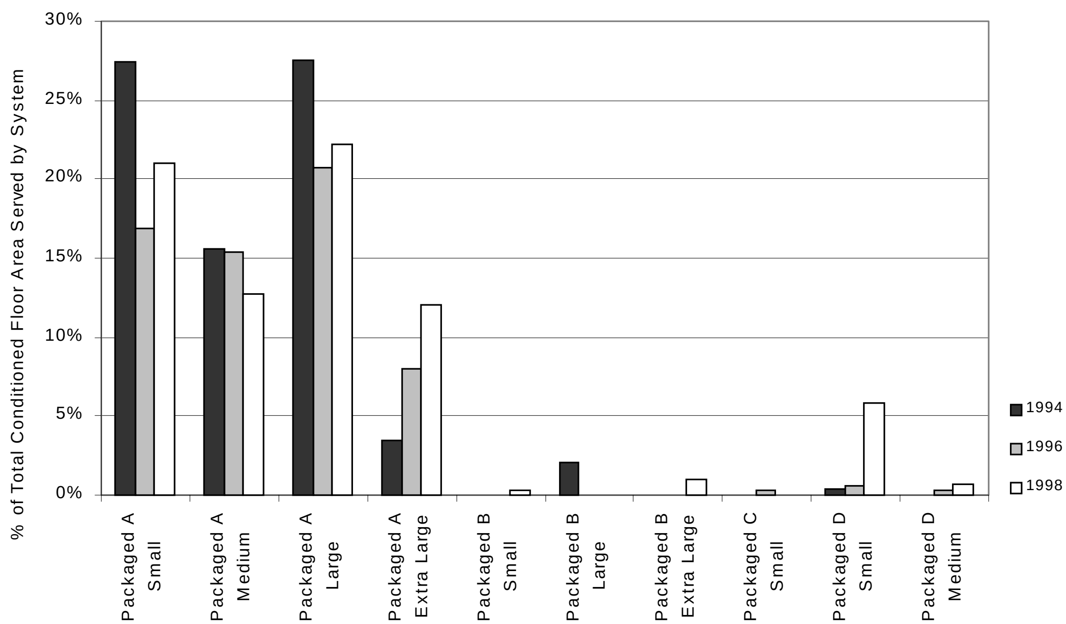

Figure 102: Percentage of Total Conditioned Floor Area Served by Packaged System Types

The average EER of Type A packaged HVAC systems is shown in Figure 103. The 1998 buildings have a higher efficiency for all sizes of type A packaged units. The data in this chart provides evidence that average efficiencies are improving over time, and thereby contributing to the improved cooling energy ratio.

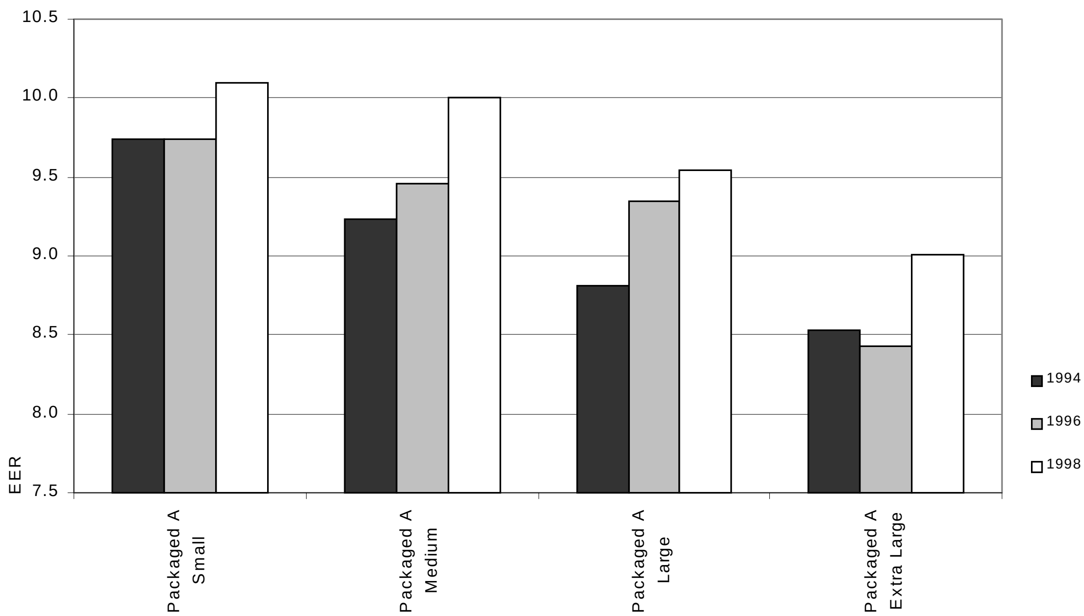

Figure 103: Average Packaged System Efficiencies by Year

Figure 104 shows the distribution of efficiencies for small system type A packaged systems. The Title 24 requirement for this type of system is 9.5 EER. Notice that almost half of the systems in 1994 are poorer than standard (Title 24 mandated) efficiency.

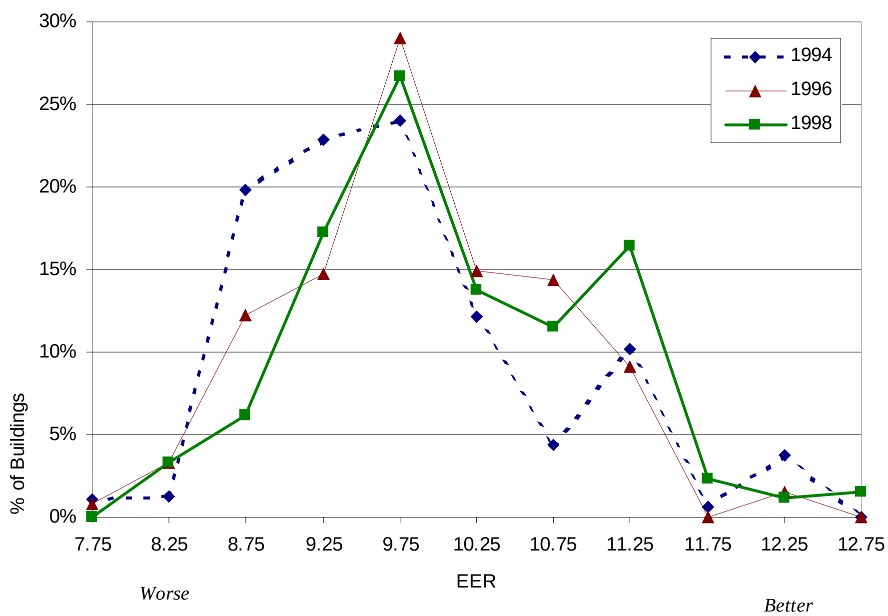

Figure 104: Distribution of Packaged System 'A-Small' Cooling Efficiencies (EER) by Year

Figure 105 shows the distribution of efficiencies for medium system type A packaged systems. The Title 24 requirement for this size of system is 8.9 EER. The percentage of sites that are below requirements has decreased from 1994 to 1998.

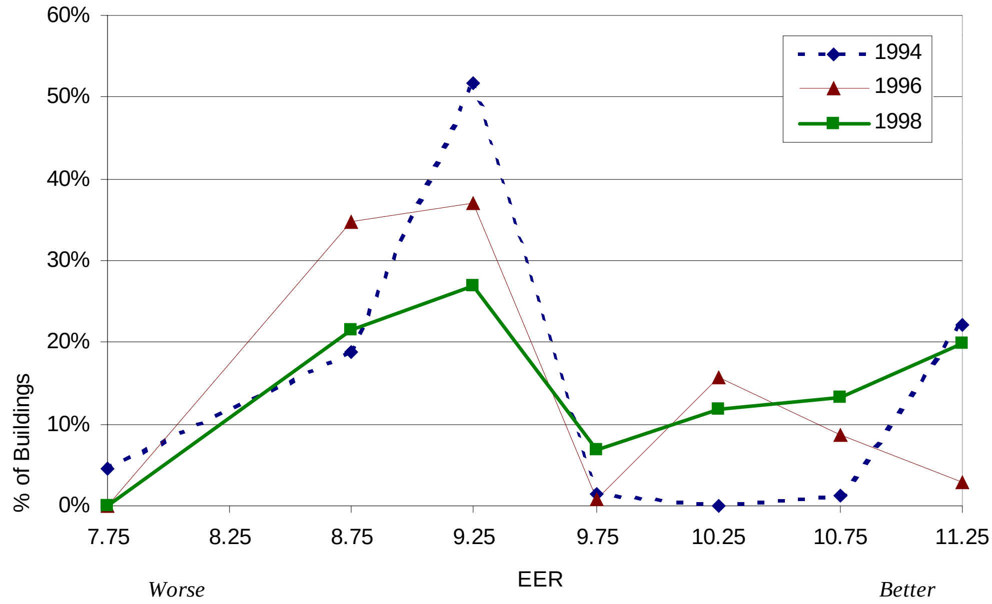

Figure 105: Distribution of Packaged System 'A-Medium' Cooling Efficiencies (EER) by Year

Figure 106 shows the distribution of efficiencies for large type A packaged systems. The Title 24 requirement for this system size is 8.5 EER. Figure 106 shows a striking improvement in efficiency in 1996 and especially in 1998. Newer systems typically have variable air volume and more sophisticated thermostat controls and sometimes multiple compressors that increase the part-load efficiency.

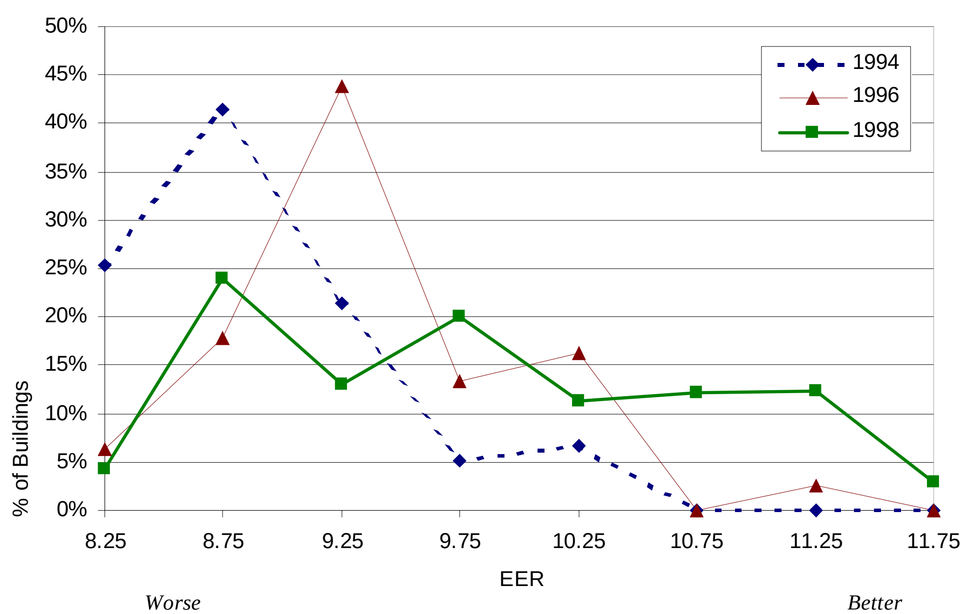

Figure 106: Distribution of Packaged System 'A-Large' Cooling Efficiencies (EER) by Year

Built-up Systems

The next section of this chapter looks at the efficiency of built up systems by year. Figure 107 shows the average efficiency of built up systems, measured in kW/ton. Here a small value is more efficient. The figure shows that the efficiency was practically constant from 1994 to 1996 but then improved by about 16% in 1998. This also helps to explain the improved cooling energy ratio.

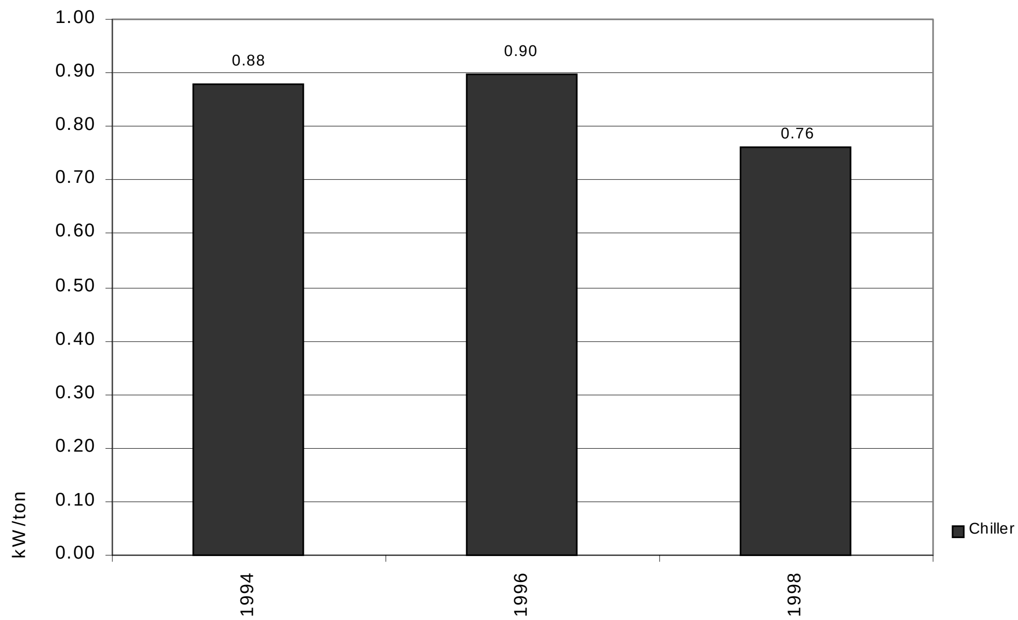

Figure 107: Average Efficiencies of Built-Up Systems by Year

However, Figure 108 shows that built-up systems were not common in the buildings that were sampled. Only 32 of our sample buildings had chillers. Twenty sites had water-cooled chillers and 12 had air-cooled chillers. Because of the small sample of chiller sites, we cannot definitively explain the reason for the changes in chiller efficiencies in the 1998 sample. However, our fieldwork suggests two possible explanations:

- Water cooled centrifugal chillers with efficiencies below 0.50 kW/ton were not available in 1994, but have become available in the last year and a half.[32]
- The Montreal Protocol, which mandated the removal from the market of ozone depleting refrigerants, has had the effect of increasing the market for complying chillers and possibly driving competition toward more efficient chillers.

[32] Communications with Carrier manufacturers representative and local consulting engineer.

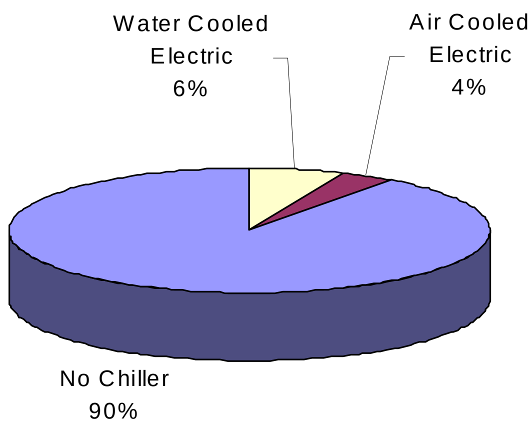

Figure 108: Percentage of Buildings with Chiller Types

TYPE OF SYSTEM	DESCRIPTION
ChillerA-*	Water Cooled Electric Chiller
ChillerB-*	Air Cooled Electric Chiller
	* = Size of System, range in tons
Small	0 < ton <= 150
Medium	150 < ton <= 300
Large	ton > 300

Table 24: Description of Chiller Cooling Efficiencies

Table 24 contains the description of the sizes and types of chillers for which data was collected during the scope of the study. The efficiency of chiller-based HVAC systems is shown in Figure 109. Most of the smaller water-cooled chiller systems, type A, have an efficiency of approximately 1.0 kW/ton. We see a wide spread of values because there are a range of efficiency requirements for chillers depending on chiller type. The higher kW/ton levels are primarily less efficient air-cooled chillers, which are type B. Type B systems shown in Figure 111 have an average efficiency of almost 1.0 kW/ton or greater for all years. However, the sample of sites with chillers is only 32.

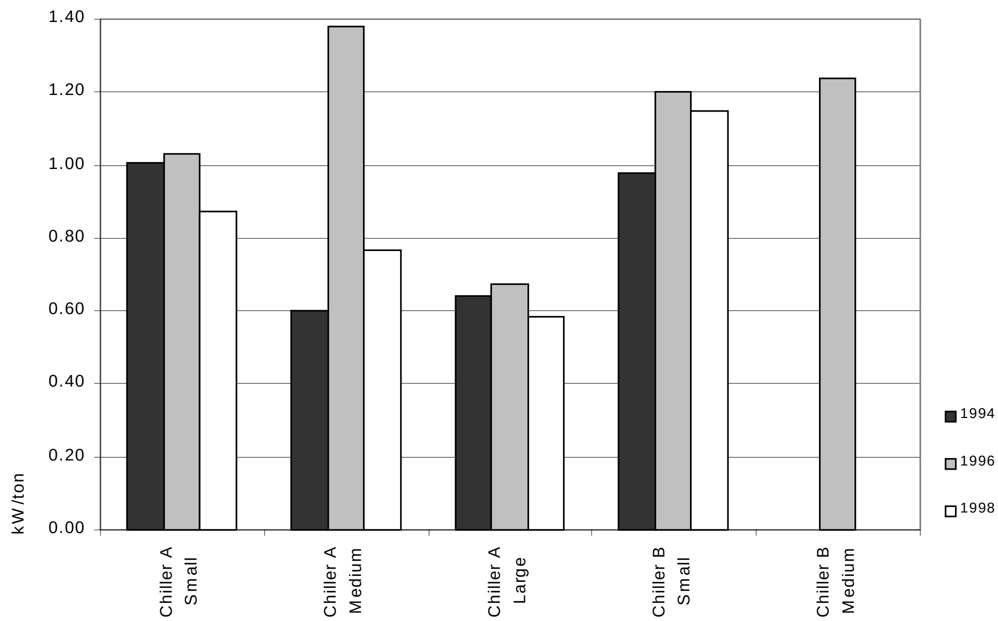

Figure 109: Average Chiller Cooling Efficiencies by Year

The distribution of chiller efficiency is shown in Figure 110 and Figure 111. The sizes of the chillers have been combined for presentation in the following graphs due to the small sample sizes. However, the large built up systems have cooling efficiencies which are generally 50 – 100% greater than the efficiencies of smaller systems, and will make up the sites on the right side of the graph, while the small systems will make up the sites on the left side of the graph.

The water-cooled chiller efficiencies are shown in Figure 110. These results suggest a trend in that the 1998 sites have the majority of the most efficient water-cooled electric chillers, while the 1994 and 1996 sites have the least efficient chillers. The 1996 sites have the widest range of system efficiencies, while 1994 sites have the smallest range. The large water-cooled chillers are typically more efficient than the other types and sizes of chillers.

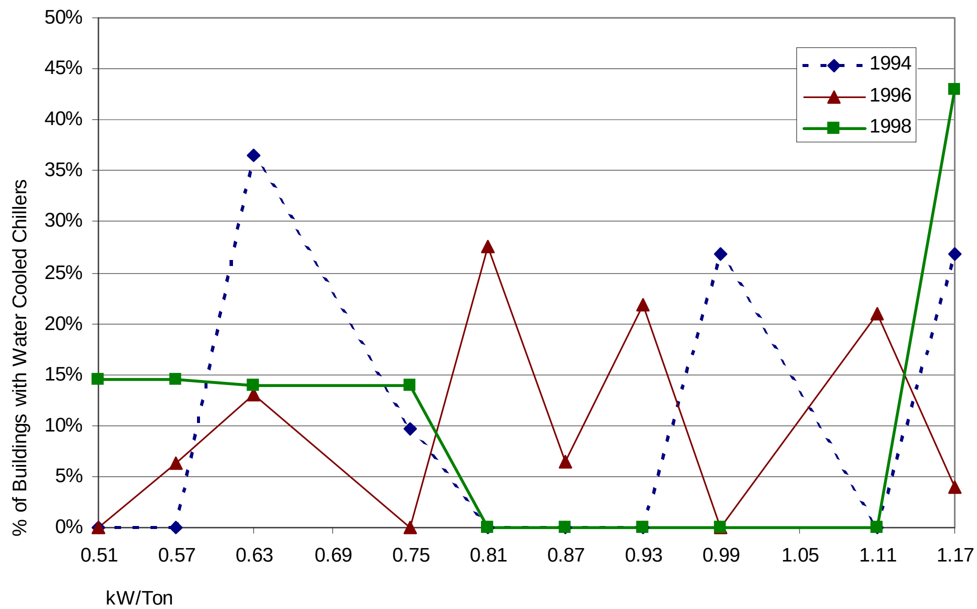

Figure 110: Water Cooled Electric Chiller Efficiency Distribution by Year

The air-cooled efficiencies are shown in Figure 111. Only 12 sites with chillers of this type existed in the sample.

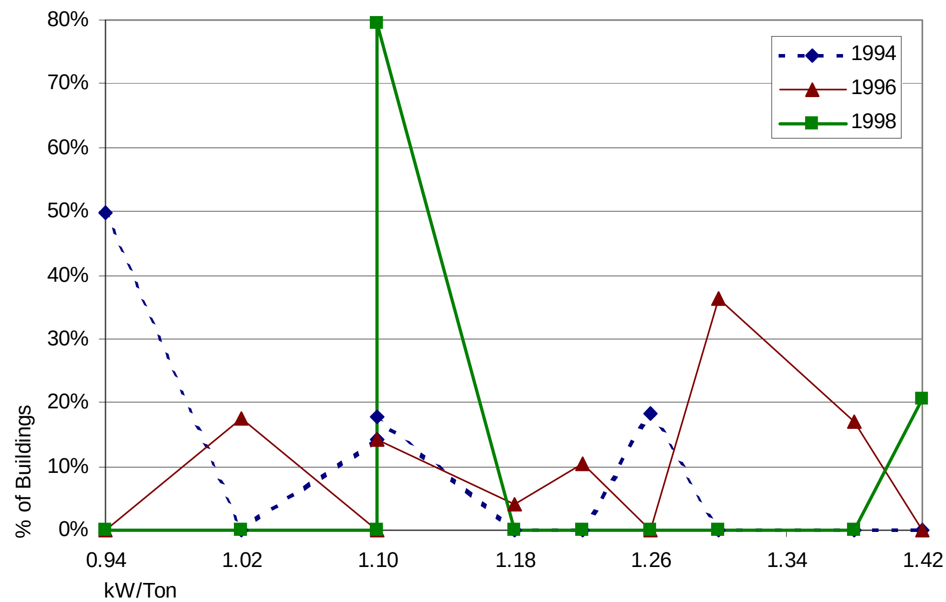

Figure 111: Air Cooled Electric Chiller Efficiency Distribution by Year

Figure 112 shows the cooling sizing ratio by year. The graph shows that the cooling sizing ratios were typically in the 0.7 to 1.3 range associated with appropriate sizing.

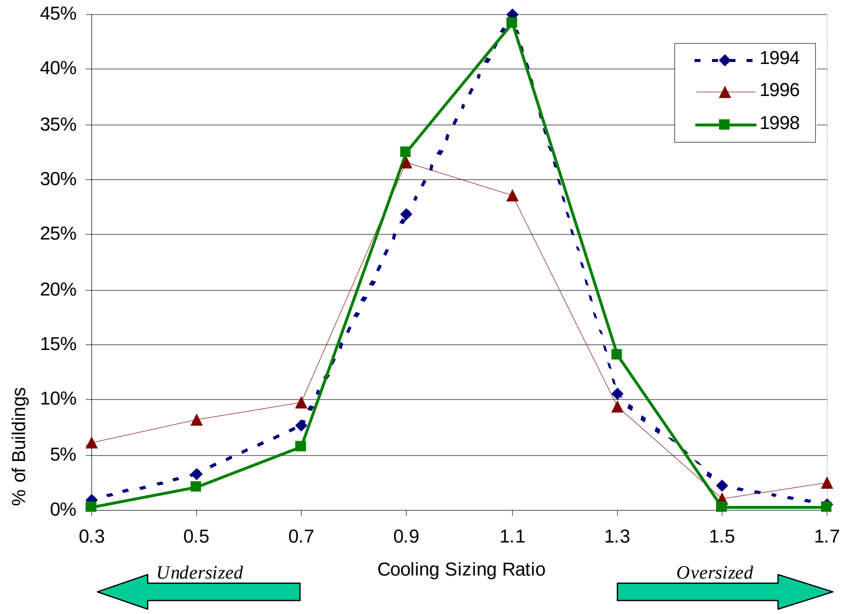

Figure 112: Cooling Sizing Ratio Distribution by Year

Building Type

Figure 113 shows the average cooling energy ratio by building type. The energy ratio for schools and offices is lower than that of the other building types.[33]

[33] The good energy ratio of schools is not, however, due to the fact that some schools are not open during the summer since the schedules have been controlled for in the energy ratios.

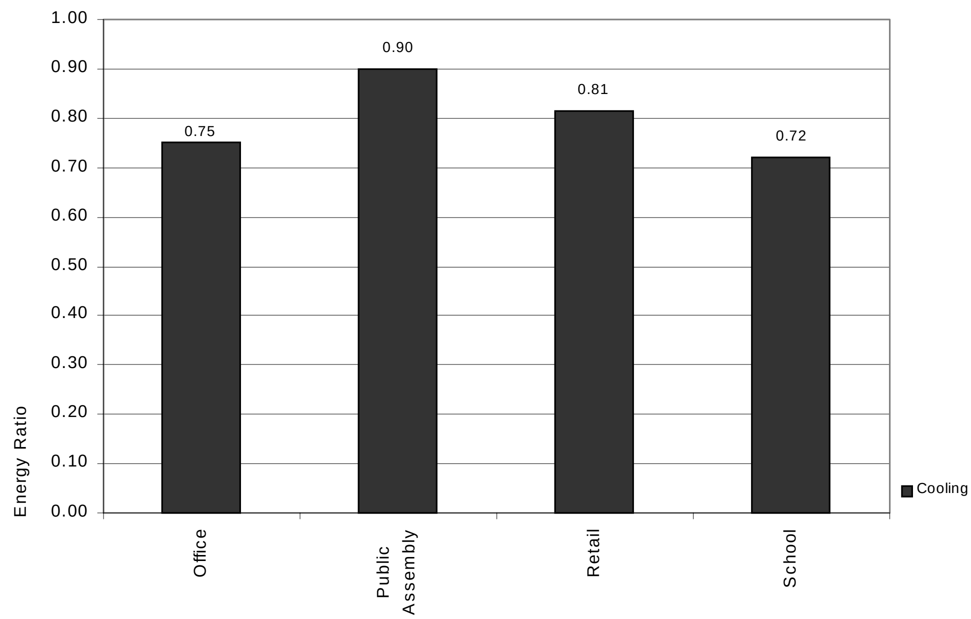

Figure 113: Average Cooling Energy Ratio by Building Type

Table 25 shows the more detailed information on cooling energy ratio by building type. Almost 95% of schools are better than baseline whereas only 70% of the public assembly buildings are better than baseline.

Building Type	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Office	40	80.6%	0.75	0.04
Public Assembly	39	70.7%	0.90	0.10
Retail	35	88.2%	0.81	0.06
School	29	94.7%	0.72	0.08

Table 25: Cooling Energy Ratio by Building Type

Figure 114 shows the distribution of the cooling energy ratio by building type. It is easy to see the high proportion of schools among the most efficient sites. Surprisingly about 5% of the schools and offices have poor cooling energy ratios. These sites may have systems that are oversized for future expansion.

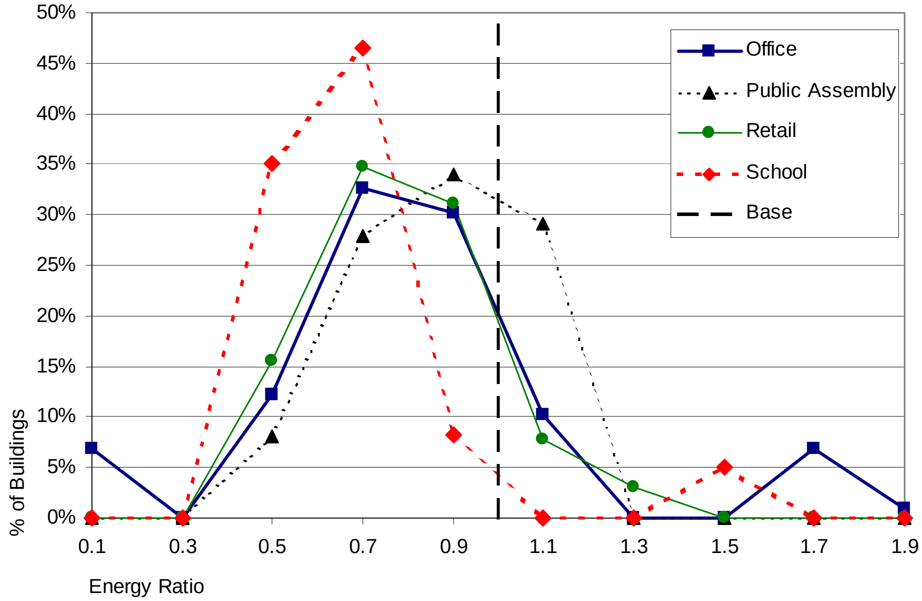

Figure 114: Cooling Energy Ratio Distribution by Building Type

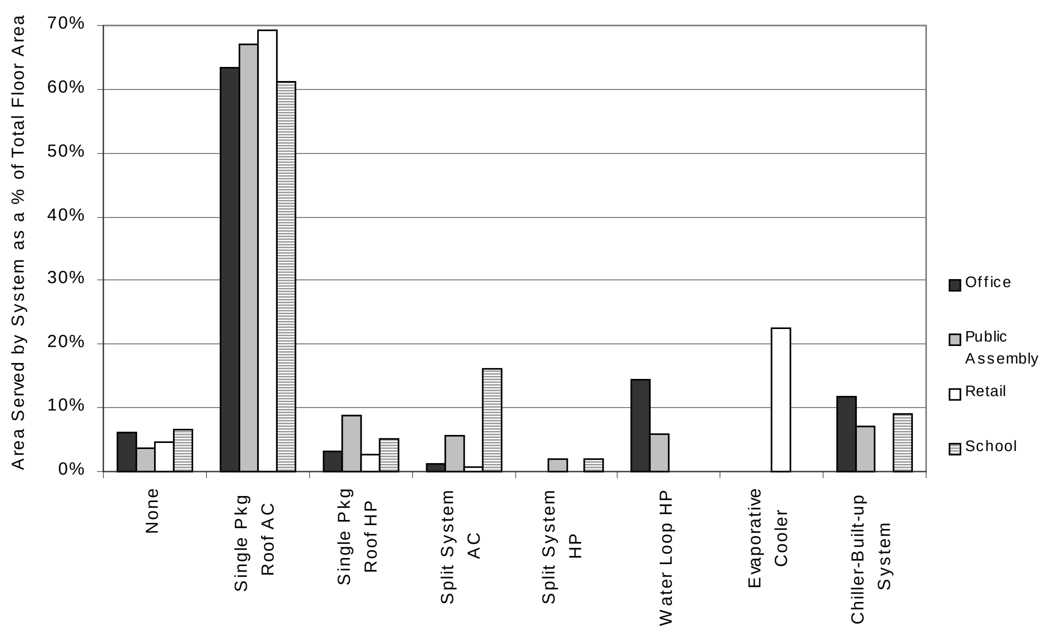

Figure 115: Cooling System Types by Building Type

Figure 115 shows the distribution of the type of cooling system by building type. Single packaged roof units dominate all building types. Evaporative cooling is being used in some retail buildings.

Figure 116 shows the cooling sizing ratio distribution by building type. The cooling sizing ratio is the ratio of the installed cooling capacity to peak cooling load. The graph shows that the majority of retail stores have a cooling sizing ratio that is very close to optimal. Schools and public assembly install units with a capacity just under their peak load.

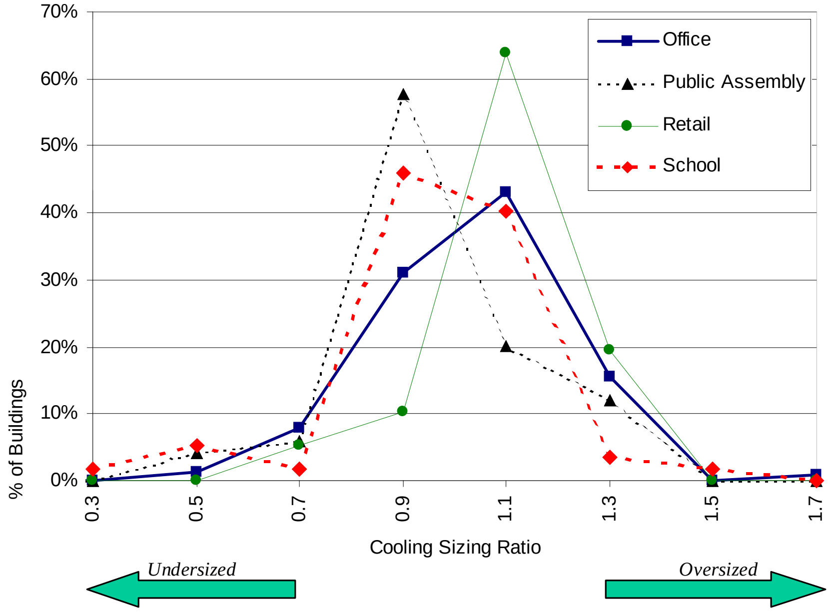

Figure 116: Cooling Sizing Ratio Distribution by Building Type

Ownership Type

Figure 117 shows the average cooling energy ratio by ownership. Once again, public buildings are lower energy consumers relative to baseline than owner-occupied buildings. The speculative sector has a slightly lower cooling energy ratio than the owner-occupied sector but the difference is not statistically significant. The corresponding statistics are shown in Table 26.

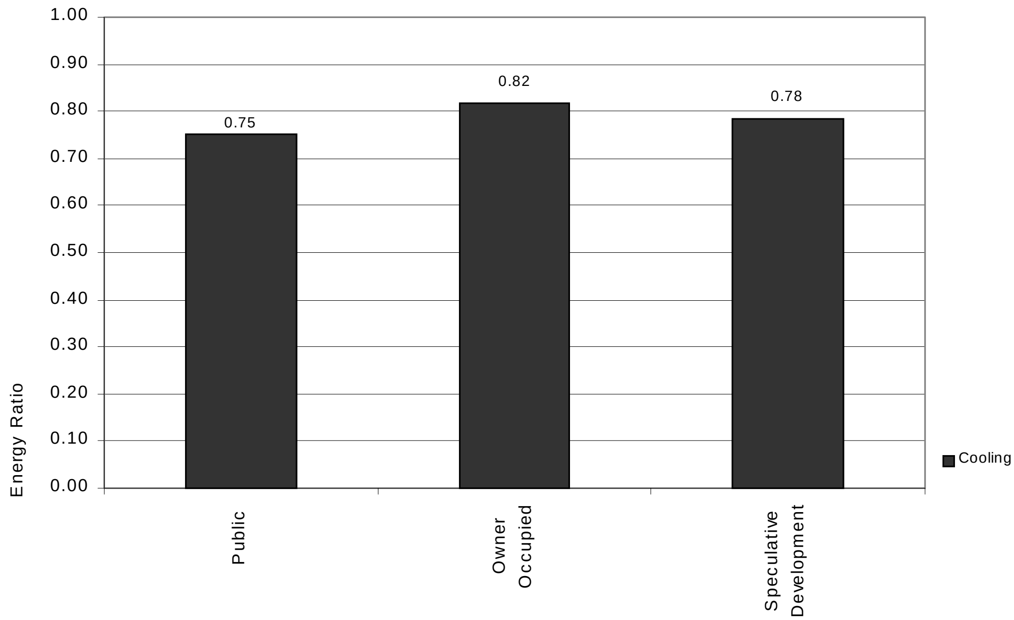

Figure 117: Average Cooling Energy Ratio by Ownership

Ownership	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Public	36	83.7%	0.75	0.08
Owner Occupied	74	80.2%	0.82	0.06
Speculative	33	88.3%	0.78	0.04

Table 26: Cooling Energy Ratio by Ownership

Figure 118 shows the distribution of the average cooling energy ratio by ownership. Public buildings dominate the most efficient ranges on the graph and speculative development dominates the least efficient ranges.

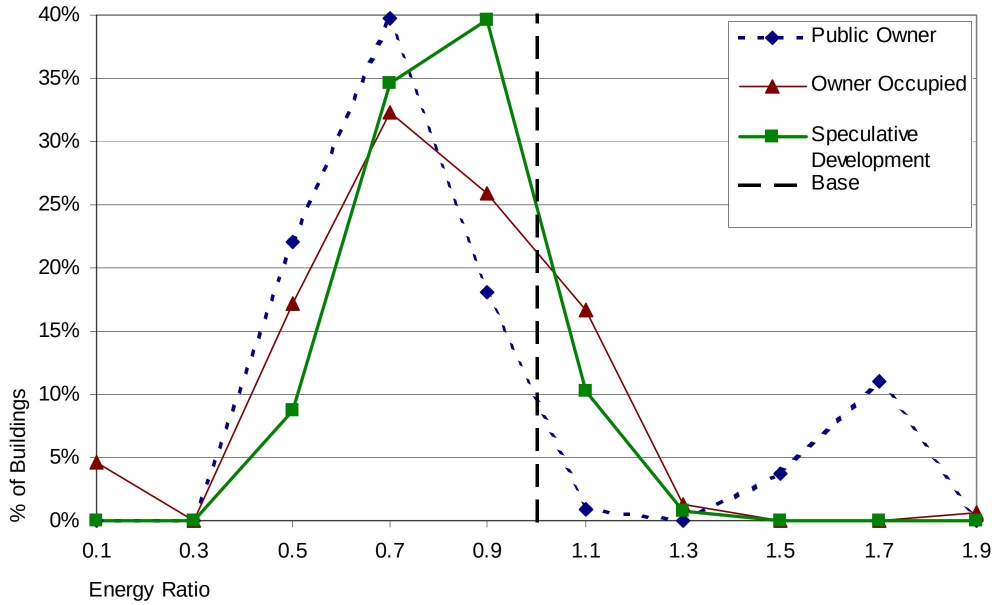

Figure 118: Cooling Energy Ratio Distribution by Ownership

Figure 119 shows the distribution of the cooling sizing ratio for each sector. This shows that the systems are sized slightly larger in the speculative development sector than in the other two sectors. On the other hand, the publicly owned buildings tend to be slightly undersized, on average.

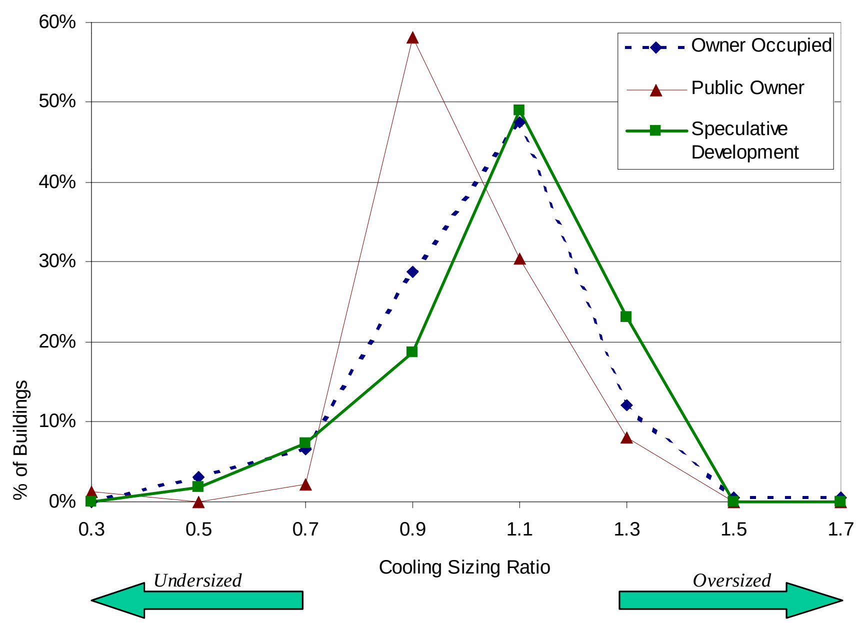

Figure 119: Cooling Sizing Ratio Distribution by Ownership

Fans

This section provides information on ventilation system fans. Ventilation systems are the fans that supply and return conditioned and outside air to building spaces. Cooling, heating, and ventilation systems require a supply fan, and in some cases, a return fan to move conditioned and fresh air. High efficiency and premium efficiency motors can be installed on these fans to increase efficiency. Adjustable frequency drives (AFD) also called variable frequency drive (VFD), are also used to increase fan energy savings. These drives control motor speed to correspond to varying load requirements resulting in optimized loading of the fan motor.

As mentioned previously, the lower fan energy can be a secondary effect of lowered lighting energy and cooling energy. Any influence on the lighting and cooling loads will also have an impact on the fan load. The fan energy can also be lowered by installing lower pressure ductwork, more efficient motors and VFD drives.

Fans are an integral part of the HVAC system, but the fan energy has consistently been separated out from cooling and heating energy in the simulations. In order to provide more detailed information on the energy savings of HVAC, the fans are analyzed separately from the cooling efficiencies, primarily for the following reasons:

- Fan energy is consumed in heating mode. However, heating systems are not being analyzed in this report since their impact on energy consumption in California is small.
- Fan systems operate at times when mechanical heating and cooling is not occurring (economizer mode, morning flush cycle).

Participant vs. Nonparticipant

Figure 120 shows the average fan energy use relative to baseline by program participation. In fan efficiency, participants appear to be more efficient than nonparticipants.

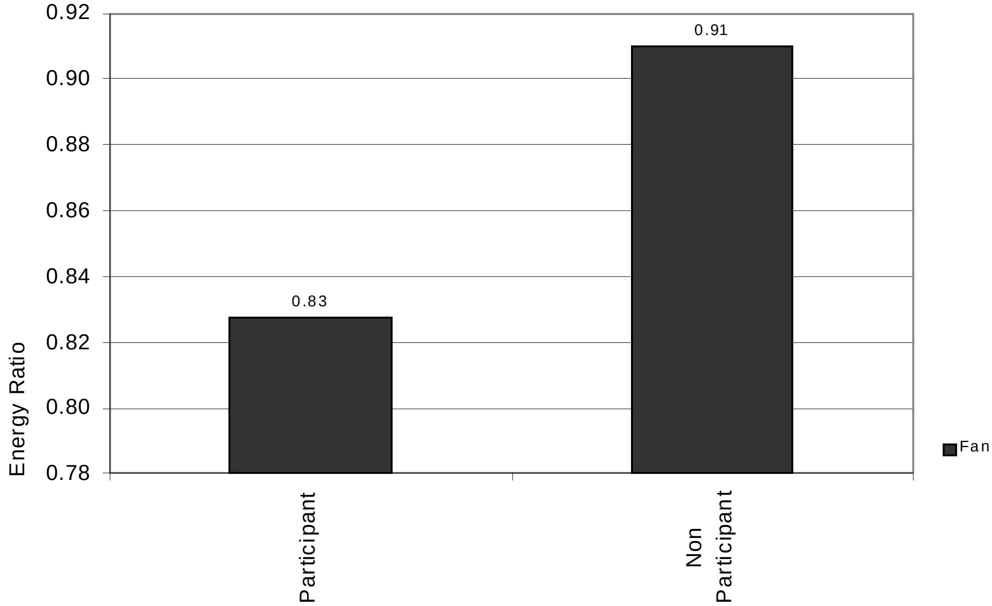

Figure 120: Average Fan Energy Ratio by Utility Program Participation

Program Participation	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Participant	254	73.8%	0.83	0.08
Non Participant	255	75.1%	0.91	0.03

Table 27: Fan Energy Ratio by Program Participation

Figure 121 shows the range of the fan energy ratio broken out by program participation. About 60% of the buildings, both participants and nonparticipants, have a fan energy ratio between 0.8 and 1.

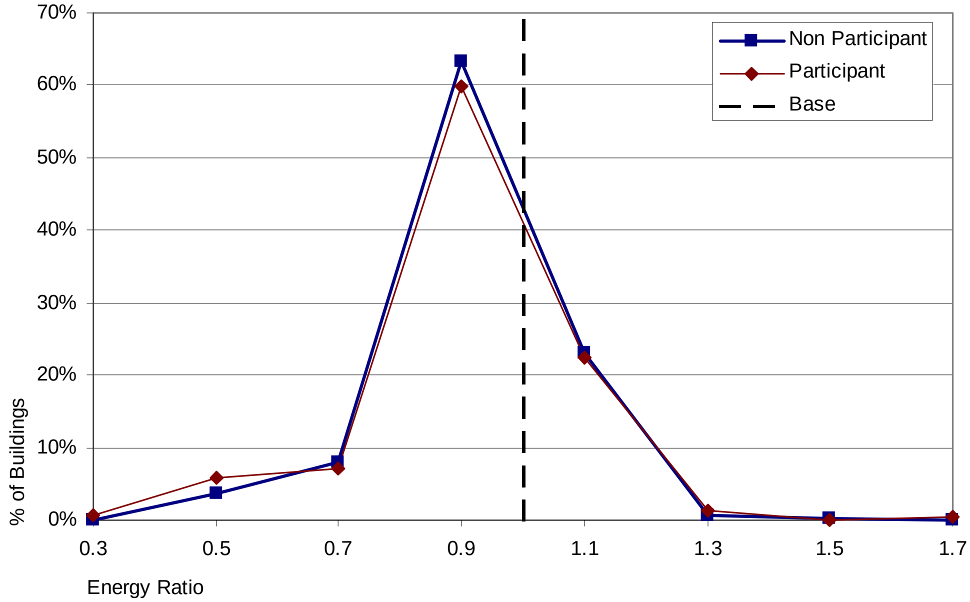

Figure 121: Fan Energy Ratio Distribution by Utility Program Participation

Time Trends

Figure 122 shows the average fan energy ratio by year. The fans seemed to have increased in efficiency between 1994 and 1996. Figure 123 shows the range of fan energy ratio by year. The savings in fan energy can be attributed to declining lighting loads

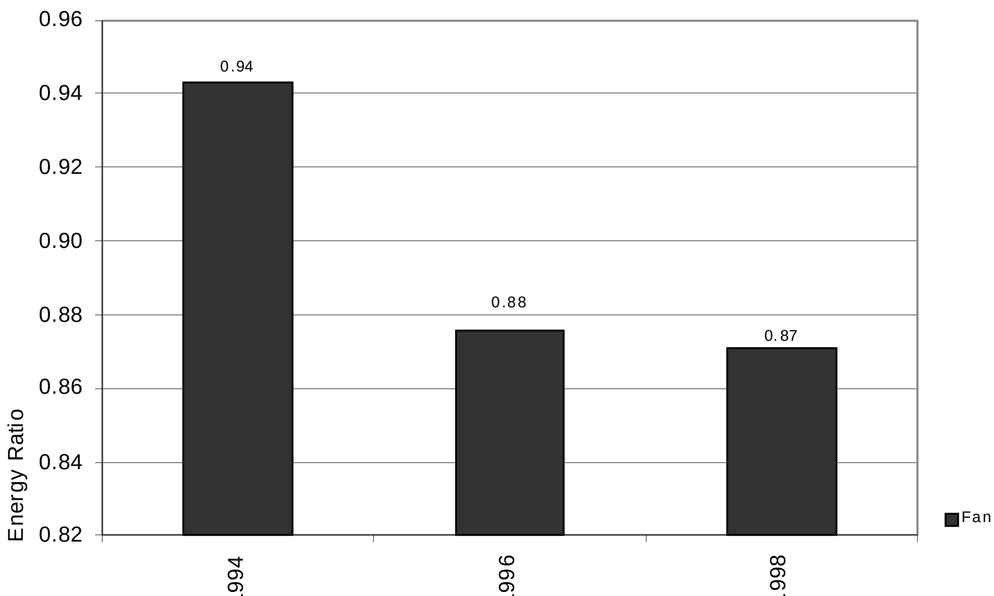

Figure 122: Average Fan Energy Ratio by Year

Year	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
1994	121	71.8%	0.94	0.04
1996	124	75.9%	0.88	0.04
1998	146	71.7%	0.87	0.06

Table 28: Fan Energy Ratio by Year

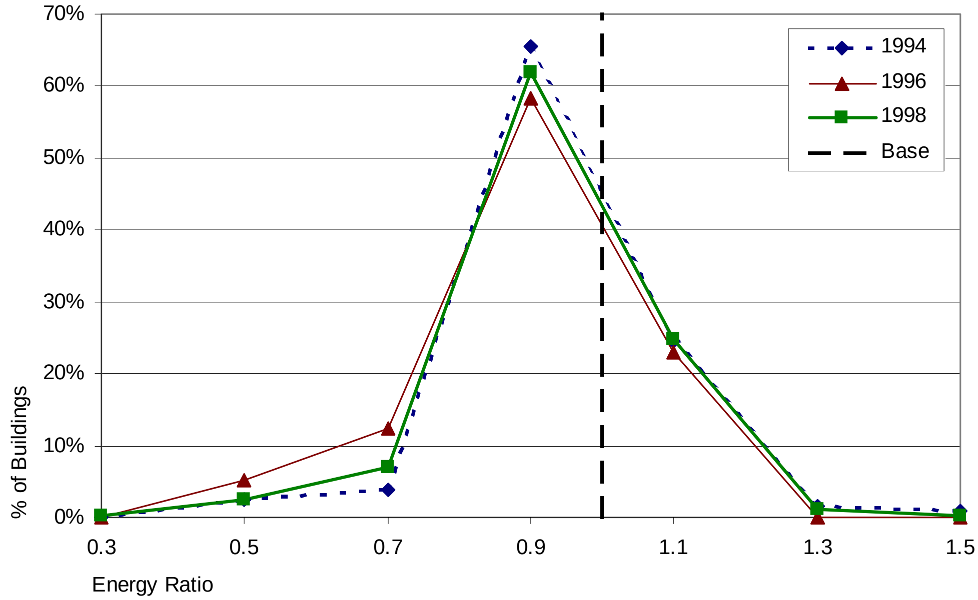

Figure 123: Fan Energy Ratio Distribution by Year

Building Type

Figure 124 shows the average fan energy ratio by building type. There is much less variation in the energy ratio among the fan end use by all market segments than the other end uses. The majority of the sites consume less than the baseline energy consumption. This can be attributed to the lighting levels, which are on average lower than baseline.

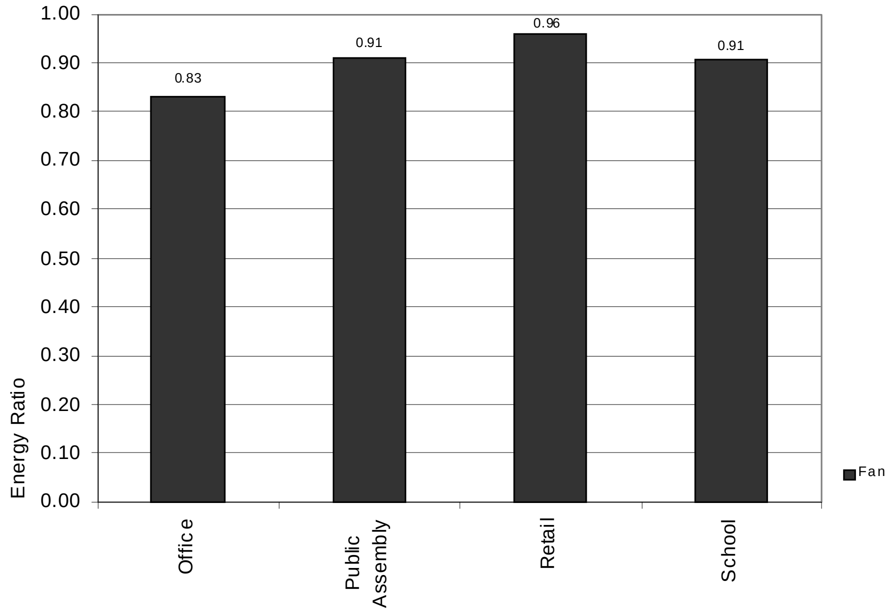

Figure 124: Average Fan Energy Ratio by Building Type

Figure 125 shows the range of fan energy ratio broken out by building type. The majority of buildings are in the interval 0.8 to 1, with far fewer buildings above 1.

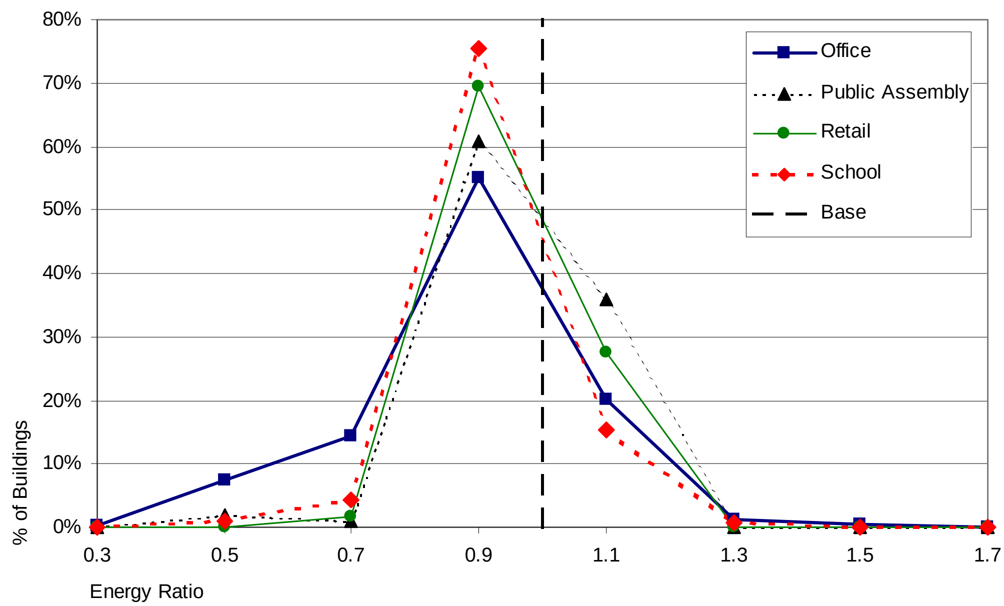

Figure 125: Fan Energy Ratio Distribution by Building Type

Table 29 shows the more detailed information on the fan energy ratio by building type. Schools have the highest percentage of sites that are better than baseline, however on average offices are the most efficient for fans. Figure 126 shows the proportion of ASDs in each building type sector. The higher frequency of ASDs in offices may contribute to the higher fan efficiency of offices, seen in Figure 126.

Building Type	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Office	228	77.1%	0.83	0.05
Public Assembly	103	63.6%	0.91	0.04
Retail	159	71.2%	0.96	0.02
School	165	80.8%	0.91	0.04

Table 29: Fan Energy Ratio by Building Type

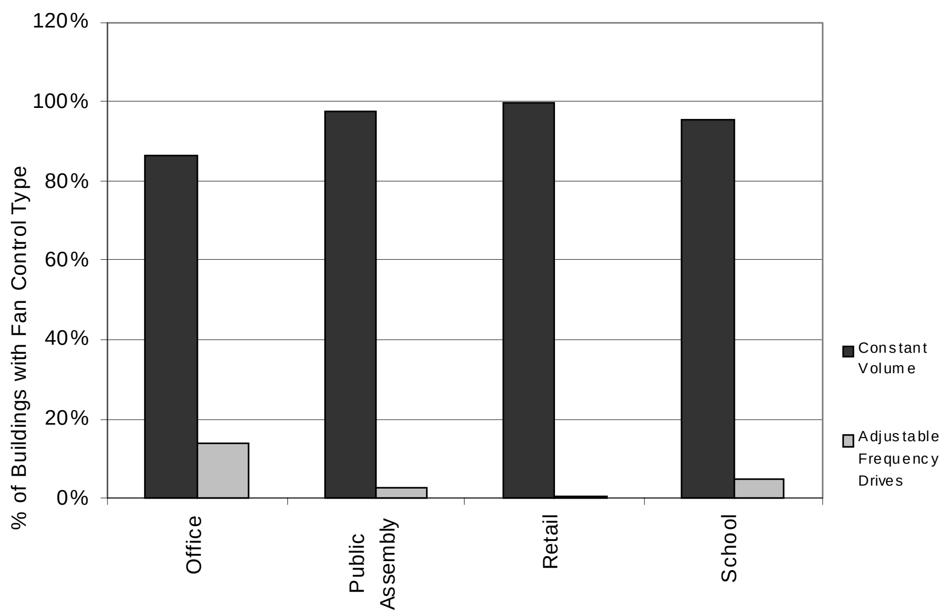

Figure 126: Percentage of Buildings with Fan Control Types by Building Type

Ownership Type

Figure 127 shows the average fan energy use relative to baseline by type of ownership. The speculative development buildings have a higher energy ratio than that of public and owner occupied buildings, implying that they are less efficient.

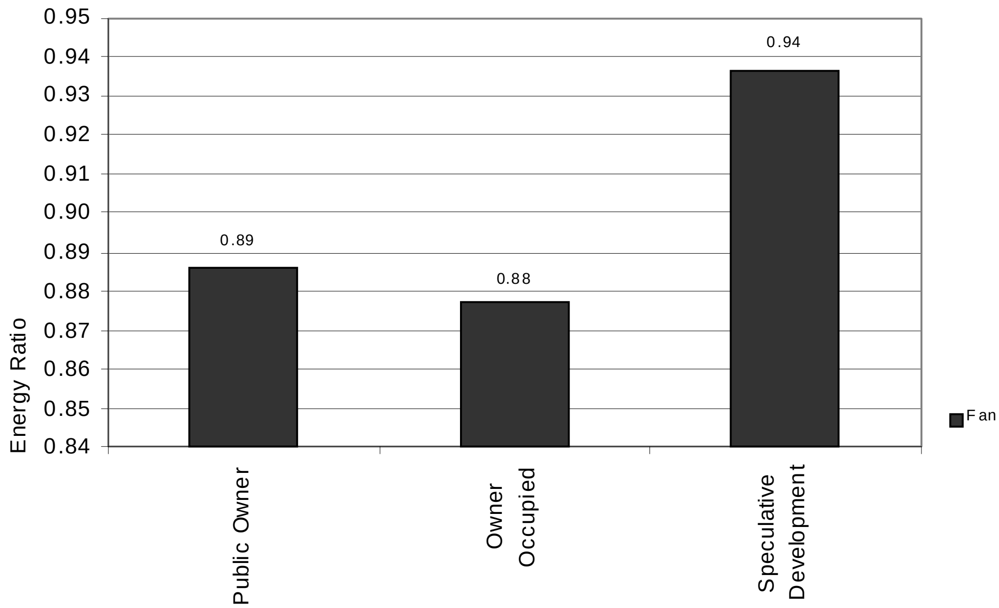

Figure 127: Average Fan Energy Ratio by Ownership

Ownership	Sample Size	Sites Better Than Baseline	Average Value	Error Bound
Public	212	76.6%	0.89	0.06
Owner Occupied	295	77.4%	0.88	0.04
Speculative	121	64.9%	0.94	0.05

Table 30: Fan Energy Ratio by Ownership

Figure 128 shows the range of the fan energy ratio broken out by ownership. Most of the sites here linger right below the baseline energy consumption level.

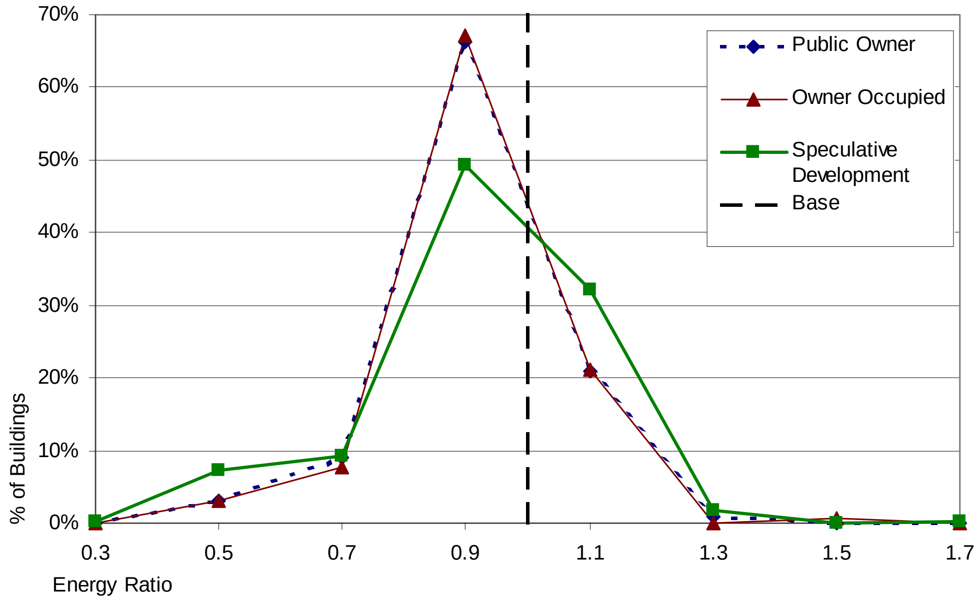

Figure 128: Fan Energy Ratio Distribution by Ownership

6. Recommendations for Further Research

In this section we will suggest some issues that ought to be addressed in a following study. These issues have been raised by the present study but were beyond the scope of our project. The following six suggestions will be discussed:

- Verification of Lighting Power Densities
- Lighting Quality
- Ancillary Benefits of Energy Efficiency
- Drivers of Best Practice
- Raising the Efficiency of Good Buildings
- Energy Impacts of Strengthened Codes and Best Practice

Verification of Lighting Power Densities

One important issue is the validity of the lighting power densities estimated in our audits. Our data shows that NRNC buildings in California have very low LPDs substantially below current Title 24 requirements. These low LPDs in turn appear to yield substantial energy savings. These results have import implications for formulating energy codes in California and elsewhere.

However these data may have measurement error since it is not easy to record LPDs accurately in onsite audits. Because of the importance of these data, there is need for additional verification of their accuracy. A follow-up study should be undertaken to verify the observed LPDs for a sample of our sites. The study should be designed to determine whether there was a measurement bias, i.e., a pattern of underestimating LPDs systematically.

Lighting Quality

A related issue is to measure the lighting quality of the sample of sites. It might be postulated that sites with low LPD have inadequate lighting quality. On the other hand, there is evidence that low LPD can be achieved without sacrificing lighting quality. A study should be carried out to determine both the objectively measured lighting quality and the occupant satisfaction with the lighting. If owners and designers can be shown that these highly efficient lighting systems are effective, then these systems may be more widely used. This study could best be carried out in conjunction with the LPD verification study.

Ancillary Benefits of Energy Efficiency

A broader question is to determine whether there is any relationship between the energy efficiency of the building and the level of comfort and overall satisfaction with the building among its owners and occupants. The findings of this study could help reassure architects and owners about the ancillary benefits of energy-efficient buildings.

Drivers of Best Practice

Another study goal would be to take a deeper look into the key drivers of the high levels of efficiency being achieved in some NRNC buildings. Is the high performance the result of high owner interest and commitment to energy efficiency? Is it driven by the use of design teams and optimal energy design practices? Or is it accidental? Understanding what drives the design of the best buildings may be a key to effective market interventions.

Raising the Efficiency of Good Buildings

A closely related issue is how to best raise the efficiency of building that exceed Title 24 requirements but are less efficient than the best buildings. In other words, how can good buildings be induced to become excellent buildings? Are there differences in the design process of the good buildings and the best buildings?

Energy Impacts of Strengthened Codes and Best Practice

What is the impact of the higher Title 24 lighting requirements currently being introduced? What is the potential energy impact if more buildings were built to best-practice standards? How much do more stringent lighting requirements contribute to the cooling and fan savings?

Synergies between these Issues

The studies are synergistic in the sense that they all take advantage of the current database of 990 audits and simulations. This database can be invaluable in ensuring that the studies are looking at the most relevant and informative buildings. Since the characteristics and efficiency of each building are known, the studies can focus on learning how and why each building came to be that way.

However, it is important to recognize that the various studies may be directed to different subsets of our sample. The lighting verification study can either use a representative sample of sites or a balanced sample of sites with low and high LPDs .[34] The study of lighting quality is probably best done in the same sample as the LPD verification study.[35] The ancillary benefits study should also be done in a balanced sample of sites with low and high energy efficiency. It might be useful to stratify the sample design by lighting savings and non-lighting savings. The lighting component of the sample may be the same as the LPD verification and quality study. But the sample may be augmented by a non-lighting component.

The best practices study can use the same sample as the ancillary benefits study. The good-buildings study is different in that the intent is to compare the best buildings with

[34] It is tempting to verify the low LPD sites only since these are the ones that are most questionable. But, since some random measurement error is inevitable, the sites with low measured LPD would tend to have negative measurement error. The best way to avoid this type of selection bias is to verify a representative sample. An alternative approach might be to use a carefully balanced sample of sites with either low or high LPDs.

[35] Again it might be tempting to focus the lighting quality study on the sites with low LPDs. However, the findings are likely to be more valid with a control group comprised of sites with high LPDs.

the good buildings. For this purpose, a good building can be defined as one near the median level of efficiency – rather than at either extreme.

Finally, the energy impacts study is different in that it does not require additional fieldwork. This study can be carried out by performing additional DOE-2 simulations on the existing sample of buildings. Additional parametric simulations should be run that raise the characteristics of our sample of buildings to the energy-efficiency levels of the best buildings in our sample. In other words, the as-built simulations should be compared to a best-practices baseline determined from our actual sample. An added series of parametric simulations should be carried out to quantify the impact of the current upgrade to Title 24 lighting requirements. New simulations should be run and analyzed with the higher lighting baseline. Finally a series of parametric simulations should be run to separate the interactive lighting effects from the efficiency improvements in cooling.

More important each of these studies will reinforce and strengthen the others. The lighting verification and quality studies are needed to validate our most important findings. Lighting is the single most important factor in achieving high efficiency. If the LPDs are accurate and the lighting quality is satisfactory in our best buildings, then this strengthens the support for more rigorous Title 24 lighting requirements and should encourage designers and owners to adopt these measure more frequently.

A better understanding of the ancillary benefits of energy efficiency, the drivers behind the best buildings, and the differences between these buildings and the good buildings may all provide added clues on how to intervene in the market more effectively to encourage the best practices. Understanding the potential energy impact can also help strengthen public support and commitment. Moreover the additional simulation results can be used in the design of the field studies.

7. Appendices

A series of technical appendices will accompany the main report for readers who wish to delve more deeply into these data:

Quantitative Survey of Market Actors

A detailed description of the methodology used to develop these data and the documentation of the resulting database. This appendix also discusses our experience in using the Internet to collect these data.

Audit and Modeling Methodology

A detailed description of the procedures used to develop the information about NRNC buildings, including the recruiting , auditing and modeling methodology.

The Buildings

The methodology used to develop the case weights for the sample buildings and further information on the schedules estimated from the buildings database.

The NCNC Buildings Database

Technical documentation of the buildings database developed in this study. This documentation provides the information needed to extract additional technical information from the database.

The MBSS Analysis Tool

Documentation of the software that has been provided with the buildings database.

Instruments

All of the data collection instruments used in the study.