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Baseline Study for Assessing the Pacific Gas and Electric Daylighting Design Tools

A Report Prepared for
Pacific Gas and Electric Company

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Executive Summary

This study of PG&E's Daylighting Design Tools provides a detailed assessment of the operations of the commercial building design community in Northern California and a baseline for daylighting related design practices. In addition, the study provides an assessment of the market potential for four daylighting design tools that PG&E is developing, Desk Top Radiance, SkyCalc, Daylighting Prospector, and Artificial Sky. Desk Top Radiance is a 3D rendering tool. SkyCalc is designed to assist building professionals in assessing opportunities for skylighting. Daylighting Prospector is designed to assist users in identifying opportunities for daylighting control. Users can test models using hemispherical lighting conditions generated by Artificial Sky. These tools will be ready for deployment or will be ready by the Fall of 1999.

The goals of this study are to identify:

- The target audiences, particularly the types, number and characteristics of actors interested in these products
- The functions of the Daylighting Design Tools
- Actors' decision making criteria and current patterns of influence among actors
- Current (baseline) market practices so that changes to the market resulting from the introduction of these products into the lighting market can be assessed
- Barriers to the introduction of these products
- The potential for these products to influence the market
- The potential for these products to be adopted into the market
- Market effects measures that will allow changes in the use of these products to be tracked in the future

This study is based on interviews with PG&E staff, 30 in-depth one-to-one interviews with building professionals lasting between 30 minutes and an hour and a half, and a telephone survey of 201 randomly selected building professionals in Northern California. The telephone interviews lasted from 15 minutes to 40 minutes or more.

Daylighting, defined as the intentional integration of elements of building design and artificial and natural lighting to provide visual comfort, aesthetics, and reduced energy usage, is used in the Northern California commercial buildings market. However, its use is not widespread and the careful integration of building design and lighting controls to provide quality lighting environments is done only a small percentage of the time.

Building orientation and architectural features are seldom analyzed in relation to daylighting. Architects rarely consider daylighting in their design practices and often indicate that this is the role of electrical engineers or lighting designers.

Title 24 drives most lighting decisions. Most lighting professionals treat Title 24 as the target rather than a minimum threshold. Daylighting is rarely used as a method for meeting or surpassing Title 24 requirements. While cost is often cited as a reason for not using advanced daylighting practices, building professionals say that meeting Title 24 standards, the reliability of the lighting system, the functionality of the lighting, the energy efficiency of the system, the physical appearance of the fixtures and the equipment, and the ease of maintenance, are all more important than cost in their decision making.

Many professionals incorporate skylights in their designs but these skylights are often used for aesthetic reasons in special spaces. Skylights in general work areas show up in 13 percent of new Northern California structures but lighting controls are integrated with the skylighting systems only about half the time. With the exception of motion controls, lighting system controls are not being widely used. Engineers cited high initial cost as a key barrier to the adoption of more advanced lighting designs.

This market assessment suggests that there are fewer than 2000 key firms that PG&E should be targeting as it markets the Daylighting Design Tools. The key players are not necessarily architects. For instance, for retail chain stores, PG&E may have to reach the building professionals working for the chain or the firm that is responsible for the building image design for the retail chain in order to gain greater acceptance of daylighting practices. Local architects and engineers are often hired to "manage" the construction of chain stores. The local architect and engineer are a target audience for PG&E's tools but their role may be limited to "pulling" the technology into the market rather than "pushing" the technology.

Major barriers to daylighting are the disciplinary boundaries of the key market actors and the timing of the analysis and design of the lighting system that often act to prevent integrated solutions. For example, architects see their role as one of dealing with the physical and aesthetic aspects of design. From their perspective, lighting is generally the province of lighting designers and electrical engineers. They may not consult with lighting designers or engineers when determining building orientation because they do not perceive their input as being important at that stage of the project. The data from this study suggest that lighting design professionals only have meaningful influence and contribute to interdisciplinary decision making in a small percentage of cases.

Professionals tell us that they use simple rules of thumb in their preliminary analyses as opposed to complex analysis tools. A simple tool that allows analysis of lighting patterns early in the design / build process might lead to the increased integration of physical building and lighting design.

Most architects are currently using 3D CAD rendering for presentation purposes and would welcome a rendering tool that is easier to use than the ones they are currently using. Rendering to evaluate internal light and shadow effects is mostly used to examine special situations such as control rooms, restaurants or lobbies. Lighting designers are more likely to use it to display their work than are architects or electrical engineers. Physical models and mock-ups are not used for the vast majority of building projects.

There is significant interest in three of the Daylighting Design Tools being developed and introduced by PG&E, Daylighting Prospector, Desk Top Radiance, and SkyCalc. While the majority of building professionals use AutoCad, the fact that some use a version of AutoCad earlier than 14.0 may, in the short-term, serve as a barrier to the use of Desk Top Radiance for some building professionals.

There is limited interest in the fourth tool, Artificial Sky. The interest in Artificial Sky is focused on testing and developing new designs, and in overcoming technical or design acceptance problems.

The key motivations for using the design tools are to model, test, and confirm designs; design, evaluate, analyze and test new ideas and their performance; show and demonstrate designs to clients, and to save energy and / or money. Reasons for not using design tools are that market players do not do the type of work that requires it, they do not generally use software tools, or there is a lack of interest on the part of clients.

Based on this study, we believe that Daylighting Prospector, Desk Top Radiance, and SkyCalc have the potential to become important resources for building professionals in the Northern California market place.

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Chapter 1. Introduction

Purpose of the report

In 1996, the California state Assembly Bill 1890 (AB1890) established a uniform funding mechanism for ratepayer funded energy efficiency programs and charged the California Public Utilities Commission (CPUC) with overseeing the mechanism. Subsequently, the CPUC established the California Board for Energy Efficiency (CBEE) to advise it on how best to provide public purpose energy efficiency programs in California.

In addition, the CPUC Decision (D.) 95-12-063 calls for public spending to shift towards activities that will transform the energy market (Eto et al. 1996). Based on the utility performance award mechanisms approved in D. 97-12-103 and updated in Resolution E-3555, adopted July 23,1998, for the 1998 Energy Efficiency programs, the CBEE has directed PG&E to use Public Goods Charge (PGC) funds to perform Market Baseline and Transformation Studies on the 1998 energy efficiency programs. The present study represents an evaluation covered under that directive. There is currently no regulatory verification plan in place for these studies. PG&E and the CBEE will use the results of these reports as appropriate to augment and refine future programs.

Program Overview

A recent study of emerging technology and practices in the building sector concludes that energy saving opportunities appear to be the most pronounced in three areas, HVAC, lighting, and integrated new building design. Based on the analysis of technologies and practices included in the study, the highest potential savings for building energy use in the year 2015, about 4.5 percent of the savings from all technologies, is projected to be from integrated commercial building design (Nadel, et. al., 1998). In order to be able to reap these savings, the integrated building technologies and practices will have to be developed and the technologies will have to be diffused to the market and adopted by practitioners.

Currently, PG&E is attempting to address both the technology and the diffusion issue by developing analysis and information tools that will enable building professionals to increase the energy efficiency, occupant comfort and value of commercial buildings they design and build. PG&E's goal is to create and deliver tools that will find acceptance in the day-to-day world of practitioners. Greater use of such tools will provide architects and designers with increased confidence in their evaluation of lighting design and daylighting options which, in turn, is expected to lead to changes in design practice. PG&E’s intent is to transfer these tools to users in order to effect changes in design practice that will increase the use of efficient lighting and daylighting in designs.

PG&E's short term objectives are to:

- create a viable set of products and an allied set of educational offerings
- transfer the products to the marketplace
- encourage others to become partners in the continuing development of these products and the market.

The tools are now in advanced stages of development and are ready for deployment or will be ready by the Fall of 1999.

Research Goals

This report is a market baseline for the PG&E Daylighting Design Tools. The goals of this report are to identify:

- The target audiences, particularly the types, number and characteristics of actors interested in these products
- The functions of the Daylighting Design Tools
- Actors' decision making criteria and current patterns of influence among actors
- Current (baseline) market practices so that changes to the market resulting from the introduction of these products into the lighting market can be assessed.
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Overview of the methods and research activities

Several data collection methods were used in this research. The first is the analysis of secondary data. These data are primarily from F. W. Dodge and represent data about construction activity in Northern California in 1997 and 1998. In addition, we have obtained and examined the lists of registered architects and electrical engineers in California in 1998.

The second source of data is 30 one-to-one interviews with architects, electrical engineers and lighting designers. The respondents are from a stratified random sample of firms representing four different levels of participation in the market based on the 1997 and 1998 F. W. Dodge data.

These interviews were conducted on-site at the respondents' premises. The interviews lasted from 30 minutes to an hour. The interviews were open-ended but were conducted using a protocol.

The third source of data is a random telephone survey of 201 building professionals including architects, electrical engineers, lighting designers, energy consultants, and others. The survey was conducted in May of 1999. The survey lasted from 15 to 40 minutes or more depending on the respondent.

The content of the survey focused on:

- Identifying the key and supporting players in the daylighting market
- Identifying criteria that inform decision making
- Determining current lighting and building design practices that are related to daylighting
- Assessing the current use of tools
- Assessing the potential that respondents might adopt and use the Daylighting Design Tools

The survey was also designed to collect firmographic and demographic information.

Data from all these sources have been synthesized to create this market baseline report.

Overview of the report

In the next chapter we describe briefly describe the Daylighting Design Tools. Chapter 3 provides a set of concepts that inform this research. The first of these concepts is the diffusion of innovation. The second is a concept that characterizes daylighting which forms the basis on which the survey was constructed. Chapter 4 describes how we went about collecting the data that are used in the report. Chapter 5 characterizes our target audiences. Chapter 6 describes what we learned about the structure of the market and the state of the market from our one-to-one interviews. Chapter 7 discusses who makes decisions and the criteria that influence professionals' decision making. Chapter 8 provides a baseline of current market practices with respect to daylighting. Chapter 9 addresses the market potential for the Daylighting Design Tools. Chapter 10 describes methods for assessing the market transformational impacts of the Daylighting Design Tools in the future. Chapter 11 summarizes the barriers, key findings, and lessons.

Chapter 2. The Daylighting Design Products as Tools for Transforming Markets

Introduction

PG&E, through the Pacific Energy Center (PEC), has set out to create a suite of design tools that will enable the designer / specifier to increase the amount of analysis that is used in decision making that affect the performance and appearance of daylit spaces. The tools include Desktop Radiance, Artificial Sky, SkyCalc, and Daylighting Prospector. this chapter briefly describes these tools. PG&E has also developed a set of information tools which are the subject of a complementary report.

Desktop Radiance

This tool builds upon an earlier tool, Radiance, which produces a high quality 3-D rendering of a spatial location viewed from a specific point. The purpose of the new software, Desktop Radiance, is to link a widely used computer aided drafting (CAD) package, AutoCAD, to Radiance, thereby eliminating the need to laboriously enter data into Radiance by hand.

Desktop Radiance translates information about AutoCAD objects into a format that can be used by Radiance. The ability to run Radiance using data from electronic design drawings represents a significant improvement in usability and reduces a significant barrier to the use of Radiance, the time required to input the data. The output of Radiance is a near photographic quality rendering of a space based on accurate estimates of illumination. The accuracy of Desktop Radiance is significantly better than for other contemporary rendering packages and offers designers and engineers the opportunity to use the output to evaluate different architectural designs and to assess different lighting alternatives prior to finalizing the design of a building.

Artificial Sky

This is a physical sky simulator facility that is being rehabilitated and upgraded. The upgraded facility allows users to create accurate and repeatable hemispherical light distribution patterns to simulate standard skies. Used in conjunction with physical models, the simulator can be used to evaluate lighting and shading effects in buildings. Because lighting conditions are repeatable, it is possible to experiment with design elements and options under the same conditions.

SkyCalc

This tool permits the user to estimate the savings from skylighting alternatives in "big box" stores that represent an estimated 70 - 80 percent of the single story commercial building market in California. Given some basic knowledge of the structure of the building, information about the configuration of skylights to be installed, and lighting equipment alternatives, one can calculate energy savings and cost effectiveness for a skylighting system.

Daylighting Prospector

Using roof top measurements of illumination, light level measurements taken in a specific location within a building, and information about lighting control hardware, this tool allows the user to determine cost effectiveness of a daylighting control system for a given space. The tool also can be used to evaluate daylighting alternatives. Further, this tool can be used in conjunction with Desktop Radiance outputs to evaluate the lighting and control system requirements and options for yet to be built buildings.

Chapter 3 A basis for understanding the market impact of the daylighting design tools

Introduction

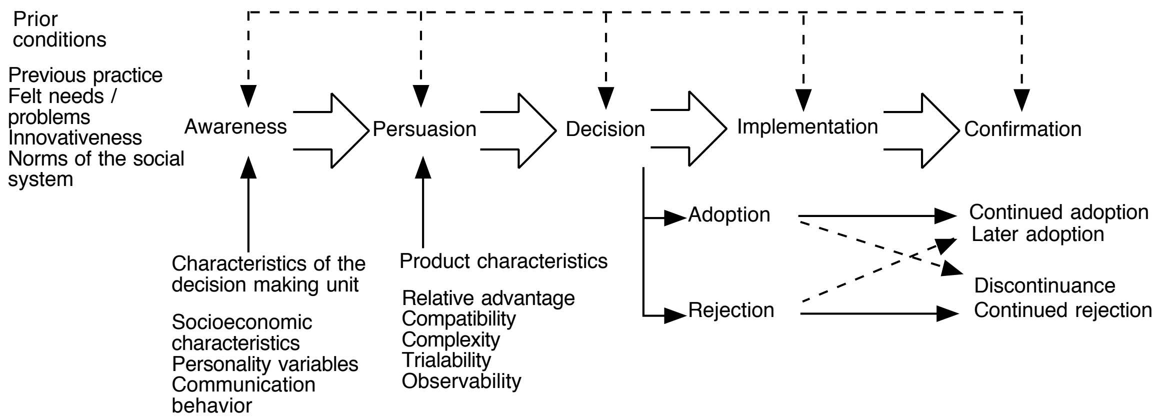
In this chapter we discuss the conceptual and theoretical underpinnings that we use to guide this research. First we discuss a concept of how innovations spread. We then describe in some detail the concept of daylighting that is used as a basis for determining the data to be collected and to measure it for use in this study.

A model for information and technology transfer

The challenge for PG&E is to get the client to accept the design packages they have to offer. Fortunately, we know a great deal about how to accomplish this.

Figure 1 illustrates a widely accepted model of the diffusion of innovations (Rogers, 1995). This model is based on a long research tradition and is programmatically oriented. The model defines a process by which market actors adopt a new innovation.

The first step in the process is that actors in a market must become aware of an innovation. Once awareness of an innovation is established, a market actor can at any point enter a persuasion stage during which the actor seeks and processes information in order to decide whether to adopt the innovation. The timing of the active portion of this stage is highly dependent on the individual and the context in which the individual is operating. At several points in time, the market actor may make a decision not to adopt, to postpone adoption, to postpone the search for information, to continue the search for information, or to adopt the new innovation. The persuasion stage is followed by a decision stage wherein the actor decides to adopt the idea. However, deciding to adopt and implementing the decision are separate acts that may occur at very different points in time. Therefore, we identify a separate implementation stage in which the actor enacts the decision. Finally, actors reevaluate or confirm their decisions to adopt and / or their implementation of the adoption.



Source: Rogers, 1995.

Figure 1 Model of innovation diffusion

The time frames for adopting an innovation can be compressed or fairly lengthy. For example, awareness of an innovation may precede the decision to adopt by months and / or years. Rogers (1995) has data showing awareness preceding the adoption of hybrid seed corn by about 1.7 years for early adopters and by as much as 3.1 years for later adopters. Further, the decision to adopt and the implementation of the decision are separate acts and may be separated in time (Reed, Erickson, Ford and Hall, 1996; Hall, 1998). Homeowners who commit to increasing the efficiency of their homes may delay implementation by as much as six months to two years.

Factors influencing the rate of diffusion of an innovation

There are a variety of factors that influence the rate of adoption of innovations that have a strong similarity to market barriers. The rate of adoption of a product or innovation is determined by the nature of the social system, by the channels used to communicate about the innovation, by the attributes of the product or innovation, by the type of innovation decision, and by the extent of promotional efforts.

The adoption of new innovations does not occur in a vacuum. Prior practice, for instance, the availability of specifications from previous jobs or rules of thumb developed from previous jobs, may weigh heavily in determining whether or not someone adopts an innovation. In the lingo of market transformation, this is a form of bounded rationality. Norms within a social system, such as union practices or local codes, also influence adoption decisions. This is undoubtedly what Eto, et. al. had in mind when they identified organizational practices or customs as market barriers.

A careful reading of the diffusion of innovation literature makes it clear that market barriers may only be revealed when attempts are made to introduce an innovation to the market.

The literature identifies five key attributes of products or services (innovations): relative advantage (for example, initial cost), compatibility (with existing culture and practice), complexity, trialability, and observability. Of these, relative advantage and observability are known to be the most important.

Relative advantage is the degree to which technologies, products or services, are perceived to be better than similar products and services. The literature identifies key dimensions of relative advantage to include “degree of economic profitability, low initial cost, a decrease in discomfort, social prestige, savings in time and effort, and immediacy of the reward” (Rogers, 1995). Scholars have found that economic profitability may explain considerably less than half of the variance associated with relative advantage. One of the goals of PG&E's Daylighting Design Tools is to reduce the amount of time needed to do analysis, in the hope that that will stimulate better design.

Energy efficient products often have characteristics that place them at a relative disadvantage in relation to other products. Whereas products that are adopted rapidly often have low initial cost, energy efficiency products often have high initial costs. Life cycle costs, a frequent justification for purchasing energy products, focus on long-term rather than the short-term rewards that are characteristic of products that have relative advantage. Increasing access to financing does not necessarily address a need for a short-term focus on rewards.

There are other product related issues. Complexity is a barrier to acceptance. The more simple the device or the idea, the more likely it is to be adopted. People are interested in ease of use. To gain rapid acceptance, innovations must be easy to understand and easy to use.

The potential for adoption is also increased with observability and trialability. Innovations are more likely to be adopted when people can see and / or experience them through sensory stimulation. This is why you see signs at the edge of fields identifying the type of seed used to plant a field. An experienced farmer driving along the road will make judgments of the crops in various fields. This is an example of observability.

Finally there is trialability. A product that is easily tried is likely to be more rapidly adopted than one which is not. Designers often install fixtures in their offices to see how they perform both in the short term and the long term. People will buy one or two of something, for example, a compact fluorescent or a fluorescent torchiere, to see how they like the product. Electricians have told us over and over that they are reluctant to install a new product until they are sure of it and that usually means trying the product in a low threat situation.

The main point is that barriers to adoption may be inherent in the product. The barrier may be as much one of performance certainties as performance uncertainties. Attention to product evaluation issues is an essential ingredient in any analysis of market transformation programs.

It is especially important to note that methods and approaches that employ value added services (for example, owner value and customer comfort) are key strategies for success (Wight, 1996). If the characteristics of a product or innovation do not meet customer needs, then it is unlikely that the market will be transformed. Too often, it seems we are dealing with products and services searching for a market rather than creating a product or service to meet the needs of a market. A closer look at the value of products and services in markets is needed before any attempt is taken to understand whether or not the market for the products and services is being transformed. This is true not only of the products and ideas that PG&E is promoting but also of the services that PG&E provides.

Without going into a lengthy discussion of decision types, we would point out that the diffusion literature defines three types of decisions: optional, collective and authority. “Optional” defines the situation in which the decision is largely a personal one. The “collective” decision involves a group. The remaining decision type is the decision driven by authority – for example, a purchasing rule, that dictates decisions be based on first cost, or a regulatory standard, such as a building code, that mandates the adoption of more efficient designs and technologies. The dynamics of a collective decision are very different than those for an individual decision. The clients of PG&E make individual decisions, participate in design teams and work with clients, group decisions, and respond to authority (such as codes and standards). An organization such as PG&E must tailor services and products that fit the context of different types of decision making.

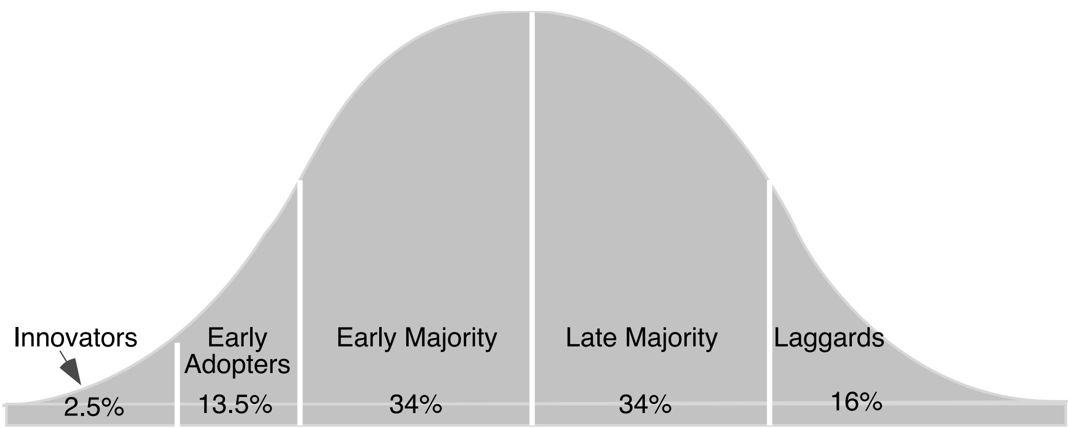
Finally, communication channels significantly influence the rate of adoption. The diffusion literature identifies two basic channels of communication, broadcast and interpersonal. A broadcast channel is a one-to-many communication path. A prime example is mass media. Interpersonal channels involve one-to-one communication, the message spreading like a contagion. Innovators and early adopters typically find out about innovations through channels, but the literature is clear, that the transformation of the market does not kick in until interpersonal channels really begin to work. This means that professional and social networks are keys to the process.

Types of adopters

Market transformation really represents a series of decisions by individuals and firms. The decision to adopt has to be made by each actor in the market, at least until the point at which actors have no alternatives but to adopt (e.g., the market is fully transformed). However, people and organizations differ in the speed with which they will accept innovations. Adopters are generally categorized into one of five groups: innovators, early adopters, the early majority, the late majority, and laggards (Figure 2).

The literature points out (Moore, 1993) that there are significant differences among the adopter groups and that these differences have important implications. *Innovators* are a very small group and they pursue technology aggressively. They purchase and use new technologies out of pure interest in the technology. *Early adopters* appreciate the potential benefits of technology and will utilize technology when they see that its benefits match their own needs and desires. Both the innovators and early adopters typically learn about and make decisions about technology based on information received through broadcast channels. These two groups can be especially important when there is an untried technology. Innovators are sufficiently tolerant so that they will use technology that is not reliable. Their feedback can be important for refining technology. PG&E may want to find innovators and work with them when dealing with unproven technologies.

The *early majority* has an interest in technology but is driven by practicality. These people will wait and see if a technology delivers on its promises. They reference others in their own group, not innovators and early adopters, before they buy. To reach the early majority one has to "convert" some of the early majority. This is the point at which the interpersonal communication channels really take on importance. This is the point where many ideas and products fail. If ideas and products attract the early majority you get "take-off" (Rogers 1995) or as Moore calls it, "a crossing of the chasm." In other words, the market is being transformed and the market for the product is becoming self-sustaining.



Source: Rogers, 1995

Figure 2 Categories of adopters

The *late majority* differ from the early majority in one major respect. They are not comfortable with technology and will wait until a product has become the standard before purchasing. The *laggards* simply do not want to have anything to do with new technology and do not consider it. The laggards may adopt only when there is no alternative.

Methodological issues in measuring market transformation

One of the difficulties faced by all efforts to assess change, including the diffusion of innovation, is the problem of measuring it. The best approaches for analyzing the diffusion of innovation rely on field experiments that include the collection of primary and secondary *time series* data for targeted and comparison areas. By tracking market interventions and changes in the target market area and by tracking changes in comparison areas where there have been no interventions, different interventions or lesser interventions and then comparing the two, one can establish causal links between the interventions and the effects. To accurately assess the effects of market interventions, time series data are needed.

Figure 3 illustrates an appropriate design. This design calls for a series of relevant measurements through time in a target and a comparison area, and measurements of program interventions. The differences between the measures at different points in time are the measures of change. Program interventions and other influences can be compared to changes in market measures in the target and comparison areas to assess the overall effects of the interventions. Because these products are not yet in the market, it is unnecessary to have a comparison group. In later efforts to assess these tools a comparison group may be needed.

Because we are in the early stages of evaluation for this market transformation effort, there are very few systematic time series measurements that are available with which to conduct the evaluation. At this point we need to establish a baseline by which future activity can be compared.

A conceptual framework for analyzing the market

In prior research conducted for PG&E (Cooper, Opinion Dynamics), researchers attempted to assess the degree to which architects and engineers were incorporating daylighting into their designs. In doing so they identified three levels of daylighting practice, the conventional approach (Level 1), limited customization (Level 2), and a customized approach (Level 3).

In the conventional approach (Level 1), architects consider daylight early in the design process and incorporate some features such as skylighting. At Level 1, cost constrains the number of natural and electric lighting design options that are considered. Features such as advanced glazing, controls for limiting the use of electric lights, light shelves, and alternative window locations and heights are not considered. While architects using the conventional approach may develop physical or computer generated models of the structure, they are principally used for presentation to clients. They seldom use physical models to simulate the effects of natural and electric light in space, nor do they use computer models to evaluate the impact of daylighting on overall building energy use.

Architects who practice limited customization (Level 2) consider natural and electric light early in the design process and these considerations impact overall design. Multiple natural and electric lighting design alternatives are considered based on the criteria of aesthetics, cost and energy efficiency. Features such as skylights, advanced window glazing, alternative window heights and depths, light shelves and clerestories are part of the designs but automatic lighting controls are typically not. Models or computer simulations are used but not for simulating the effects of natural and electric light in space. The impact of daylighting on overall building energy use is not typically modeled or not used to modify building design.

In the customized approach (Level 3), light and shadow effects are considered early and drive the overall building design. As with the Level 2 practice that incorporates limited customization, multiple solutions are considered which balance the use of natural and electric light in a pleasing and productive environment. The customized approach

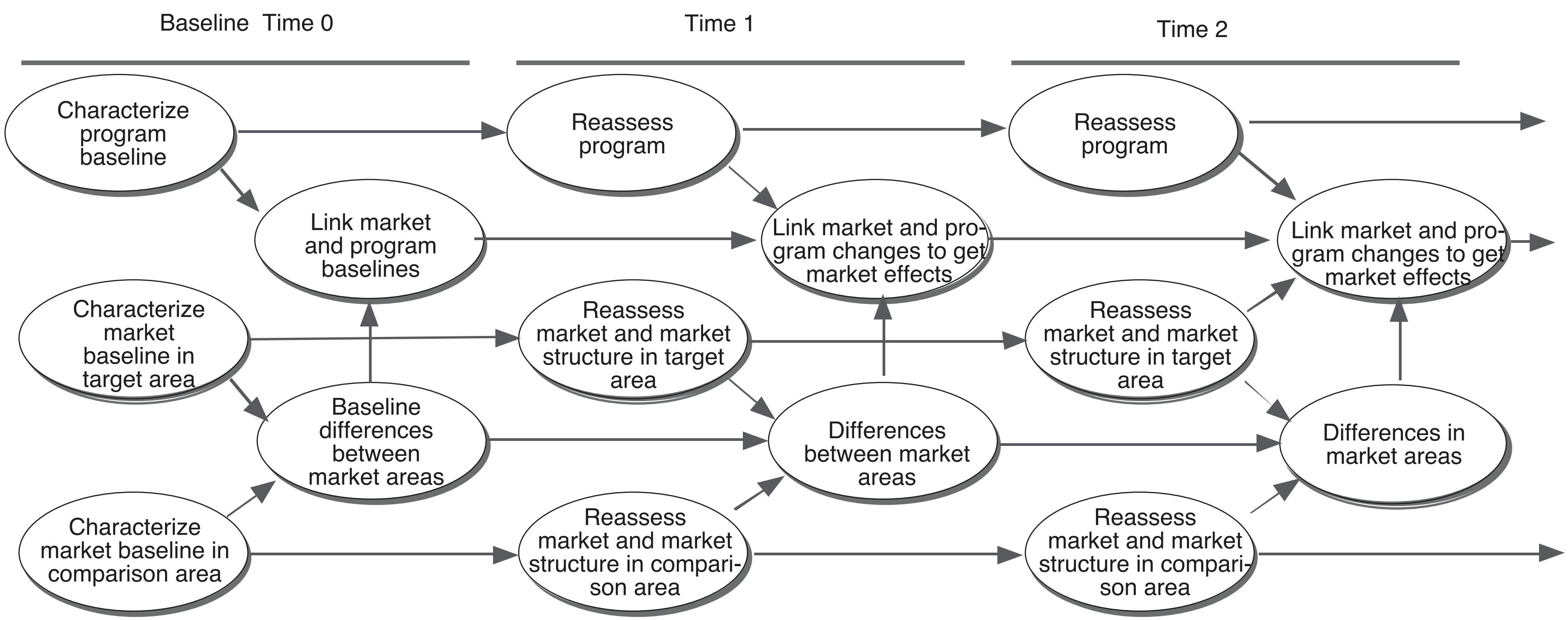


Figure 3 Model for a market transformation study

integrates natural and electric lighting control features. Physical models or computer simulations are used to model the impacts of daylighting on overall building use.

The authors of these studies categorized architects by these three levels of practice. Of the architects they interviewed, a majority fell into the category of the conventional approach (59 percent), slightly more than a third (36 percent) fell into the category of limited customization, and about six percent fell into the category of customized practice.

In the current study, we have attempted to revise and extend this framework. One of the difficulties we encountered is that most designers say that they include daylight in their design. What they mean is that they are trying to maximize the amount of natural light entering the building while meeting Title 24 (The California Building Code). In preparing for the current study we realized that we needed to be able to assess practice without using the term "daylighting."

We also realized that we needed to take into account the fact that the structure, façade, and window systems are typically the province of architects and that lighting is more typically the province of the electrical engineers unless lighting is being used for aesthetic purposes in specialized spaces. Thus, it became clear that we needed to be able to deal with the physical features of the building and lighting separately. We can easily conceive of situations where lighting designs might be quite advanced but the building is not designed with good daylighting features in mind. The reverse could also be true.

The underlying dimensions to this categorization scheme are the degree to which natural lighting is a driver of building design, the degree to which efficiency, customer value and energy efficiency are optimized in making choices about artificial lighting and the degree of integration of these two values.

Figure 4 shows an alternative way of conceptualizing the intentional design process with respect to natural and electric lighting. We deliberately chose the word intentional because the goal of PG&E's programmatic efforts is to increase the <u>intentionality</u> with which daylighting is used. One can conceive of circumstances in which a building performs well from a natural and / or electric lighting standpoint but where light and shadow effects are not key considerations in the design.

For purposes of definition, we can define the upper right hand quadrant as daylighting focused. In this definition, daylighting is the intentional use of electric lighting and controls in conjunction with natural light to provide a comfortable and productive environment that is efficient. The lower left-hand quadrant is conventional design. In conventional design, neither the entry of natural light to working spaces nor the use of natural light is intentionally examined in depth in the early stages of design. The result may be a situation in which neither the natural or electric lighting systems may provide a comfortable and optimally productive environment. The upper left corner describes a design process in which the entry of natural light may have been well planned but where artificial light was less considered and therefore less well integrated into the design to provide comfort, value and efficiency. Buildings resulting from the design process in this quadrant may or may not have quality electrical lighting but would have naturally well lit spaces. The lower right quadrant defines a design process in which the use of artificial lighting may have been well planned but attention to the entry of natural light may or may not have been considered. Buildings resulting from this process may or may not make use of natural light.

From a logical standpoint, it is difficult to believe that one would find many cases in the upper left quadrant. If a designer pays attention to details that make for a building that takes good advantage of natural light, then it is difficult to believe that that designer would fail to ensure that the artificial lighting was made to compliment the natural lighting component. Still, it is a possibility.

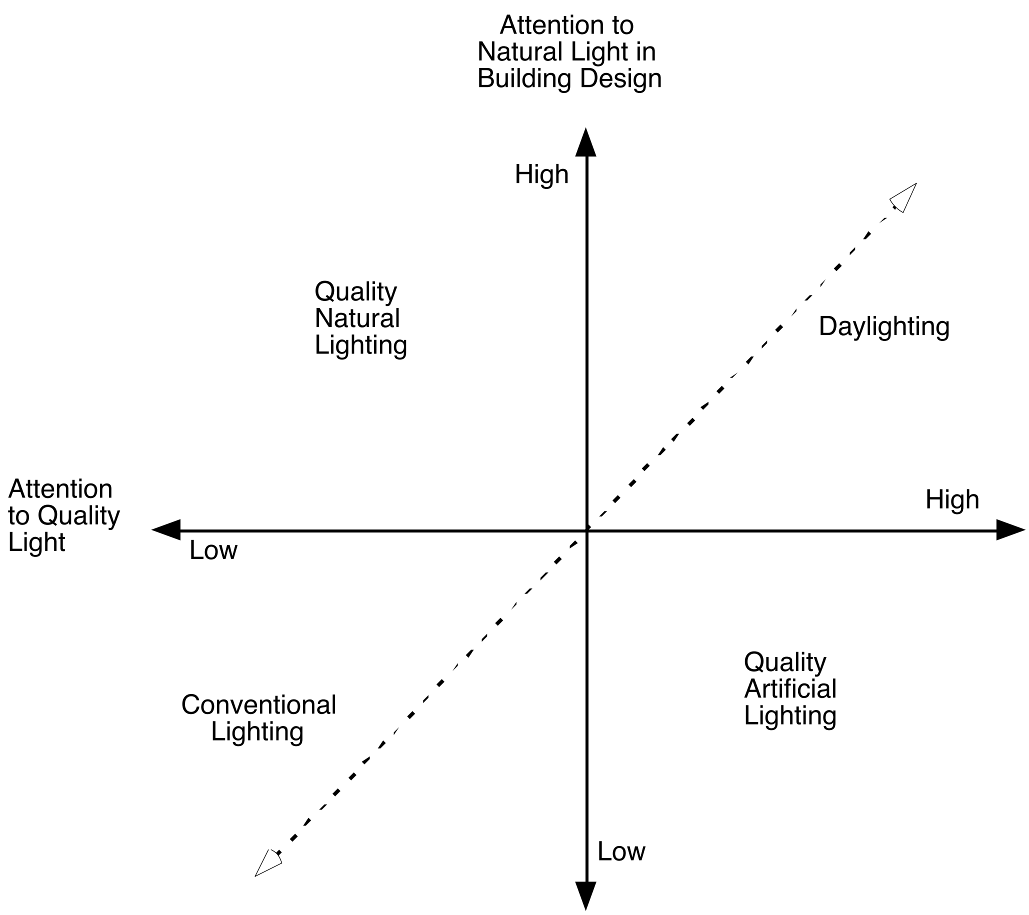


Figure 4 Components of intentional lighting design

This way of conceptualizing daylighting extends the idea of the levels of practice in several important ways. First, it focuses on the components of daylighting and allows us to recognize that design practice may involve intentionality with respect to none, one, or both of the components. A building might be well done in terms of the lighting and shadow effects with respect to natural light but less well done with respect to artificial lighting. It is important to be able to make this distinction because it can help us to understand which parts of the market are changing and which may need to be changed. There are different disciplinary segments in the market and the pace of change in the practices in the market may vary.

Secondly, the attributes of each component can be assessed separately. This means that we can focus on asking about behaviors and use the answers about behavior to assess levels of intentional design with respect to each component. This allows us to skirt the problem of different definitions of daylighting. We also avoid having to sort out the confusion between those who may view getting natural light into a building as daylighting and those who are more intentional about dealing with natural lighting in ways that enhance comfort, value and efficiency.

The two components are typically associated with different portions of the building design and construction cycle and typically involve different professionals. Figure 5 is a schematic of the building design process. The vertical axis represents the number of decisions to be made or the latitude for changing decisions and the horizontal axis represents the stages of construction.

If we conceive of the construction of a building as following the scheme laid out in Figure 5, then issues relating to natural lighting must be addressed in the concept or schematic phase of the design process. In a traditional design process, this is the stage at which the orientation of the building, the features of the facade, the size of windows and their placement are made. These types of decisions are the province of architects.

The ability of the architect to address these issues is also dependent on the situation. In traditional construction the architect may have considerable authority to address these issues. In a design / build environment, the basic structure may be largely set and the architect or designer may be limited to addressing issues of the facade and ornamentation and may have little opportunity to influence the overall design. A key point is to understand that we must assess the market environment in which the architect is working as well as the architect's orientation.

The designs for the electric lighting are typically produced in the design and construction phase and may not feed back to the structure and facade of the building. The lighting issues are largely the provenance of lighting designers and / or electrical engineers acting as lighting designers. Unless the architect / designer makes an effort to include the lighting designer, the coordination of the components is more likely to be reactive than proactive. The lighting may be done as a reaction to the design rather than as part of the design. The goal of the PG&E programmatic efforts is to increase the degree to which there is an interaction between the two aspects of design in order to create better lighting environments.

Viewing the intentional lighting design process in terms of the components and their integration also has the advantage that the concept is relevant to replacement, retrofit and rehabilitation situations. In these instances, structural changes and alternations to the building may not be possible. Even so, the lighting design can be optimized for efficiency and comfort in relation to the existing structure. Thus, even if the artificial lighting dimension is the only relevant dimension, we can still assess change in that area.

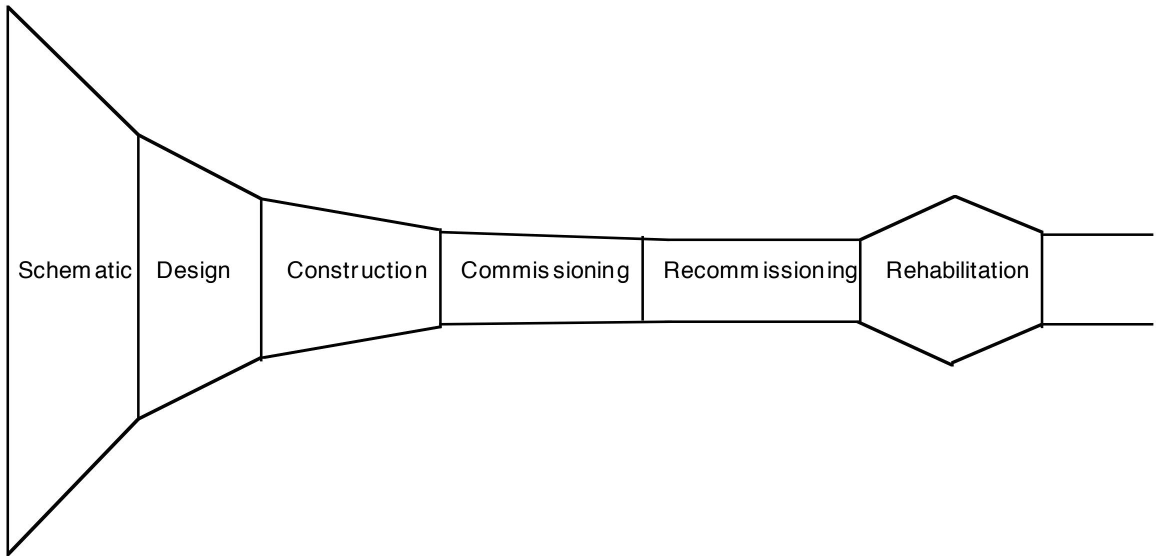


Figure 5 Schematic for the range of decisions in a traditional architect driven design model

Table 1 lays out some key indicators of intentional design with respect to daylighting practice. The indicators provide a basis for building a quantitative baseline of practice among building professionals.

Each of the indicators represents one or more interview or survey questions. The questions ask whether the respondent engages in the particular practice or behavior. The responses to the questions tell us which practices are being widely observed in the market and which are not. Because we are asking about specific practices rather than about daylighting, we can avoid the trap of misclassifying individuals who design buildings with many windows but who may do so without giving much thought to good daylighting design. The questions are designed to get at the intentionality of the practices.

Table 1 Indicators of intentional lighting design practice

Attention to the influence of building design on internal lighting and shadow effects
Analyze the effects of building orientation on internal light and shadow effects
Analyze the effects of the placement of windows and or skylights on internal light and shadow effects
Analyze the effects of window size with respect to internal light and shadow effects
Analyze the effects of different glazings and their influence on internal levels of lighting and heating load in the schematic phase
Investigate alternative passive architectural elements such as external light shelves as a way to influence internal light and shadow effects

- Evaluate alternative internal or external shading devices (not blinds)
- Evaluate and analyze the shape of the structure or architectural elements (other than light shelves or shading devices) with respect to interior lighting and shadow effects
- Analyze the potential of active or passive window treatments
- Consider actively controlled elements such as louvers and optics in relation to interior light and shadow effects

Attention to quality and efficiency of lighting

- Analyze illumination requirements in relation to needs
- Analyze the effects of color in relation to the use of interior space
- Consider and analyze alternative fixtures and lamps and their placement in relation to efficiency, comfort, and customer value
- Analyze lighting levels to establish the need for controls or natural light
- Analyze where designs optimize the perceived quality (comfort and value) of the lighting while minimizing energy use

The individual measures can be analyzed and combined to characterize design practice with respect to natural light and design practice with respect to electric light. The goal of PG&E's programs is to increase awareness of practices and techniques, to increase the information about the techniques and practices, and to encourage their consideration in building and lighting system design. By assessing changes in the indicators we can understand what change is occurring as well as how rapidly change is taking place.

We can think about PG&E's programmatic efforts and how they may influence intentional design practice. Desktop Radiance is a tool that helps users be more sophisticated with respect to the natural lighting (vertical) axis. Desktop Radiance allows users to assess the effects of different architectural design choices on light and shadow effects. The effect will be to drive users in the vertical direction with respect to intentional design. Daylighting Prospector is a tool that allows users to make more informed choices about lighting and lighting controls. Its effect will be to drive practice to the right on the horizontal axis. The combination of Desktop Radiance and Daylighting Prospector is likely to help move design to the upper right quadrant.

SkyCalc is a tool that will help to increase movement in the vertical dimension but it also has characteristics that will move people in the horizontal direction. Artificial Sky can help to increase the use of architectural design elements. Because the different tools influence different dimensions we can set the stage for examining the influence of the tools in the market when time series data become available in the future.

Chapter 4 Market Evaluation Methods and Sources of Data Used in this Study

Introduction

Because of the nature of a market baseline, an adequate characterization of the market requires data from many different sources. This is especially true when one is dealing with a variety of design tools targeting many different audiences. Data are needed to define the scope of the target populations. Information is needed about the relationships among people in the population. The products must be described through analysis of documents and interviews. Each of these data sources contributes to an overall understanding of the market and the potential for a product to penetrate the market. This study utilizes data from a number of sources including one-to-one interviews with staff and selected buildings professionals, a review of the products, the development of a sampling frame, and the completion of a market actor survey. This chapter briefly describes the data sources and methods that are used.

One-to-one interviews with staff and building professionals

In conjunction with the start-up meeting, TecMRKT Works staff interviewed the project manager for the Daylighting Design Tools. In addition, interviews were conducted with each of the firms and organizations involved in developing the tools. These interviews lasted between an hour and two hours. In each case we attempted to view the software or program that was being developed.

In addition, TecMRKT Works conducted 30 one-to-one interviews with building professionals in Northern California. For the most part, these interviews were conducted in person with representatives of firms that were randomly selected from firms that were identified as being active in commercial construction based on information obtained from F. W. Dodge. A few telephone interviews were conducted to verify certain types of information with persons who are knowledgeable about certain aspects of the market.

The interviews were conducted from March 20, 1999 through April 2, 1999, several weeks after the project initiation meeting. The interviews were completed in conjunction with the interviews for the Lighting Exchange project. The length of interviews ranged from 30 minutes to an hour and a half. The portion of the interview devoted to discussing the Internet and the Lighting Exchange typically lasted 10 to 15 minutes.

The formal parts of the interviews were based on a protocol that was designed in advance. The protocol was used as a guide and checklist. The interviews were done in a conversational style in which the interviewer pursued issues as they arose rather than strictly following the protocol. The protocol is found in Appendix B.

Review of existing materials

TecMRKT Works completed a review of the materials that were available that describe the tools. In addition, we were able to review pre-delivery versions of the Daylighting Design Tools. The products that are being delivered appear to be very close to the products we viewed.

In addition, we reviewed some existing studies of the professional buildings market.

The construction of the sampling frame

One of the most difficult aspects of this project was establishing the sampling frame for the project. There is no list or set of lists that identify target audience membership.

In 1998, there were 20,667 licensed architects in California. Of these, 78 percent were resident in California. In that same year, there were 8,098 licensed electrical engineers of whom 6,033 or 74 percent were California residents.

Because many architects may work exclusively in the residential sector, may work in allied occupations, may not be practicing architects, or may have retired, etc., the total number of architects is not a good estimate of the size of the architectural audience. Similarly, we know that many of the electrical engineers work outside the area of lighting design and for companies that are not involved in commercial new construction.

As a way of identifying companies that are directly involved in the commercial buildings market, we obtained the F. W. Dodge data for all construction projects that were in some stage of construction requiring a permit in California in 1997 and 1998. From the Dodge data, we identified a total of 42,500 commercial building projects for the two years or approximately 21,250 projects per year.

Because our goal was to identify projects where there was likelihood that the tools would be used, we selected all commercial, retail, office and warehousing projects that met the following criteria:

- New construction of 10,000 square feet or greater
- Projects that are additions or renovations to chain stores even if less than 10,000 square feet

- Projects in the category of office, retail, education, warehouse, manufacturing, leisure, transportation, municipal, religious or freight
- Projects in Northern California that are roughly north of a line drawn from Monterey to Fresno

After screening for these criteria, removing the duplicates, and cleaning the data, we identified 1908 projects of interest that were in some stage of completion in these two years. There were 919 architectural firms and about 100 electrical engineering firms of record for these projects. The number of projects completed by firms ranged from one to several hundred or more.

Table 2 shows the distribution of projects by type. The largest number of projects were offices, followed by retail stores, educational facilities, and warehouses.

Table 2 Projects meeting criteria by type in Northern California in 1997 and 1998

Project type	Percent of projects in Northern California
Office	42
Retail	21
Educational	10
Warehouse	7
Manufacturing	7
Leisure	6
Transportation	3
Municipal	2
Religious	1
Freight	1
Total	100

N=1908

Table 3 shows the distribution of firms and the number of projects reported in the F. W. Dodge data. About 20 percent of the firms completed slightly more than half of the projects.

Table 3 Number of firms and number of projects in Northern California

Category	Number of projects	Number of firms	Percent	Number of projects	Percent
Small	1 – 2	784	83	927	48
Medium	3 – 5	113	12	417	22
Large	6 – 9	34	4	233	12
Extra Large	10 – 100	17	2	349	18
Total		948	101	1926	100

There are some significant limitations in the F. W. Dodge data. We know from our interviews that some firms have been involved in many more projects than are identified in the Dodge data. One likely explanation is that firms may be playing a supporting role and may not be listed as the firm of record. Another point is that the Dodge data is based on permitting applications and there may be numerous projects which are in the planning stages but for which permits have not yet been issued. There may also be projects that are planned but are delayed or not completed. Finally, F. W. Dodge may not necessarily obtain data for all projects.

As a source of sampling data, the F. W. Dodge data is somewhat problematic because it does not identify specific individuals except where the firm name carries the name of an individual who is a member of the firm. Thus, one of the problems in constructing the sample frame based on this data is to identify individuals within firms from whom we could request an interview. Attempts at blind calling are almost always rebuffed.

We tackled this problem in several ways. First, we had a list of architects and their firms that we derived from the Construction Market Database (CMD), Inc.'s, *Profile on the Web Database* (http://www.cmdg.com/profile/search.html). We used the firm name from that database and matched it with the F. W. Dodge data. When we got a match we then recorded all names associated with that firm in our sample frame database.

As a second resource, we took the list of licensed architects and engineers from California and matched them to the F. W. Dodge data. Because licenses are issued to individuals and do not show company affiliation, we used the street addresses on the licenses and matched those with the addresses in the F. W. Dodge data. The license addresses vary with respect to whether they are a home address or a business location so we were able to match only some businesses in this way. Again, we recorded the name of any individual at an address as being associated with the firm located at that address.

Finally, from a previous PEC project we had two lists. The first was a list of all PEC participants and the second was an independent list of lighting designers that we generated.

We compared these two lists with the F. W. Dodge list. Where we were able to match a firm name, we copied those names to the sampling frame database. We also included anyone from these lists who was from a firm that was not on the F. W. Dodge list but who was shown as being an architect, designer, or engineer.

The result was a sampling frame of approximately 2,200 firms. We believe this represents most of the firms who are active in Northern California. In many instances we had the names of multiple individuals within a firm. However, there is a catch. The architect lists identified licensed architects and did not list architecturally trained employees who are unlicensed. Most firms have a small number of licensed architects who are usually supported by one or more architecturally or technically trained staff. The ratio of licensed staff to trained but unlicensed employees may be several to one. A firm with 15 employees may have two or three licensed architects and 10 – 12 technically trained personnel. Potentially all of those staff members are members of the target audience. Although the technical staff may not be the main decision makers, they may significantly influence decisions as a result of their recommendations, and it is these staff who are most likely to use the tools to do the analysis. The only method we had for capturing these staff was through the PEC records. Many of these staff attend events at the PEC.

The construction of the telephone surveys

The survey was developed on the basis of the theoretical structure outlined in Chapter 3. The survey instrument included questions about the respondents discipline and the type of firm, the type of designs the firm does, the firm's partners and clients, project decision makers, practices related to building and lighting design, decision criteria for different types of decisions, and a series of product related questions about current use of existing products and the potential for using the products being developed by PG&E. In addition we asked a few firmographic and demographic questions. A complete copy of the survey is included in Appendix C.

Multiple drafts of the survey were completed. The survey contains a very complex set of skip patterns. Once the survey was loaded into the CATI system it was reviewed by numerous reviewers to insure that the skip patterns were correct. Minor modifications were made to the survey after completing the first few interviews.

Survey administration

As part of the market assessment, TecMRKT Works contracted with the Pine Company to conduct the telephone baseline survey. The survey was conducted in May of 1999.

Ten attempts were made to contact a respondent before the respondent was dropped from the sample. Because we had multiple names of individuals at firms, survey takers were allowed to substitute the name of another person at the firm if they could not reach the person initially selected.

The survey is quite detailed and depending on the respondent took from 18 to 40 minutes or more to complete if the respondent did not take many of the skips. Respondents were screened to identify the types of decisions with which they were involved and then were asked questions specific to their decision making involvement of lighting and architectural design.

Table 4 shows the disposition of the sample. During the interviews we found that members of the target audience were very difficult to reach. The number of calls that went to the full ten attempts 646 is a good indicator of the problems of reaching these individuals.

Table 4 Disposition of the survey sample

Result	Number
Completed interviews	201
No such person	203
Disqualified because didn't meet requirements of the sample	78
Language problems	4
Computer tone on the telephone line	42
Disconnected telephone number	279
Initial refusal	293
Terminated at some point in the interview	42
Wrong number or type of business	69
Number of respondents receiving the maximum attempts	646
Sample problems (i.e., no number, no identifiable person, etc.)	364
Sample total	2,221

Processing and analyzing the data

The data from the CATI system were moved directly to SPSS. The raw data from the open-ended questions were placed in an Excel spread sheet. The responses for each open-ended question were reviewed and a series of categories established. Each response was then reviewed and assigned as many as three content codes. These data were then merged into the SPSS data set.

The primary modes of analysis were to produce frequency distributions, crosstabulations, means, medians, and multi-variable frequency distributions. Care was taken to select the appropriate cases for the analysis being considered.

Chapter 5 Characteristics of the Target Audiences

Introduction

The purpose of this chapter is to briefly describe the characteristics of the sample. The sample was drawn so that the respondents represent firms. An attempt was made to complete the survey in such a way that no firm was represented in the survey more than once.

Characteristics of the individuals in the sample

Eighty-nine percent of the respondents are male and 11 percent female. Table 5 shows the distribution of the sample by years of experience and years in current position. The median number of years of experience in the field is 20 years and the median number of years in their current position is 10 years.

By profession, the largest group in the sample is architects (see Table 6). They are followed by electrical engineers and then by lighting designers and energy consultants. There is a smattering of persons representing other disciplines.

The respondents have a broad array of titles and responsibilities (Table 7). By title, the largest group are owners / partners. This reflects the fact that many architectural firms are small. The next largest group by title is architects. Engineers and senior engineers are about 15 percent of the sample. Eighty-eight percent of those in the sample supervise another person.

The most typical level of education is a bachelor's degree (Table 8). About an

Table 5 Years of experience and years in current position

	Years of experience	Years in current position
less than 10	7	40
10 to 19	35	37
20 to 29	30	15
30+	27	7
Refused	1	1
Total	100	100

N = 201

Table 6 Percent of respondents by profession

	Percent
Architect	51
Electrical Engineer	19
Lighting Designer	11
Energy Consultant	10
Civil / Mechanical / Structural Engineer	4
Interior Designer	2
Electrical Contractor	2
Other	1
Electrician	<1
Total	100

N = 201

equal number of people have education beyond the bachelor's degree. Seventeen percent of the respondents had less than a college education.

Table 7 Occupational title of respondents

	Percent
Owner / Partner	34
President	11
Senior Manager	2
Manager	8
Senior Engineer	7
Engineer	8
Senior Architect	3
Architect	15
Senior Designer	2
Designer	4
Other	6
Total	100

N=201

Table 8 Respondent's level of education

	Percent
High school or less	2
Associates degree	4
Some college	11
Bachelor's degree	41
Bachelor's degree plus some additional education	15
Master's degree	20
Master's degree plus additional education	4
Ph.D. or equivalent	2
Refused	1
Total	100

N=201

Characteristics of the firms

The types of firms represented in the sample somewhat mirror the occupation of the respondents. Over half of the firms represented in our sample are architectural firms (Table 9). Another 19 percent are engineering firms. Lighting and interior design firms make up about 10 percent of the total

About two-thirds of the firms have a single location although eleven percent worked for firms that had offices in four or more locations (Table 11).

Table 9 Principal business of respondent's firm

	Percent
Architectural design	53
Engineering-Electrical / Lighting	16
Engineering-HVAC and other	3
Other	9
Lighting Design	7
Energy Consulting Firm	3
Contractor-Electrical / HVAC and other	3
Interior Design	2
Manufacturer	2
Property Owner / Management	1
Total	100

N=201

As the reader might surmise from the employment information, the number of projects completed by the firms in this sample range from a few to nearly a thousand. About a third of the firms (Table 10) had ten or fewer projects in the last twelve months. More than a fifth had 80 or more.

We had anticipated that some firms might do a significant amount of business outside of Northern California. However, the data show that for most firms the majority of their projects are in Northern California.

The median number of employees belonging to firms represented in the sample is less than 10. Fourteen percent of the firms represented in the sample had 100 or more total employees.

Firms in the sample most commonly had completed low rise office and retail structures other than big box stores and educational buildings. Eighty percent of the firms were involved with low-rise office projects. Over half of the firms had completed warehouse structures. Just under a half had completed big box retail structures and manufacturing facilities. More than a third of the firms had completed health facility projects and office buildings of 4 stories or more.

Table 11 Number of offices that the respondent's firm has

	Percent
1	69
2	13
3	7
4	2
5-9	3
10+	6
Total	100

N = 201

Table 12 Total company employees and employees in respondent's office

	Employees firm wide	Employees at respondent's office
Less than 10	54	58
10 to 19	16	18
20 to 29	8	8
30 to 49	4	4
50 to 99	4	7
100 to 499	7	4
500+	7	1
Refused	<1	<1
Total	100	100

N = 201

Table 10 Location and number of projects

	Total projects	Northern California Projects
less than 10	32	38
10 to 24	29	28
25 to 79	17	16
80+	22	18
Total	100	100

N = 201

One of the issues that arises in this market is the relationship between firms. Building professionals do not necessarily work directly for building owners but may take direction from other building professionals. We asked the respondents how often they worked for a variety of different clients. Eighty-seven percent of the firms had worked directly for a building owner. Almost two thirds had completed projects with developers and more than half had completed projects with general contractors and almost half with architectural firms. Slightly more than a third of the firms had done work for retail chains and slightly less than a third had completed projects with engineering firms.

Table 13 Percentage of firms that completed at least one project of the building type

Type of structure	Percent of firms completing at least one project
Low-rise office 1 – 3 floors	80
Other retail	66
Educational buildings	59
Warehouses	53
Big box retail	48
Manufacturing facilities	42
Health and hospital facilities	39
Higher-rise office 4+ floors	35
Other public buildings	56
Other commercial / industrial structures	60

N=201

Summary

This chapter describes individuals and the firms represented in the sample.

Table 14 Percent of firms having different types of clients

Client	Percent of firms with at least one client which is…
Building owner	87
Developer	64
General contractor	59
Architectural firm	46
Retail chains	34
Engineering firm	28
Other	28

N = 201

- The largest group in the sample is architects and the next largest group is engineers.
- The most frequent occupational title among the respondents is owner / partner which reflects the many small firms in the sample as well as the way in which the sampling frame was constructed.
- The most common level of education is the bachelor's degree. The same number of people have additional education through and including a master's degree with some additional education.
- The size of the firms range from the vary small with one or two employees and a few projects through large firms with multiple offices, hundreds of projects, and hundreds of employees.
- The firms in the sample primarily do business in Northern California.

- The firms complete projects for a broad range of building types. The type of structure common to most firms are low-rise offices, retail stores that are not of the big box type, and educational buildings. The number of firms completing big box projects is about 48 percent of the total sample.
- Nearly every firm works directly for building owners but most complete projects for a wide variety of other actors including developers, contractors, retail chains and other architectural and engineering firms.

Chapter 6 The Structure of the Market

The daylighting market includes players from a broad array of disciplines who interact in a variety of ways and who use different criteria to make decisions. The purpose of this chapter is to describe how the actors relate to each other and the criteria they use in decision making.

The Structure of Key Market Segments

In the 30 preliminary interviews we identified three basic types of decision making structures. There are more but most are simple variations on one of these three. It is important to understand these structures because the decision makers who influence design vary from structure to structure. The implication of this for the tools project is that the target audiences will vary and the message and methods for reaching the audiences need to vary as well.

Figure 6 represents a design / build environment that is more or less typical of chain stores, such as Target, Circuit City or Safeway, that are renovating sites or building new buildings. Chain stores are constantly leasing or building property and therefore usually have in-house staff which include property managers, architects and engineers who are responsible for property acquisition and development and construction management.

Chains will usually have an external firm that specializes in designing and developing a marketing image that the retail spaces are to have. This firm also provides drawings and specifications for the construction of buildings. For the most part these specifications are quite specific and there is little latitude for variation. Chains typically work with a developer and / or a contractor to construct or renovate buildings. The construction may be subject to bid but the contractor is likely to be someone with long standing working relations to the chain. The contractor is often the lead.

In one variation of this structure, the contractor hires a local architect, one or more local engineering firms and other subcontractors to complete the building. In another variation on this structure, the architect and contractor may both report directly to the chains' property managers. In either case, the local architects and engineers are responsible for ensuring that the building meets state and local building codes and for obtaining the necessary approvals and permits.

In the design / build environment for chain stores, cost and specifications drive projects. The local architects and engineers have relatively little influence over the configuration of a building. They are able to make suggestions and they can certainly plant ideas, but they can only minimally influence the use of new designs and technologies. They can pull but not push.

In order to significantly influence the use of advanced designs in this structure, it is important to reach the primary decision makers who are the in-house staff of the chains and the external architectural firm(s) who are responsible for developing the market image building specifications. If one is interested in encouraging the use of skylights it may be particularly important to target the firms responsible for architectural image. If these decision makers can be influenced to accept advanced designs and to use new tools then it is likely the designs will be adopted in some form regionally or nationally.

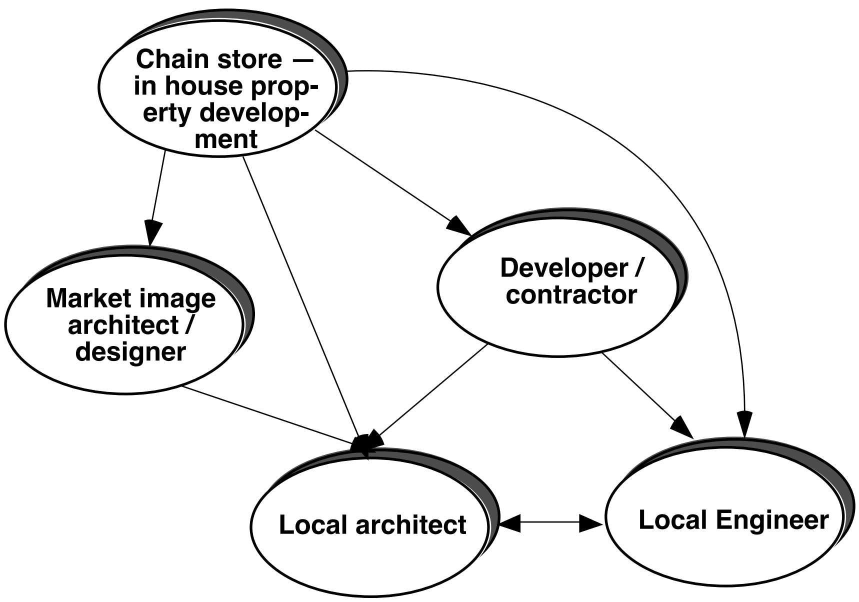


Figure 6 Commercial building decision making model for a national or regional chain

Figure 7 displays two decision making structures that are typical of the way other types of commercial projects, such as office buildings and warehouses, may be developed. In both instances, the developer is represented with a broken line because the developer may or may not be represented in the structure. Based on our interviews we believe that a developer is more commonly present in the left hand structure than in the right hand one.

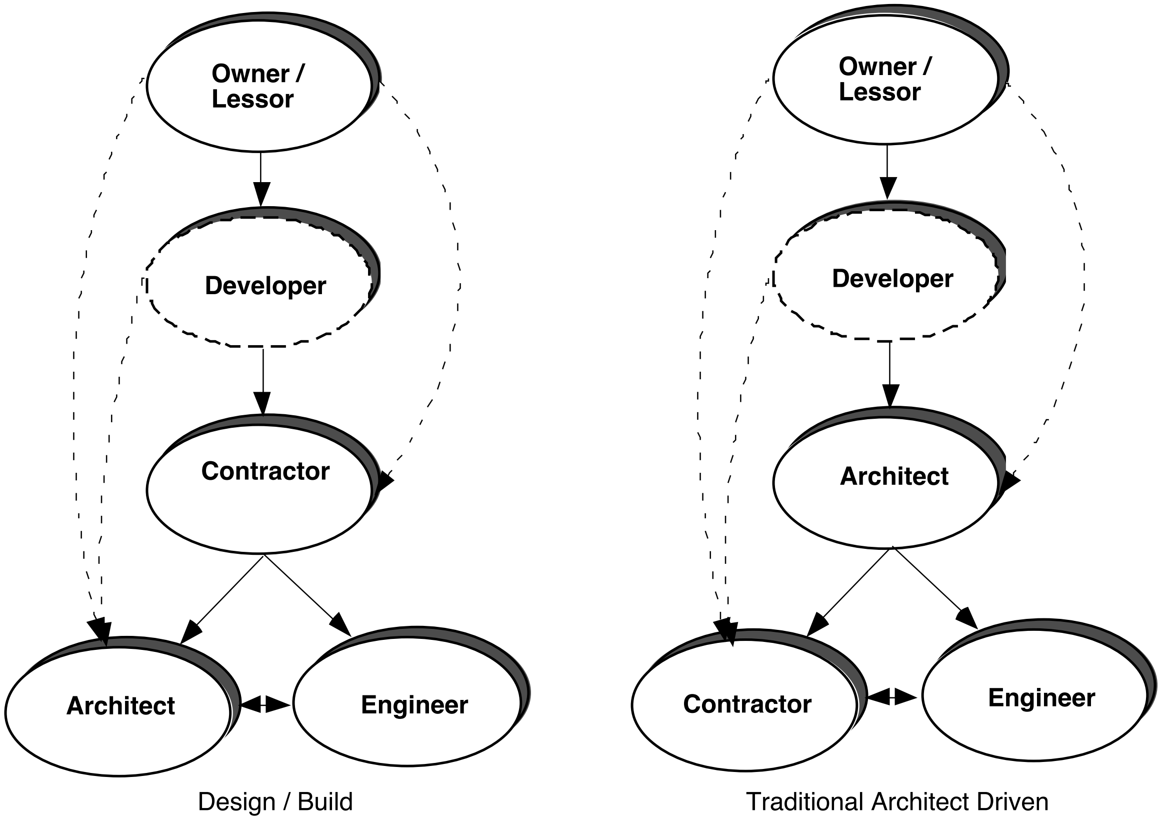
The structure to the left is typical of the design / build method of construction that is in widespread use in Silicon Valley. In this structure the key decision makers are the owner / lessor and the contractor. The developer may secure the contract with the owner / lessor. The contractor then organizes and manages the construction. The contractor may take bids for the architectural and engineering work or may go directly to a specific firm. Typically there are groups of firms that have developed long standing relations with one another that coalesce to build a specific project.

In this structure, roles are well defined. The architect is responsible for the facade and specialized spaces such as lobbies. The architect may get involved in lighting design when it may influence the aesthetics of specialized spaces. One or more engineering firms are responsible for the electrical system including the lighting design and the

HVAC systems. In the interviews, both the architects and the lighting designers emphasized that the lighting design is the province of the electrical engineer and is usually addressed at the detailed design stage of the project.

Architects generally make the decisions about building orientation but they may have little control over the orientation of the buildings. Siting is primarily a function of orienting the building for public presentation and optimizing parking and access and egress, as well as placing the building to address any geologic issues. These are often controlled by the developer and / or local regulations.

The amenities that are designed into the building are a function of the requirements of the owner / lessor and cost. Several of those we interviewed indicated that owners / lessors expressed interest in automation but few actually carried through after learning about initial costs. Some of the high technology firms are very interested in giving their employees control over their environments and are requesting and installing controls in workspaces. Buildings that are built for speculative purposes are typically built to minimum standards. When you talk with architects and engineers who work in these kinds of structures, they say that they have minimal opportunity to introduce new and innovative ideas.



Items and linkages with broken lines represent paths that may or may not exist

Figure 7 Commercial building decision models for design / build and more traditional architectural models

In the third model the architect plays a more central role in development. In effect, the role of the architect and contractor are reversed. This model represents a more traditional view of the architect's role. In this case, especially when there is no developer, the architect becomes a key decision maker. In these projects the architect may have more influence over siting and engineering parameters. How and when architects choose to exert influence is still and issue.

Barriers and potential barriers to penetrating the segments.

Regardless of which model, we found that architects tend to view lighting, except in specialized spaces such as a lobby or boardroom where there is interest in aesthetics, as an issue for the electrical engineers or the lighting designer and the electrical engineer. Outside these specialized areas architects expressed little interest in lighting issues and in a few instances seemed to know very little about the lighting and controls that were installed in the buildings on which they had worked. They expressed little interest in integrating lighting and the physical design of the structure.

Almost uniformly architects told us that the analysis of light and illumination levels is done for two reasons: to insure that there is sufficient light to meet the functional requirements assigned to a space and to insure that light entering through glazing does not increase thermal loads to the point where the building cannot meet Title 24 requirements. Both architects and engineers agreed that these types of analysis were the province of the engineers.

We asked what happens when the light entering through the glazing causes a building to exceed Title 24 standards. We were told that a typical response is to add insulation, then to change the type of glazing, and finally, if necessary, to change the size of windows. Changing the glazing and size of windows is clearly a last resort and the engineers typically appear to try and solve problems by adjusting components of the building that are within their purview, for example, the amount of insulation, before making other changes. An important point is that there typically appears to be very little communication about the integration of natural and artificial light except when it is ascertained that the design may not meet Title 24 requirements.

Given this, we asked how architects determined the size, placement and characteristics of glazing on the structure of buildings. Based on feedback from other design experiences, architects develop rules of thumb that they use in determining the amount and the characteristics of glazing to be used in a design. In about 30 interviews, we found only two instances where an architect or engineer indicated that they did any extensive preliminary analysis to ascertain the trade-off. Several respondents indicated that they would welcome a wire frame model that could be used for quick and dirty preliminary analyses at the conceptual stages of design.

In the course of our interviews, we asked about the use of advanced controls. A very common response was that controls were used but we were told that the controls were mostly motion detectors that are being placed in bathrooms. One respondent said that motion detectors were placed in bathrooms because the client’s customers complained to the clients about the waste of electricity when bathrooms were not being used. There were several comments about the problems of motion sensors causing the lights to go out when people were in a room but outside a sensor’s angle of reflectance.

With the exception of controls in a very high-end command and control room application, no one spontaneously mentioned the use of sensors and dimming ballasts during the interviews. The main reason cited for not using such controls was first cost. We asked if clients could be convinced to use them if controls were shown to be cost effective and have a reasonable payback. Respondents seemed reluctant to suggest that life cycle cost information would make any substantial difference. At least two or three respondents replied by pointing out that the leases were often of short duration, 3 – 5 years and that the paybacks would have to make sense in these terms.

Numerous architects told us that they had incorporated skylights into their designs. However, most of these were instances where one or two skylights were being used in specialized spaces at the request of clients. These were used as aesthetic and comfort features rather than as an attempt to provide a functional alternative to artificial lighting.

None of those who used skylighting in this way indicated that the artificial lighting system was designed to work in an integrated fashion with artificial light.

In four of our interviews, we found that skylights were being installed as systems to provide light. In one notable instance, a firm that specializes in automobile dealerships said that skylights are regularly installed in automobile dealers' maintenance areas. Skylights are requested by the mechanics and dealers respond positively to that. While the local architect cannot deviate from the plans for the showroom, the local architect does have the latitude to include requested features such as skylights in the maintenance area.

We also found architects who told us about using skylighting in warehouses or the warehouse areas of a building. Two important points seem to emerge from this portion of the interviews. When skylighting is incorporated into a building it is often done without benefit of analysis. As one person put it, "We just put the skylights between the supporting structures." An architect who had been involved with skylighting in a warehouse area expressed uncertainty about using them because the "skylights didn't line up with the work areas and the shelving blocked the light." One professional we talked with had called in to "do something" about heat and glare problems from a skylighting system that was installed in the work area of a computer manufacturing facility. Finally, none of those with whom we talked knew whether the lighting designs were integrated with the skylighting and several people indicated that they were not.

We also explored the use of rendering in some detail. As many as half of those we talked with said that they are doing rendering with most doing rendering solely for presentation purposes. Several respondents indicated that they did rendering in order to see how something looked, a form of low level analysis. In only three interviews did we actually find people who said that they were doing rendering as part of their analysis to assess light and shadow effects in enclosed spaces. When asked what packages they were using, people typically identified Viz3D and Lightscape.

Several respondents cited the cost of rendering as an obstacle to its use. People are either not doing it because of the cost or they indicated that they use it sparingly because of the cost. Cost can be broken into setup time and runtime. In terms of runtime, those who are already using rendering indicate that they are accustomed to doing overnight runs. It is clearly the set-up time that is the key. This is where Desktop Radiance may be strongest. The amount of time they are willing to assign to setup is less clear. A common comment was that budgets were too tight to permit rendering for the sake of analysis.

Rendering is mostly done in house although we did talk with people who use external contractors for rendering.

When we described the potential for using Desktop Radiance for analysis, two key points emerged. Architects almost universally saw the analysis of illumination levels as being in the province of the engineers or lighting designers. Further, the architects perceived the analysis of the illumination levels as coming too late in the process to influence the design of the buildings.

On the other hand, engineers expressed the opinion that such rendering of illumination levels and the use of that information to influence the physical design of the building were outside the scope of their work. The definition of the disciplinary boundaries appears to present a barrier to analysis and use of data to produce an integrated solution.

In part this is related to where in the design process conceptual design issues are resolved and where in the process the detail data for illumination studies is available. The physical features of the building are locked in fairly early while the details of lighting come late. A few respondents suggested the need for simple wire frame models that could be used to evaluate physical design features early in the design process.

Architects are increasingly making use of the Internet. Many of those we interviewed indicated that they frequently search the Internet for product data. The architects were concerned that product databases developed by PG&E might go beyond lighting to other materials such as glazing materials. There was concern among those that we interviewed about keeping the databases current.

Those we interviewed felt that a moderated list serve might be helpful although several people expressed concerns about the volume of materials. Most felt that they would make occasional use of it.

Key findings about diffusing tools into the market

There are three basic types of decision making structures within the market, the national / regional chain model, the non-chain design / build model, and the traditional architect driven model. Depending on the type of structure the key decision makers will vary. For example, if the goal is to encourage retail chain outlets to make greater use of skylighting, then the key targets will be the in-house staff of the retail chain and the firm or firms that are responsible for the design of the market image for the chain's buildings. These firms should be an important target audience for both the message about skylighting and for use of the software. The latter firms may often be located outside of California.

Chains use local architects and engineering firms to insure that buildings meet state and local codes and to ease the local permitting process. These firms can influence the process but their influence is minimal. They should also be a target audience for the message about skylights and the software because of their supporting role. These firms are frequently responsible for finalizing the designs and for seeing that buildings meet specifications.

In the design build environment, the customer and the firm responsible for managing the overall construction, frequently a construction contractor, are the key to changing practices with respect to daylighting. Therefore, they should be the primary targets of efforts to introduce daylighting concepts into new construction. These audiences may be less interested in the tools than in information and data demonstrating that daylighting may lead to increases in productivity and may represent effective life cycle cost solutions. In these settings architects and engineers can play a “pull” role in bringing the technology into the market and they need to have the tools and training to use the tools. If they have the tools they may be able to exert some influence on the clients.

In the more traditional architect driven environment the architects are key players.

In our analysis of the data from the one-to-one interviews we found that in Northern California:

- Building orientation and siting is seldom done in response to lighting requirements
- Architectural elements that provide shading currently are not widely used
- Architects attend to the size of windows and glazings because of the need to comply with Title 24 requirements
- Architects probably use learned rules of thumb to determine the size and placement of windows
- It is the engineers who do the heat load analysis. Unless there are significant problems in meeting Title 24 requirements, engineers will specify solutions that are within their purview and that do not require changing the physical elements of the structure
- Architects see their role as one of dealing with physical and aesthetic aspects of design. Generally they view lighting as being outside of the range of their responsibilities
- Architects see engineers and lighting designers as being responsible for designing lighting systems
- Engineers are providing lighting solutions that meet Title 24 requirements
- Except for motion controls in selected areas, automated lighting controls are not generally being specified
- Engineers cited the cost of control systems (particularly the costs of ballasts) as being a key barrier to the adoption of lighting dimming systems
- Engineers thought life cycle cost data might help overcome the resistance to control systems but they were unsure of their ability to influence the process
- There are some buildings, usually those for high tech customers, where controls are being specified as a way to give staff more control over their environments
- Many architectural firms are now using 3D CAD rendering for presentation purposes
- Architects would welcome a rendering tool that is easier to use than the ones they are currently using
- Architects see the use of a rendering tool to examine illumination levels as being an engineering function
- Architects are more likely to use a rendering tool to examine light and shadow effects in special settings where lighting is critical to the aesthetic of the space
- Many firms are incorporating skylights into buildings, however, the skylighting tends to be minimal and done for aesthetic and comfort reasons
- Skylighting does appear to be done in automobile maintenance areas and in some warehousing
- The evidence suggests that when skylighting is being done, lighting and lighting control systems are not being considered to form a comprehensive integrated solution

Overall, we conclude that there is little current evidence that the physical and lighting elements of design are being intentionally integrated to form good daylighting solutions. A major barrier to integration is the definition of disciplinary boundaries by the players and the timing of analysis, which act to prevent integrated solutions. Several people suggested that a simple tool that would allow analysis of lighting patterns early in the process might increase the potential for integration.

It is clear that effectiveness of PG&E's efforts to diffuse these technologies will be much enhanced if the target audiences are segmented and targeted separately. Initially, it may be important to target engineers for these tools because they are the ones who are most like to use them first.

Chapter 7. How decision making gets done

Introduction

The purpose of this chapter is to describe who does the decision making with respect to key decisions that influence the quality of daylighting. This chapter answers the following questions:

- Who are the key decision makers?
- What decision makers support the key decision makers?
- What are the important criteria that decision makers use in making their decisions?
- What implications do the patterns of decision making have for daylighting?

The key decisions influencing quality daylighting

Based on the concepts in Chapter 3, we have identified eight key decisions that influence the potential for daylighting in commercial structures. Table 15 identifies those decisions. In the interviews, respondents were asked a series of questions about who makes these decisions. We asked them to tell us who, on the basis of their projects, the primary or key decision maker is for each type of decision. We then asked who the secondary decision makers are. Finally, we asked how often their firm played the key role with respect to these decisions for their projects.

Who does the decision making

Table 16 displays the percentages of respondents indicating a decision maker for the different decisions. The values for the most frequent key decision makers are highlighted in gray.

Table 15 Key decisions for creating quality daylighting

Who determines building orientation?
Who determines window size and placement?
Who makes the decision about glazing materials?
Who decides on architectural elements such as shading devices?
Who determines if skylights will be used?
Who decides on lighting locations and placement?
Who determines lighting specifications?
Who decides on the use of dimming controls?

For building orientation, placement of windows, choices of glazing materials, the use of architectural elements and the use of skylights, architects are clearly the primary decision makers. For these decisions small percentages of respondents identified owners or developers as the key decision makers.

Table 16 Percent of primary decision makers for different types of decisions

	Developer	Owner	Tenant	Architect	Lighting designer	Interior designer	Electrical engineer	Electrical contractor	HVAC engineer	General contractor	Other contractor	DK/NA	Total
Exact orientation of building	5	12		73				1	1			8	100
Size / placement of windows	1	8		82		1						8	100
Glazing material	1	6		78	1	1			2	1		9	99
Use of architectural elements	1	5		83	2	1	1	1			1	5	100
Use of skylights	3	12		76	1	1					1	5	99
Lighting location / placement		3	1	47	17	1	24	1				5	99
Lighting specifications		4	1	24	19	1	42	2				5	99
Dimming controls	1	9	1	24	18	1	38	1				6	99

N = 201

For decisions about lighting placement, lighting specifications, and dimming controls, respondents differed in their assessment of who the key decision makers are. For lighting placement, a near majority indicated that architects are the most frequent key decision makers. However, more than 40 percent of the respondents said that either the lighting designer or an electrical engineer is the key decision maker with respect to this decision.

For decisions about lighting specifications and dimming controls, a majority of the respondents said that the electrical engineer (38 percent), the architect (24 percent) or the lighting designer (18 percent) is the key decision maker. Owners were consistently identified as key decision makers for each type of decision by a small percentage of respondents.

Who plays the supporting roles in decision making

We can now turn to the issue of who plays the supporting roles for each of the eight decisions. After respondents told us who they believed the primary decision maker is with respect to their projects, we asked what other actors played supporting roles. Respondents could nominate as many supporting actors as they liked. We then created a tree diagram describing the key and supporting actors for each decision. We only created diagrams for key actors identified by at least 5 percent of the population.

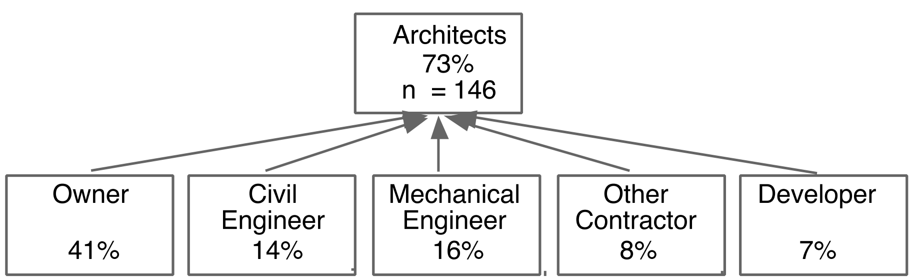


Figure 8 Professionals who make decisions about building orientation

For building orientation, 73 percent of the respondents told us that the architect is the key decision maker. There are five supporting decision makers (Figure 8) who influence building orientation. According to our respondents, building owners and civil engineers support or influence the decision most often, 41 percent and 14 percent respectively. The role of owners seems obvious. Civil engineers are clearly important because of site preparation and layout. About 15 percent of the respondents identified other contractors (eight percent) and developers (seven percent) as playing a supporting role. Mechanical engineers influence the decision 16 percent of the time. The role of mechanical engineers is undoubtedly related to determining the solar induced thermal loads in response to Title 24. Electrical engineers and lighting designers play almost no role and are not identified in the graphic. These data suggest the lighting issues and lighting professionals are not factors in building orientation.

As another way of getting at the state of practice, we asked building professionals about the criteria they use in making decisions. Respondents were presented with a set of criteria and asked to rate the importance of each criterion on a scale of 1 to 10.

Table 17 shows the results from rating the criteria for building orientation. The table shows the percentage of cases for scale scores (columns 2 – 7) and the mean score (last column). The criteria are displayed based on their ranking from highest to lowest mean score.

Table 17 Importance of different criteria for determining building orientation

	Percent having score								
	1 to 5	6	7	8	9	10	Don't know	Total	Mean
Maximize use of ground space	6	4	11	19	12	48		100	8.7
Meet code requirements	17	4	3	11	3	61	1	100	8.4
Visual presentation	5	4	11	28	15	37		100	8.4
Access / egress	8	7	9	24	19	33		100	8.2
Parking	16	7	11	21	17	28		100	7.8
Solar orientation	42	11	17	11	8	11		100	6.2

N = 123

Table 17 shows that for building orientation, utilizing the ground space was ranked as the most important criterion. Meeting code requirements and producing a visually attractive building with good access and egress were the next most important. Parking was also rated as being important. Solar orientation was rated least important with 37 percent of respondents giving solar orientation a score of five or less. These data reinforce the observation in the previous paragraph about the relative lack of importance attached to building orientation in relation to sun and shadow effects.

When it comes to the placement and sizing of windows (Figure 9), the architect is the key decision maker. The owner is the actor most frequently identified as playing a supporting role. Owners concerns are probably aesthetic and cost related. Less than a quarter of the respondents identified mechanical engineers as having a role. Again, the obvious interpretation is the need to meet Title 24 requirements. Note that lighting designers and electrical engineers play supporting roles relatively infrequently. These findings are indicative of decision making that affords low levels of attention to the integration of daylighting into buildings.

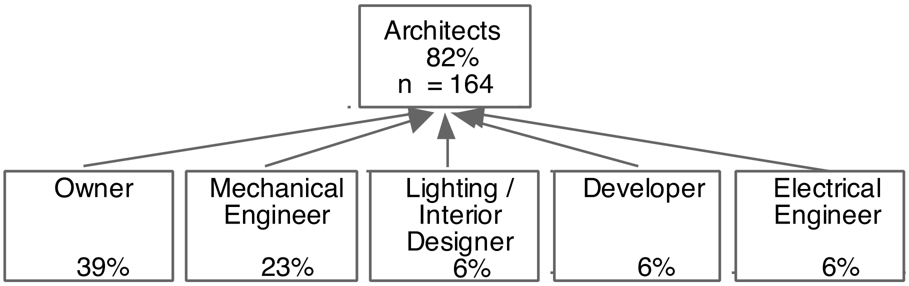


Figure 9 Professionals who determine the size and placement of windows

Several players are involved in supporting glazing decisions (Figure 10). Owners most frequently play supporting roles. Their interests are likely to be image and cost related. The critical role of glazing in helping to meet Title 24 requirements is probably indicated by the percentage of respondents saying mechanical engineers and energy consultants support glazing decisions. In comparison, lighting designers and electrical engineers are involved a much smaller percentage of the time.

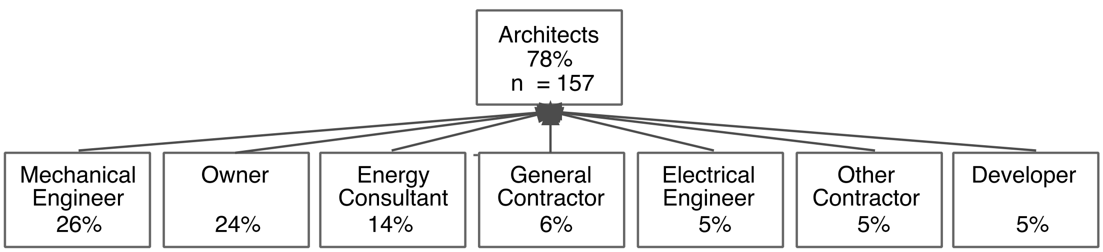


Figure 10 Professionals who make decisions about glazing materials

We asked building professionals to rate the different criteria that building professionals use in making decisions about glazing (Table 18). For this decision, meeting code requirements is by far the most important criterion. The next level of decision factors have to do with cost and aesthetics followed closely by the characteristics of the glass, insulating ability, daylight / visual transmission, and heat reflectivity. The heat reflectivity and insulating ability are significantly related to the code issue. Maximizing the amount of glazing is ranked last.

Table 18 Important criteria in decision making about glazing

	Percent having score							
	1 to 5	6	7	8	9	10	Don't know	Total	Mean
Meet code requirements	9	1	5	12	9	64		100	9.0
Cost	8	10	13	27	19	23		100	8.0
Aesthetics	14	5	12	26	14	29		100	7.9
Insulating ability	17	6	12	30	16	18	1	99	7.6
Daylight / visual transmission	19	8	14	27	11	21		100	7.5
Heat reflectivity	21	8	13	25	14	18	1	99	7.5
Maximize amount of glazing	31	9	14	26	8	12		100	6.9

N = 146

We also examined who the decision makers are with respect to introducing architectural elements such as shading devices to the physical structure of a building (Figure 11). After owners, lighting / interior designers and electrical engineers are the most frequent decision makers supporting decisions about architectural elements. If you combine the percentages of lighting / interior designers and electrical engineers and add energy consultants, 41 percent of the supporting actors may be aware of lighting design issues. From a daylighting perspective, a possible implication of this finding is that when architectural elements to control light are implemented, the decision makers incorporate electric lighting controls as well.

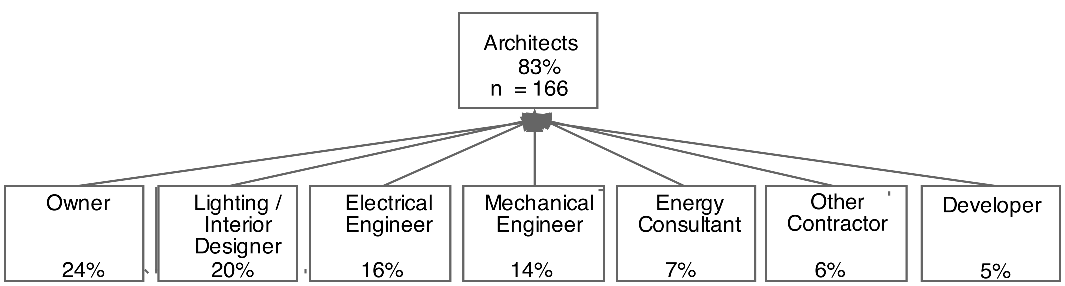


Figure 11 Professionals who make decisions about including architectural elements such as shading devices

Architects are also the key decision makers with respect to skylighting. In our interviews, several professionals told us that owners often request skylighting but they are often unable to incorporate skylighting because of budget constraints. The survey data are consistent with the notion that owners request skylighting. The interesting pattern in the survey data is that the supporting professionals include both those who deal with HVAC as well as lighting. The data from the one-to-one interviews seems to suggest, with rare exceptions, that decisions about skylights are mostly made with owners and with very little analysis. The survey data imply that there are somewhat numerous instances when skylighting is used when there is attention to both the solar thermal consequences of skylighting and the potential to reduce lighting energy use. The difference may be that many of those interviewed in the one-to-one interviews were introducing skylighting for visual affect whereas the survey asks somewhat explicitly about skylighting used in main work areas.

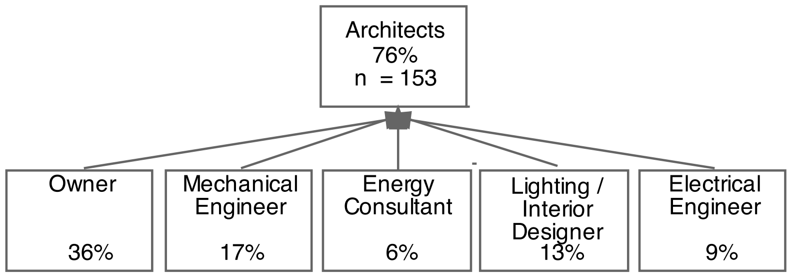


Figure 12 Professionals who make decisions about skylighting

Until now, the discussion has centered around decisions about building design in which there is one dominant decision maker, the architect, and supporting decision makers. When we move to the arena of decision making about lighting, we see a different structure emerge, one where the key decision maker may be an architect, an electrical engineer or a lighting designer. No one profession dominates.

For decisions about the lighting placement (Figure 13), architects are the primary decision makers about half the time, but if the percentages of electrical engineers and lighting designers are combined they play the key role almost as often. When either an electrical engineer or a lighting designer is the key decision maker, an architect plays a supporting role in the decision making in a very high percentage of cases. This is somewhat different than the impression we were left with in the one-to-one interviews where the respondents said that lighting was largely left to electrical engineers and lighting designers. We also see from the structures that when an electrical engineer or lighting designer is the dominant player, there is a small percentage of cases where the other plays the supporting role. These interactions no doubt reflect lighting designers' interests in aesthetics and electrical engineers' interests in the design of the electrical networks. These data show a fair amount of interplay between architects and electrical engineers with respect to lighting placement.

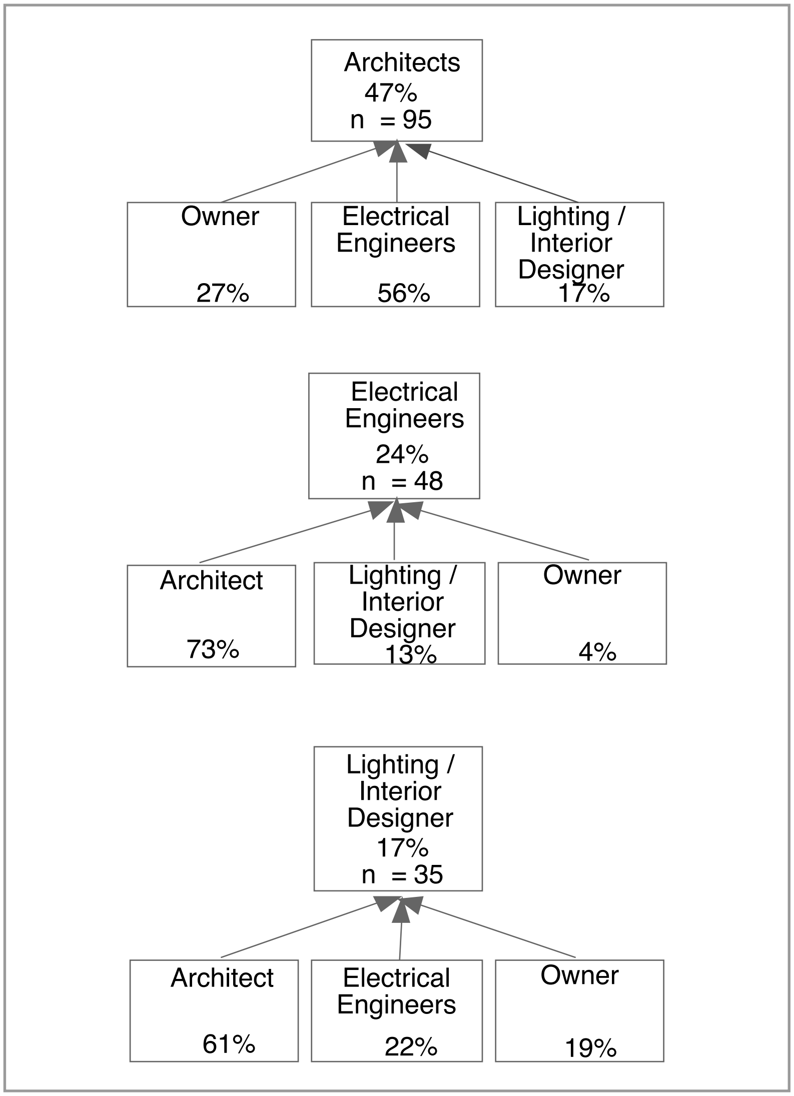


Figure 13 Decision making structures for lighting placement

The decision making patterns for lighting specifications are somewhat the same as for lighting placement. However, this is clearly an area in which the electrical engineers take the lead. When they do so, architects play a supporting role in a large percentage of cases. When architects take the lead they are heavily supported by the electrical engineers. When the lighting designers take the lead, they too are supported first by architects and then by electrical engineers. It would appear that lighting designers are slightly less likely to be supported by architects in specification decisions than in lighting placement decisions. For both lighting placement and lighting specification, owners are identified as playing a role about a quarter of the time or less.

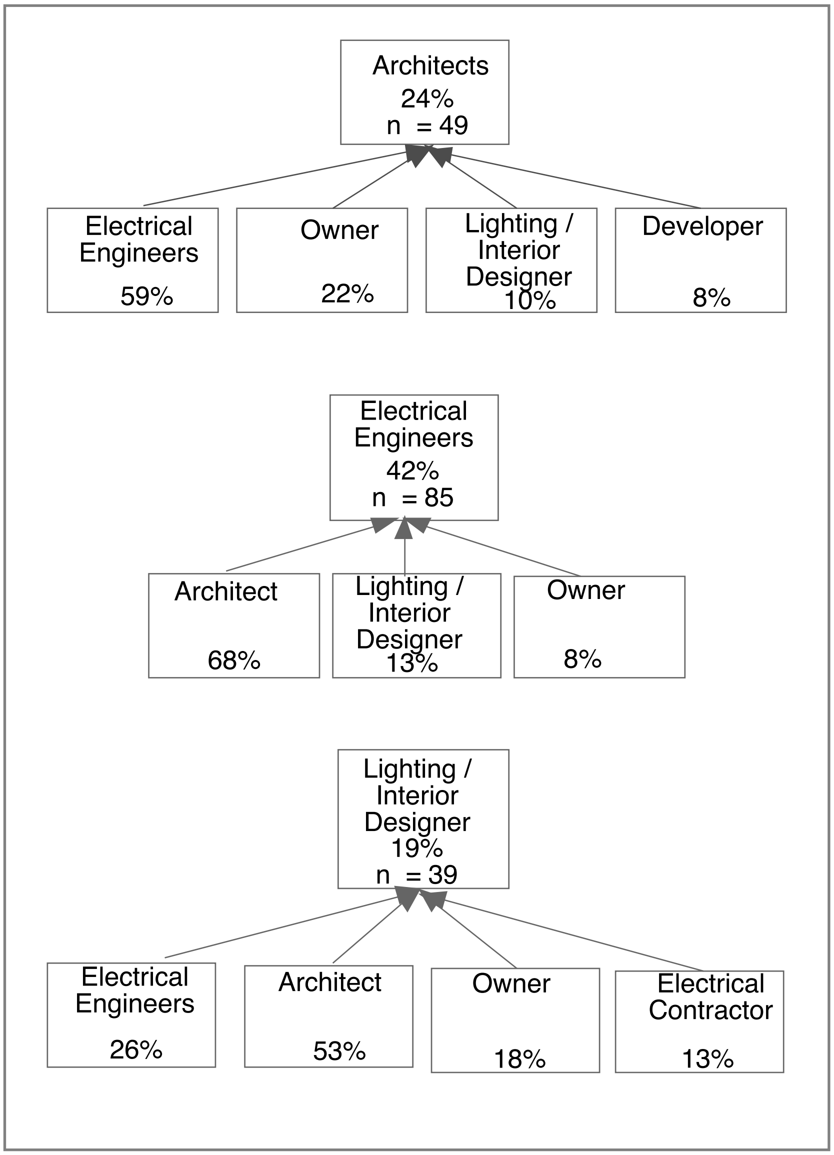


Figure 14 Decision structures for lighting specifications

As was the case with decision making about glazing, lighting specifications (see Table 19) appear to be code driven (i.e., Title 24 driven). Meeting functional requirements, reliability, and energy efficiency follow closely as important criteria. We have repeatedly seen reliability being called out as important in equipment selection in different studies. The energy efficiency of equipment follows closely behind in importance and is clearly code related. Visual appearance rounds out the top four criteria.

Table 19 Criteria important to making lighting decisions

	Percent having score							
	1 to 5	6	7	8	9	10	Total	Mean
Meet code requirements	5	1	3	13	5	74	101	9.3
Reliability	7	3	9	30	18	33	100	8.4
Functional lighting requirements	6	4	11	33	14	32	100	8.4
Energy efficiency	7	6	10	28	19	30	100	8.3
Appearance of fixture / equipment	8	5	11	27	19	30	100	8.2
Ease of maintenance	12	9	15	32	13	19	100	7.7
Initial equipment cost	15	9	16	35	7	18	100	7.6
Color of light	17	5	15	30	10	23	100	7.6
Component lifetime	23	13	15	28	7	14	100	7.1
Potential for glare	21	11	19	28	7	14	100	7.1
Ability to work with control systems	26	14	17	11	9	23	100	7.0

N = 175

Ease of maintenance, initial cost of the equipment, and the color of the light are ranked in the lower middle portion on this scale of importance. Component lifetime, potential for glare and ability to work with controls systems are at the bottom of the rankings.

In the mind of these respondents, reliability and component lifetime are different. It is more important for components to operate reliably over their lifetimes than it is to have components operate for longer lifetimes. This may reflect the fact that many commercial facilities are renovated at relatively short intervals, 3 – 5 years.

A final point is the criteria that are related to quality lighting (paying attention to color and the potential for glare) and the ability to do daylighting (lighting that will work with dimming systems) rank relatively low in the list.

As with the lighting specifications, electrical engineers are most likely to be the key decision makers with respect to dimming controls. When architects are the key decision makers, the electrical engineers are most likely to play a supporting role. When lighting designers make the decisions, electrical engineers and architects are equally likely to be the key decision makers.

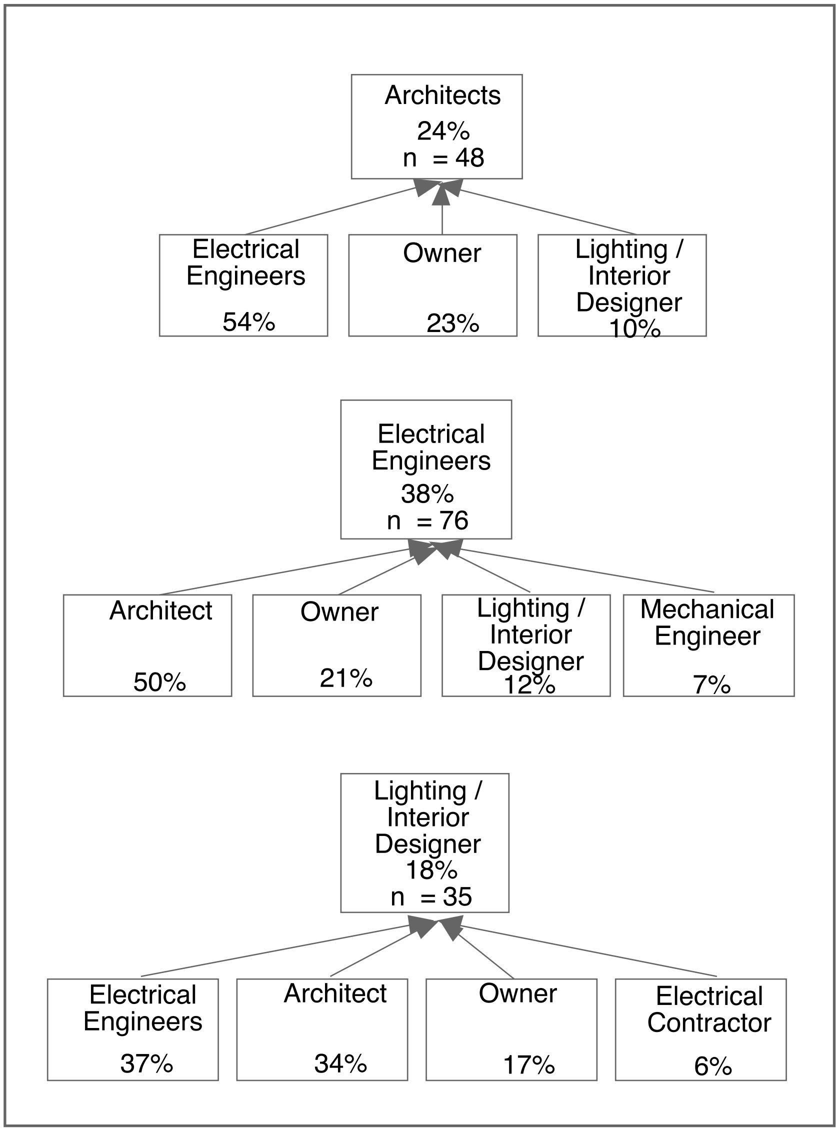


Figure 15 Decision structures for dimming

Finally, we analyzed criteria that may be important in making decisions about dimming controls. Once again, code requirements are at the top of the list. In relative terms energy efficiency, reliability, and user controllability are all seen as being of intermediate importance. The criteria rated least important have to do with initial equipment cost and ease of maintenance.

Table 20 Important criteria in making decisions about dimming controls

	Importance (percent)							
	1 to 5	6	7	8	9	10	Total	Mean
Meet code requirements	6	1	7	8	4	74	100	9.2
Energy efficiency	6	5	11	35	19	24	100	8.3
Reliability	8	1	11	35	18	27	100	8.2
User controllability	8	5	12	29	15	31	100	8.2
Initial equipment cost	15	8	12	45	6	14	100	7.5
Ease of maintenance	17	8	18	29	10	17	99	7.4

N = 98

Summary and conclusions

In this chapter we have examined eight decision areas to determine who makes the decisions and the criteria that are important in making these decisions. One finding that is very clear is that compliance with Title 24 is a strong factor in decision making. From the standpoint of improving overall energy efficiency, Title 24 is clearly working. However, there may be a downside. Throughout the survey and the one-to-one interviews, we detected a driving interest in meeting the Title 24 sometimes to the exclusion of considering alternatives that would yield even greater energy efficiency. One of the benefits of the design tools is that they may help to increase the ability of professionals to more than meet the requirements of Title 24. We certainly do not wish to imply with this observation that Title 24 should be changed in any way.

Architects are clearly in the drivers seat when it comes to decisions about physical design issues. It is fairly clear that they need the assistance of professionals for Title 24 compliance issues. Further, the data seem to show that lighting design professionals only have influence over aspects of design that would lead to quality daylighting in a relatively small percentage of cases. Also based on the relative importance of the various criteria, it appears that decision making criteria that would lead to quality daylighting designs are viewed as relatively less important. Thus, in terms of our concept of quality daylighting, it appears the current approach to projects is to the bottom and to the left of the diagram in Figure 4.

With respect to decision making about the use of architectural elements to create light and shadow effects and the use of skylights, the data suggest that for relatively small percentages of cases, their may be integration of decision making across disciplines.

Chapter 8 Current Baseline Practices and State of the Market

In this chapter we explore current practices of the building design community which may be relevant to the Daylighting Design Tools. This chapter addresses eight general questions:

- What types of buildings are being designed?
- For whom do building and lighting professionals work?
- How are lighting systems specified?
- How does the current market operate with respect to lighting systems and lighting control systems?
- What computer aided design (CAD) tools are in use and how are they used?
- How is rendering used?
- How are models and mock-ups used?
- How are skylights specified and used?

Types of commercial structures

Based on the survey data we developed three sets of numbers that help us to describe the types of projects being done in Northern California. The first is the percentage of firms saying that they have done a project of a certain type. The second is the average percent of projects completed by firms that have done projects of a type. The third is our estimate of the percentage of projects of the type that have been done in Northern California based on the information requested in the survey. Since we did not request information on all types of projects, this is not the percentage by type of all projects in Northern California.

For example, from Table 21 column four, we see that low-rise office structures (one to three stories) are the most common category of new building in Northern California. Eighty-percent of the 201 firms sampled, design at least some low-rise structures. The 160 professionals who report designing low-rise structures, report that low-rise structures represent an average of 35 percent of their total projects. The projects completed by these 160 firms represent 26 percent of the projects of this type completed by firms in our sample in the last 12 months (Table 21, Column four) in Northern California.

The next most common types of structures with which professionals work are educational buildings (13 percent), big-box retail (10 percent, other types of retail (eight percent), high rise office structures (four or more floors) (seven percent), warehouses (eight percent), and health care facilities (six percent).

More than half the professionals have worked on most of the structure types (column 1). The exceptions are big-box retail (48 percent of building professionals), manufacturing facilities (42 percent), health facilities (39 percent) and high-rise office structures (35 percent).

Table 21 Types of building projects in Northern California between June 1998 and May 1999

Building Type	Percent of firms saying that they have at least some projects of this type N = 201	Average percent of projects of this building type*	N	Percent of new Northern California projects of this building type N = 8517**
Low-rise office structure from one to three floors	80	35	160	26
Educational buildings	59	25	119	13
Big box retail including retail food stores	48	15	96	10
Other types of retail	66	17	132	8
Manufacturing facilities	42	17	85	8
Higher-rise office structures of four or more floors	35	16	71	7
Warehouses	53	14	106	8
Health facilities and hospitals	39	17	78	6
Other public buildings	57	17	114	8
Other buildings types	62	23	124	8

* Average percentage – only for firms who reported doing projects of this type.
** N is the total sum of projects in Northern California for the 201 firms represented in our sample.

For whom respondents work

In order to ascertain how decision making works, we asked professionals to whom they are most likely to be responsible for their projects, that is, who signs off on their work. Eighty-seven percent of building professionals said they report to building owners for at least some of their projects. Sixty-four percent say that they report to developers, 59 percent report to general contractors, 34 percent to retail chain stores, and 28 percent to engineering firms (Table 22).

In terms of the average number of projects, building professionals are most likely to report to a building owner other than a developer (41 percent). In about 30 to 35 percent of their projects, building professionals say they report to developers and architects. In terms of the average number of projects, building professionals are least likely to report to an engineering firm.

In terms of the total number of projects in Northern California, building professionals are most likely to report to one of three types of firms, architectural firms (24 percent), building owners other than a developer (21 percent), and developers (17 percent). The remaining projects are managed by general contractors (13 percent), retail chain stores (eight percent), "other" types of firms (eight percent), and engineering firms (seven percent).

Table 22 For whom building professionals work

Firm type that building professional reports to	Percent of firms saying that they report to this type of firm on at least some projects N = 201	Average percent of projects where firm reports to this firm type*	N	Percent of new Northern California projects by to whom building professional reports N = 8517**
Architectural firm	46	34	92	24
Building owner other than developer	87	41	175	21
Developer	64	31	128	17
General contractor	59	23	119	13
Retail chain store	34	20	68	8
Other type of firm	28	28	56	8
Engineering firm	28	16	56	7

* Average percentage – only for firms who said they reported to this firm type.
** N is the total sum of projects in Northern California for the 201 firms represented in our sample.

For whom projects are completed

Ninety percent of building professionals have completed at least some projects for known tenants and 63 percent have done so for tenants to be determined (Table 23). For building professionals that have completed projects for known tenants, they do so for 79 percent of their projects, while building professionals who complete projects for unknown tenants, do so for 23 percent of their projects. Similarly, 81 percent of all Northern California projects are completed for known tenants and the remaining 19 percent for tenants to be determined.

Table 23 For whom projects are completed

Known / Unknown tenant	Percent of building professionals who complete projects for tenants on at least some projects N = 201	Average percent of projects completed for…*	N	Percent of new Northern California projects completed for… N = 8517**
Known tenant	90	79	181	81
Lease or occupancy to be determined	63	23	126	19

* Average percentage – only for building professionals who reported completing projects for this type.
** N is the total sum of projects in Northern California for the 201 firms represented in our sample.

How lighting is specified

We asked professionals a series of questions pertaining to their role in specifying lighting. Sixty-nine percent of building professionals in our survey (Table 24) say they play a key role in analyzing the amount of artificial illumination needed in relation to task needs on at least some projects. Seventy-five percent also say they play a key role with regard to analyzing lamps and fixtures in relation to color quality needs. Approximately equal numbers, about 65 to 70 percent, say they play a role in commissioning or inspection of lighting control systems, recommending or implementing measures for reduced glazing, and working with others to examine potential facade elements to control natural lighting. Finally, 41 percent play key rolls in using physical or computer models to assess internal light and shadow effects.

Professionals say they play these roles for an average of from 39 to 62 percent of their projects (see Table 24). The task they complete most often is analyzing lamps and fixtures in relation to color quality needs while the task they complete least often is using physical or computer models to assess internal light and shadow effects do so on 39 percent of their projects.

Table 24 Percent of projects in which building played key role in lighting related activities

Lighting specification aspect or activity	Percent of building professionals who played a key role in this aspect in some projects N = 201	Average percent of projects where key role played*	N	Percent of new Northern California projects where activity was provided N = 8517**
Analyze amount of artificial illumination needed in relation to task needs	69	61	138	37
Analyze lamps and fixtures in relation to color quality needs	75	62	150	37
Commission or inspect lighting system or controls	66	53	133	28
Recommend or implement measures for reduced glazing	69	53	138	28
Work with others on design team to examine potential façade design elements to control natural light	70	45	141	18
Use physical or computer models to assess internal light and shadow effects	41	39	83	15

* Average percentage – only for building professionals who reported playing key role in this aspect.
** N is the total sum of projects in Northern California for the 201 firms represented in our sample.

Building professionals tell us they analyze the amount of artificial illumination needed in relation to task needs on an average of 37 percent of new Northern California projects (see Table 24). By contrast, building professionals tell us that they work with others to examine potential facade design elements aimed at controlling natural light in about 18 percent of Northern California projects and that they use physical or computer models to assess internal light and shadow effects for just 15 percent of projects. These latter tasks bear significantly on the introduction of quality daylighting.

Baseline use of lighting controls

We also examined the use of lighting controls in a manner similar to the way in which we examined how lighting is specified. Table 25 lists a series of practices related to the use of lighting control. The list has been ordered from most to least frequent use in projects, column 4.

Table 25 Lighting control practices in Northern California

Lighting control practice	Building professionals who did this on at least some projects N = 201	Average percent mean of projects having this practice*	N	Percent of new Northern California projects having practice N = 8517**
Used bi-level or tri-level lighting in some area	69	64	139	45
Used motion sensors in some area	63	42	127	25
Established lighting control zones for common use areas	44	58	88	20
Analyzed different dimming equipment and options	37	51	75	15
Used dimming ballasts with sensors in special areas	64	35	129	13
Examined potential sensor locations to see if they work with different carpet and furniture	31	52	63	15
Used dimming ballasts with sensors in main work areas	49	32	98	8
Established protocols and procedures for commissioning control sensors	25	47	54	13
Established lighting control zones based on cost effectiveness calculations	33	52	67	13
Commissioned lighting control sensors	27	46	51	11

* Average percentage – only for building professionals who reported lighting control practice.
** N is the total sum of projects in Northern California for the 201 firms represented in our sample.

Based on this analysis, bi-level and tri-level lighting are currently used in about 45 percent of the newly constructed commercial projects. Motion sensors are used in about 25 percent of projects. Based on the remaining items in the list, it appears that sensors and dimming controls are used in 15 percent or fewer projects. This is consistent with what we were told in the open-ended interviews. Thus, we conclude that the integrated use of lighting control analysis, strategies and systems may only occur in from 10 to 15 percent of the market in May of 1999. In other words, lighting controls are just beginning to penetrate the market.

We examined who is specifying lighting controls by profession. Our analysis indicates that electrical engineers most frequently work with the various aspects of control systems (Table 26). The data show that energy consultants least frequently work with elements of control systems. Lighting designers are less likely to work with motion sensors and bi- and tri-level lighting than are architects and engineers. Compared to electrical engineers, there is a slight tendency for architects and lighting designers to be more aware of the environment in which controls are operating. For example, lighting designers and architects are slightly more active in dealing with furniture and carpet in relation to sensors than are electrical engineers.

Table 26 Use of lighting control systems and strategies

	Percent of Architects	N	Percent of Electrical Engineers	N	Percent of Lighting Designers	N	Percent of Energy Consultants	N	Percent Total
Used bi-level or tri-level lighting	75	78	84	36	52	14	44	8	71
Used motion sensors in some areas	61	63	86	37	63	17	39	7	65
Established lighting control zones for common use areas	44	46	51	22	44	12	33	6	45
Analyzed different dimming equipment and options	33	34	51	22	44	12	28	5	38
Used dimming ballasts with sensors in special areas	65	68	70	30	74	20	44	8	66
Examined potential sensor locations to see if they work with different carpet and furniture	31	32	35	15	41	11	22	4	32
Used dimming ballasts with sensors in main work areas	50	52	53	23	52	14	39	7	50
Established protocols and procedures for commissioning control sensors	17	18	44	19	37	10	28	5	27
Established lighting control zones based on cost effectiveness calculations	28	29	49	21	37	10	27	5	34
Commissioned lighting control sensors	17	18	42	18	33	9	22	4	26

From the standpoint of Daylighting Prospector, a most interesting question is whether building professionals are using cost effectiveness analysis. It appears that only 49 percent of the electrical engineers that specify controls are doing this. The number of architects, lighting designers and energy consultants who do this is lower (27 to 37 percent).

Current levels of daylighting practice

As we pointed out in Chapter 3, daylighting is the intentional integration of building and lighting practices in order to optimize the amount of quality natural light entering a structure while controlling the amount of artificial light in order to provide a quality lighting environment. This concept is presented as a two dimensional space in Figure 4 of Chapter 3. Design professionals who do not use daylighting friendly *lighting practices* appear to the left on the horizontal axis while those who use daylighting friendly lighting designs are to the right. Professionals who employ daylight friendly *building designs* appear at the top of the vertical axis while those who do not, appear at the lower end. By definition those in the upper right quadrant are those who are doing daylighting.

If we combine some of the measures in our survey we can create separate measures for daylight friendly building and lighting practices. These can then be plotted in a two dimensional space like the one in Figure 4. This allows us to identify where building professionals are vis-à-vis daylighting. By creating the same plot for data collected in the future we will be able to see whether the use of daylighting is changing.

From the survey, we identified 15 lighting design questions and eight building design questions to examine the use of daylighting (See Table 27). All but two of the questions ask respondents to indicate the percent of their projects in which a specific lighting or building practice was used during the last 12 months. These questions give us a measure of the use of daylighting friendly practices in the market as a function of the practices of the market actors.

The two questions that do not ask about percent of projects asked about the importance of design practices to their projects on a 0 to 10 scale. Responses to these questions were converted to "percent" questions by multiplying their response by 10 percent. The questions are now on the same scale although there is some doubt about the meaning of the percent.

The percentages of projects for the eight daylighting friendly building design practice questions were summed and divided by eight to form an average percentage of projects having daylighting friendly design characteristics for each respondent. We created a similar average for the 15 lighting design practices. If the number of projects using daylighting friendly building and lighting practices increase, then our indices should increase over time. If the use of daylighting practices decline, then the indices should decline. If there is a change in one or the other dimension, then that will show as movement in either the vertical or horizontal dimension of the graph.

The eight building design and 15 lighting design questions included in the survey are presented in Table 27.

Table 27 Questions from the survey used to build daylighting indices

	Quality lighting design questions	Quality building design questions
1	For what percent of your firm's projects have you or someone in your firm analyzed the amount of artificial illumination needed in relation to task needs?	How important is solar orientation of the building in your decision about building orientation? (response x 10)
2	For what percent of your firm's projects have you or someone in your firm recommended or implement measurers for reducing glare?	How important is the daylight or visual transmittance of glazing in your selection of glazing materials? (response x 10)
3	For what percent of your firm's projects have you or someone in your firm analyzed lamps and fixtures in relation to color quality needs?	For what percent of your firm's projects have you or someone in your firm used computer models to assess internal light and shadow effects?
4	For what percent of your firm's projects have you or someone in your firm used physical or computer models to assess internal light and show effects	For what percent of your firm's projects have you or someone in your firm worked with others on the design team to examine potential façade design elements to control natural light?
5	For what percent of your firm's projects have you or someone in your firm commissioned or inspected lighting systems or controls?	For what percent of your firm's projects have you or someone in your firm used physical models to analyze such things as interior light and show effects?
6	For what percent of your firm's projects have you or someone in your firm used motion sensors?	For what percent of your firm's projects have you or someone in your firm used mock-ups to analyze the effects of artificial and natural lighting in interior designs?
7	For what percent of your firm's projects have you or someone in your firm used bi-level or tri-level lighting?	For what percent of your firm's projects have you or someone in your firm used general skylighting in a substantial proportion of the building to provide light in work spaces?
8	For what percent of your firm's projects have you or someone in your firm used dimming ballasts with sensors in just a few special places?	For what percent of your firm's projects have you or someone in your firm determined the size and number of skylights based on illumination requirements?
9	For what percent of your firm's projects have you or someone in your firm used dimming ballasts with sensors in the main work area?	
10	For what percent of your firm's projects have you or someone in your firm analyzed different dimming equipment options?	

11	For what percent of your firm's projects have you or someone in your firm established lighting control zones based on cost effectiveness calculations?
12	For what percent of your firm's projects have you or someone in your firm established lighting control zone boundaries based on common use areas?
13	For what percent of your firm's projects have you or someone in your firm examined potential sensor locations to see if they ill work with carpet and furniture in the proposed locations?
14	For what percent of your firm's projects have you or someone in your firm established a protocol for commissioning lighting sensors?
15	For what percent of your firm's projects have you or someone in your firm commissioned the sensors?

Establishing the baselines

One of the strengths of this method is that it allows us to ask simple questions about lighting and building practices and to combine them to form the scales. This approach is not without its problems. For instance, not every measure is necessarily appropriate to every project. Therefore, many respondents may not come close to 100 percent. Even so, the approach can help us understand when the market is relative to daylighting and provide a basis for measuring change in the future. As we work with and develop the approach we may be able to establish norms and we are likely to find better ways to aggregate the data into indices.

Survey questions

Figure 16 shows the distribution of average percentage of projects for the 15 daylight friendly lighting measures. The horizontal axis is the number of respondents and the vertical axis is the average percentage of lighting projects for the fifteen daylighting friendly lighting practices. Scores range from zero, indicating none of the practices were used in any projects, to 85, indicating that most of the practices were used on most projects. The average score for all respondents combined for lighting design practices was 26. The plot of these scores provides the baseline practice scores for the market as a whole with respect to lighting design practices.

The same procedure was used to examine the baseline for building design practices (Figure 17). For building design practices, the low score was zero and the high score was 58. The average percentage of projects with daylighting friendly building practices is 23.

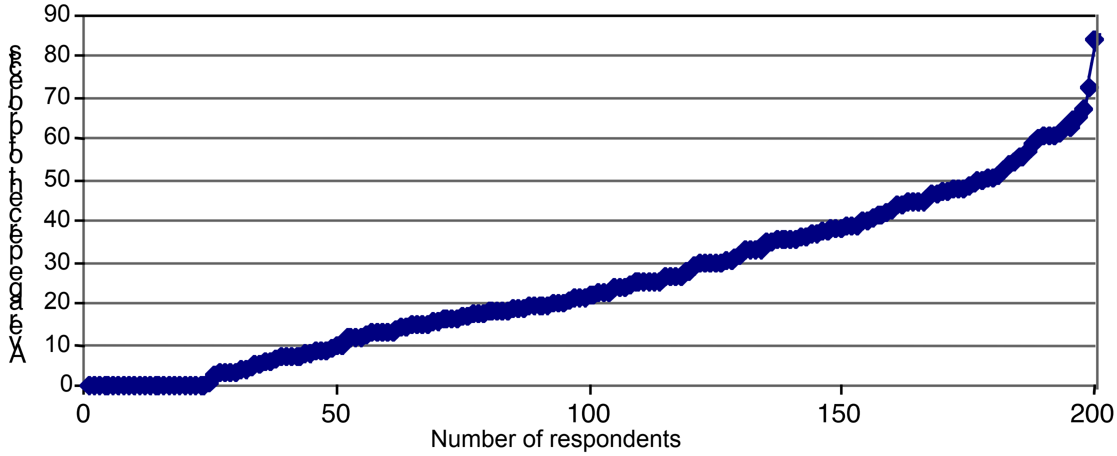


Figure 16 Daylighting friendly lighting design practices

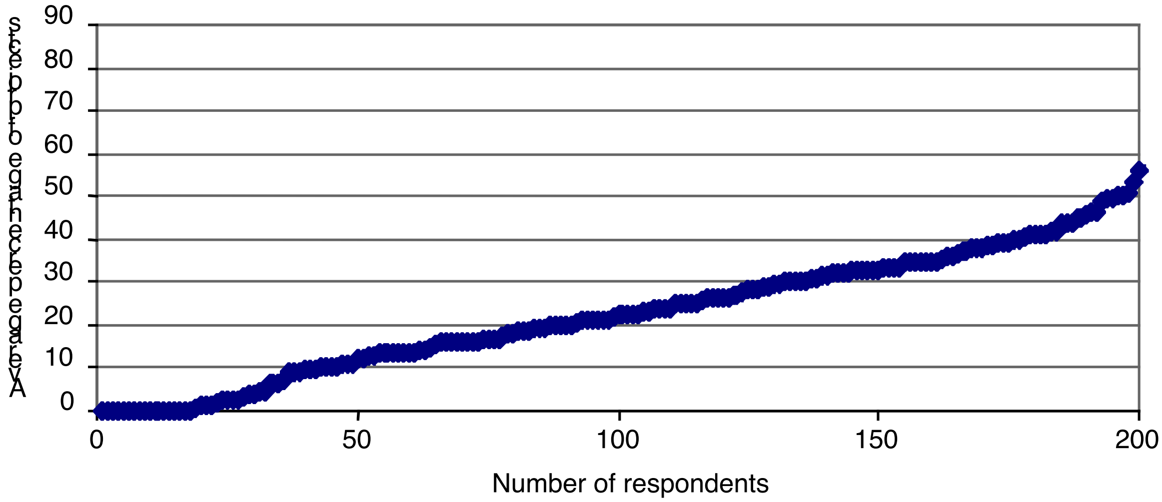


Figure 17 Daylighting friendly building design practices

When the measures Figure 18 are combined, the majority of respondents cluster in the lower left hand quadrant, indicating that buildings in Northern California are predominately constructed using standard practices that do not incorporate advanced skills or methods typically associated with daylighting systems.

The quartiles of the distributions are identified. As market transformation occurs in the targeted market these quartile points should move to the right and up to the degree that the practices are adopted in the market place.

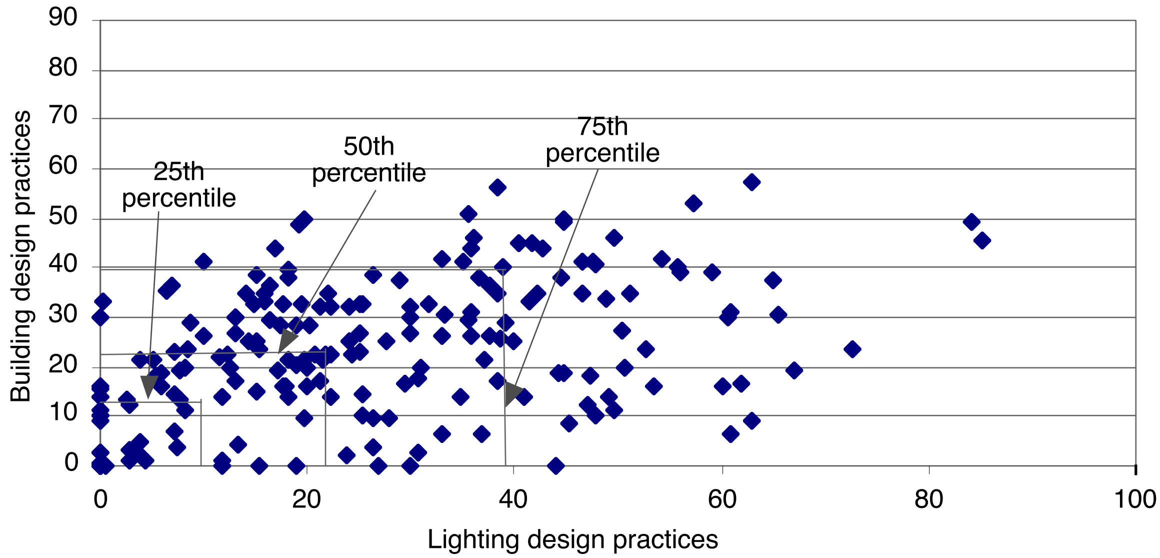


Figure 18 Current levels of daylighting practice

CAD (Computer Aided Design) software and rendering

In this section of the report, we explore building professionals' use of CAD including what they use and how they use it. If CAD is not widely used or if building professionals use other types of CAD other than AutoCAD, the adoption of Desk Top Radiance may be slowed. Also, because this is a baseline study, we want to learn more about how building professionals are currently using CAD.

In order to get at these issues we asked respondents about their use of computer aided design (CAD) software and rendering. The questions we asked addressed use of both 2D and 3D CAD software and the applications that are used.

Use of 2D CAD

Eighty-nine percent of respondents currently use some type of CAD software. Among current 2D CAD users, 72 percent use AutoCad, two percent use MicroStation, 20 percent use "other" software, and eight percent are unsure what their firms use. Additionally, five percent of the current 2D CAD users also use a secondary software package. The one that was identified most often was Archipad (14 percent) and "some other program".

Table 28 Software in use among 2D CAD users.

2D CAD Software	Percent
AutoCad	72
MicroStation	2
"Other" software	20
Can't remember name	6
Total	100

N = 179

Thirty-six percent of respondents said they use 3D CAD software to generate images of interior or exterior building spaces. A total of 75 percent recalled the name of the software. AutoCAD was the most frequently mentioned (43 percent) followed by 3D Studio (Table 29). Less than two percent use Architect PC, AutoCare, AutoDesk, Form Z, Graftsoft, Microsoft, R14, Rhinasouras, SoftCad, and Visio for 3D. The remaining 25 percent could not recall the software name. Additionally, five percent employ Lightscape, two percent employ AutoCad, and two percent employ SoftDesk as a second software package.

Table 29 3D software used to produce building images

3D CAD Software Application	Percent
AutoCad	43
3D Studio	13
DataCad	10
MiniCad	7
Chief Architect	3
Don't Remember	25
Total	101

N = 61

Because AutoCad has been a 3D software package for several years we expect that most firms have 3D capability in their current versions of AutoCad. However, we did not ask respondents to identify the specific version of the software they are using because respondents are typically unable to report these accurately.

How design professionals use rendering

In presenting the results of how design professionals use rendering, we needed to characterize the market actors who do and do not use rendering. To do this we asked respondents to tell us if they use 3D rendering in specific situations such as external design, internal design, and analyzing internal lighting and shading effects.

3D rendering as an external visualization design tool

Thirty-three percent of all respondents use some form of rendering to help clients and code officials visualize features on at least some of their projects (see Table 30). Specifically, 40 percent of architects, 33 percent of electrical engineers, 14 percent of lighting designers, and 11 percent of all energy consultants render the external shells of buildings (see Table 31).

Among those that use rendering for visualizing external design features, respondents estimate they use rendering in 45 percent of their projects (see Table 30). Architects use external rendering on average in 51 percent of their projects. The average use for electrical engineers, lighting designers, and energy consultants is 21 percent, 50 percent, and 55 percent, respectively (see Table 31).

When weighted by the number of projects at each firm at which rendering is used, we see that respondents are using rendering as an external design tool in only eight percent of all projects in Northern California (see Table 30).

Table 30 Usage of 3D rendering as a design tool

Rendering usage	Percent of building Professionals who say they use rendering on some projects in this way N = 201	Average percent of projects using rendering in this way*	N	Percent of new Northern California projects using rendering in this way N = 8517**
Use rendering to present external design features to clients and code officials	33	45	63	8
Use rendering to present internal design to clients	35	37	67	8
Use rendering to analyze internal light and shadow effects	18	24	35	4

* Average percentage – only for building professionals who reported rendering practice.
** N is the total sum of projects in Northern California for the 201 respondents in our sample.

Table 31 Use of rendering for external designs

Respondent type	Percentage of respondents using rendering for external design	N	Average percentage of projects in which rendering is used for external design	N
Architects	40	104	51	42
Electrical Engineers	33	43	21	14
Lighting Designers	14	27	50	5
Energy Consultants	11	18	55	2
Average	33		45	

3D rendering for visualizing internal spaces

Thirty-five percent of respondents use rendering for to visualize internal designs. By profession, 38 percent of architects, 37 percent of electrical engineers, 26 percent of lighting designers, and 22 percent of energy consultants use rendering for internal design purposes on at least some projects.

Among all of those who use 3D rendering for internal design, 3D rendering is used on an average of 37 percent of projects. By profession, architects use rendering in 44 percent of their projects, electrical engineers in 21 percent of their projects and energy consultants in 50 percent of their projects, and 41 percent of energy consultant projects (see Table 32).

When weighted by the number of projects, rendering for visualizing internal design is used in only eight percent of projects in northern California (see Table 30, Last Column).

Table 32 3D rendering as an internal design tool

Respondent type	Percentage of respondents using rendering for internal design	N	Average percentage of projects in which rendering used for internal design	N
Architects	38	104	41	40
Electrical Engineers	37	43	21	16
Lighting Designers	26	27	50	7
Energy Consultants	22	18	41	4
Average	35		37	

3D rendering for analyzing internal light and shadow effects

Seventeen percent of all respondents use 3D-CAD to analyze internal light and shadow effects. Table 33 shows how this breaks down by discipline.

Among those using rendering for internal lighting and shadow effects, respondents use rendering in 24 percent of their projects (Table 30). Lighting designers use rendering to analyze light and shadow effects on an average of 48 percent of their projects. Members of other disciplines use rendering for this purpose for less than 25 percent of their projects. (Table 33). Rendering is obviously an ideal way for lighting designers to show their clients their product.

When weighting by the number of projects at each firm, rendering for analysis of internal lighting and shading effects is used in only four percent of the projects in Northern California as of May 1999 (Table 30).

Table 33 Use of rendering for internal lighting and shadow effects

Respondent type	Percentage of respondents using rendering for internal light and shadows	N	Average percentage of projects in which rendering used for internal light and shadows	N
Architects	16	104	19	17
Electrical Engineers	28	43	25	12
Lighting Designers	15	27	48	4
Energy Consultants	11	18	18	2
Average	18		24	

Thirty-six percent of all respondents said they use 3D rendering to generate images interior or exterior building spaces. Seventy-nine percent of the projects that are rendered are done in-house. There is almost no variation between disciplines in terms of whether rendering is done in house (Table 34).

Seventy-one percent of 3D-CAD users expect their use of rendering to increase in the next two years and while three percent expect it to decrease. Among those not currently using 3D-CAD, 70 percent expect to start using rendering in the future. Rendering is clearly the future.

Table 34 When 3D rendering used, percent of projects where rendering is done in-house

Respondent type	Percent of projects done in-house	N
Architects	78	43
Electrical Engineers	75	18
Lighting Designers	89	8
Energy Consultants	82	4
Average	79	

Respondents were asked why they planned to increase their use of CAD software in the future. The predominant reason is that the newer software is better, cheaper, more powerful, and faster than in the past. Also, they report that their clients are increasingly expecting CAD and they report that their competitors are using it. The primary reason for not increasing use of CAD is that the cost of buying the software and the time involved in learning and using it. During the one-to-one interviews, many firms said they were solving the learning problem by hiring recent graduates who know how to use CAD

Those who use renderings cited numerous advantages. Most of the reasons were client centered. The primary value is using images to sell ideas. CAD is also a good marketing tool to present products to future and potential clients.

There are some barriers to the use of CAD. The cost of the software was mentioned frequently. The amount of time involved in learning to use software and in creating files is significant. There is very little extra or unallocated time available for skills development. Respondents said the software does not provide better or more information than conventional methods but provides it in a different way. Presumably Desktop Radiance might address this issue.

Physical models

We also asked respondents about their use of physical models. We did this for two reasons. Rendering may be a replacement for physical models. And, those who use physical models might be more inclined to use the Artificial Sky facility.

Fifty-percent of respondents say that they use physical models or mock-ups in their work in at least some of their projects. Forty-eight percent of all respondents use physical models to present designs to clients or local code officials, 24 percent say they use them to analyze interior light and shadow effects, and 21 percent use mock-ups to see the effects of artificial and natural light in interior design for some projects(Table 35).

Building professionals who use models to present designs to clients and code officials, do so for an average of 24 percent of their projects. The average percent of projects where models are used to analyze interior light and shadow effects is 21 percent, and 19 percent say they use mock-ups to see the effects of artificial and natural light in interior designs (Table 35).

Table 35 Use of physical models and mock-ups

	Percent of building Professionals saying that they use physical models on some projects N = 201	Average percent of projects using physical models / mock-ups in this way*	N	Percent of new Northern California projects using physical models in this way N = 8517**
Use physical models to present designs to clients and local code officials	48	24	92	5
Use physical models to analyze internal light and shadow effects	24	21	46	3
Use mock-ups to see the effects of artificial and natural light in interior designs	21	19	40	3

* Average percentage – only for building professionals who reported physical model or mock-up usage.
** N is the total sum of projects in Northern California for 201 respondents in sample.

When weighted on the basis of number of projects per firm, physical models are used to present designs to clients and code officials in about five percent of Northern California projects. Similarly, models are used in about three percent of Northern California projects to analyze internal light and shadow effects. Three-percent of projects use mock-ups to observe the effects of both artificial and natural light in interior design (See Table 35).

When we segregate the use of physical models by profession, architects (59 percent) and lighting designers (63 percent) most often use physical models to present designs to clients and local code officials. In contrast to this, 26 percent of electrical engineers and 11 percent of energy consultants use models in this way (Table 36). By discipline, the average number of projects for which physical models are used to present designs to local officials is about the same, except for energy consultants who seldom use models for this purpose for their projects.

Table 36 Use of physical models to present designs to clients and local code officials

Respondent type	Percentage of respondents using physical models to present designs	N	Average percentage of projects in which physical models used to present designs	N
Architects	59	104	24	61
Electrical Engineers	26	43	24	11
Lighting Designers	63	27	25	17
Energy Consultants	11	18	3	2
Average	48		24	

When we look at how physical models are used to analyze lighting and shadow effects, we see a somewhat different pattern. About 48 percent of lighting designers use physical models to analyze internal lighting and shadow effects. However, the use of physical models for this purpose by architects (23 percent) is much lower than their use for presentation purposes (59 percent). Among the 24 percent of the respondents using physical models in this way, they use the models in an average of 21 percent of their projects (Table 37). Lighting designers use them most frequently in their projects architects and energy consultants use them less frequently. Electrical engineers use models to examine internal lighting and shadow effects least often.

Table 37 Use of physical models to analyze internal lighting and shadow effects

Respondent type	Percentage of respondents using physical models to analyze internal light and shadows	N	Average percentage of projects in which physical models used for internal light and shadows	N
Architects	23	104	16	24
Electrical Engineers	12	43	32	5
Lighting Designers	48	27	26	13
Energy Consultants	17	18	13	3
Average	24		21	

Use of mock-ups is fairly common. Building professionals often construct them in warehouses or in client spaces to show clients how their spaces may work. According to our data, lighting designers are much more likely to use mock-ups than other professional groups. Forty-four percent of lighting designers use mock-ups to examine the effects of artificial and natural light in interior spaces (Table 38). The remainder of the disciplines say that they use mock-ups less than 17 percent of the time, with only 17 percent of architects, 17 percent of energy consultants, and 14 percent of electrical engineers using mock-ups in this way.

The 21 percent (Table 38) of all respondents who use mock-ups use them to see the effects of artificial and natural light in interior designs. On average, those who use mock-ups use them for about 19 percent of their projects. Of those who use mock-ups to examine artificial and natural light on interior design, electrical engineers use it most often in their projects (26 percent). This may be because electrical engineers tend to be from larger firms, which are most likely to have larger projects which can afford mock-ups. Overall, respondents use mock-ups in about three percent () of their Northern California projects.

Table 38 Use of mock-ups to see the effects of artificial and natural light on interior designs

Respondent type	Percentage of respondents using mock-ups	N	Average percentage of projects in which mock-ups are used	N
Architects	17	104	20	18
Electrical Engineers	14	43	26	6
Lighting Designers	44	27	15	12
Energy Consultants	17	18	12	3
Average	21		19	

In general, lighting designers are among the more frequent users of physical models and mock-ups while architects are frequent users of physical models for client and code official presentations. However, for all three of the physical models / mock-up purposes described above, use is currently limited to a very small minority of projects (three to five percent) in the Northern California market place. This implies it may take a while for the use of renderings to study light and shadow using advanced computer tools to gain widespread acceptance.

The use of skylights

In the one-to-one interviews, we found that many professionals had used some skylighting. They often mentioned doing skylighting in specialized spaces such as lobbies or multi-purpose areas. As a result, we determined that we needed to be careful to ask about the use of skylights in specialized places as well as their use in general work areas.

Seventy-one percent of respondents have used skylights for a few selected special places within buildings on at least some of their projects. This group has used skylights for an average of 43 percent of their projects accounting for 13 percent of the projects completed in Northern California (Table 39).

Fifty-seven percent of skylighting users claim to have used general skylighting to provide light to illuminate workspaces on at least a few projects. This group has done so for an average of 25 percent of all of their projects, accounting for 14 percent of the projects completed in Northern California over the last 12 months (Table 39).

Table 39 Skylight usage

	Percent of respondents saying that they have some projects that use skylights in this way N = 201	Average percent of projects using skylights in this way*	N	Percent of new Northern California projects using skylights in this way N = 8517
Use skylights for a few selected or special spaces within the building	71	43	139	14
Use general skylighting in a substantial proportion of building…designed to provide light in workspace	57	25	113	14

* Average percentage – only for building professionals who reported skylight usage practice.
** N is the total sum of projects in Northern California for the 201 respondents in our sample.

By profession, architects are the most frequent specifiers of skylights for selected spaces within a building. Fully, 90 percent of architects (Table 40) say that they specified skylighting for specialized spaces for 50 percent of their projects. Fifty-six percent of lighting designers have included skylights in 43 percent of their projects. Electrical engineers and energy consultants have had fewer projects involving skylights.

Table 40 Use of skylights for selected or special spaces

Respondent type	Percentage of respondents using skylights in this way	N	Average percentage of projects in which skylights used in this way	N
Architects	90	104	50	94
Lighting Designers	56	43	43	21
Electrical Engineers	49	27	18	15
Energy Consultants	39	18	30	7
Average	71		43	

Architects are also the most frequent users of general skylighting over workspaces, as 70 percent have done so on 25 percents of their projects (Table 41). What is interesting is that architects have a fairly high mean percentage of projects for specialized spaces but it is the energy consultants who have the highest mean percentage of projects for skylighting in general work areas. This implies that it is the energy consultants who are critical to specifying skylighting in general use spaces.

Table 41 Use of general skylighting to provide light to workspaces

Respondent type	Percentage of respondents using skylights in this way	N	Average percentage of projects in which skylights used in this way	N
Architects	70	104	25	73
Energy Consultants	42	43	29	18
Electrical Engineers	41	27	17	11
Lighting Designers	44	18	25	8
Average	57		25	

Skylighting is most effective as a daylighting tool if it is used in conjunction with lighting controls. If respondents said that they had used skylights to provide light to work spaces, they were asked if they had 1) specified the position of skylights based on the location of structural elements, 2) assessed illumination requirements, and 3) used lighting controls to reduce the use of artificial light in the presence of natural light from the skylights (Table 42).

Table 42 Specifying skylights based upon structural elements, illumination requirements and natural light

	Percent of building Professionals saying that they specify skylights on some projects in this way N = 201	Average percent of projects skylighting specified in this way*	N	Percent of Northern California projects, where skylights specified in this way N = 8517**
Based the number, size, and position of skylights on the location of structural elements	51	64	101	19
Determined size and number of skylights based on illumination requirements	42	46	83	11
Specified controls for electric lighting in response to natural light entering the space	42	44	82	14

* Average percentage – only for building professionals who reported skylight specifications practice.
** N is the total sum of projects in Northern California for 201 respondents in sample.

What the data in Table 42 show is that positioning of skylights is mostly based on where the structure is located, a not unexpected result. It also shows that fewer than half of the projects take into account illumination requirements. Finally, it shows that only slightly more than half of the projects install lighting controls when general skylighting is used.

About two-thirds of architects and roughly one-third of the other professionals who specify skylights over work areas do so based upon structural elements (See Table 43).

Table 43 Specifying skylights based upon structural elements

Respondent type	Percentage of respondents specifying skylights based upon structural elements	N	Average percentage of projects being specified in this way	N
Architects	63	104	69	66
Electrical Engineers	37	43	56	16
Lighting Designers	37	27	63	10
Energy Consultants	33	18	40	6
Average	51		68	

However, it is the energy consultants and the lighting designers who are most likely to use illumination requirements to specify skylights, based on the percent of projects (Table 44).

Table 44 Specifying skylights based on illumination requirements

Respondent type	Percentage of respondents specifying skylights illumination requirements	N	Average percentage of projects being specified in this way	N
Architects	51	104	47	53
Electrical Engineers	30	43	34	13
Lighting Designers	37	27	57	10
Energy Consultants	22	18	58	4
Average	42		47	

Architects that specify skylighting are the most frequent to design their use in response to natural light entering the building (48 percent), and do so on 40 percent of their projects (Table 45).

Table 45 Specifying skylights in response to natural light entrance

Respondent type	Percentage of respondents specifying skylights in response to natural light entrance	N	Average percentage of projects being specified in this way	N
Architects	48	104	40	50
Electrical Engineers	37	43	45	16
Lighting Designers	37	27	49	10
Energy Consultants	22	18	41	4
Average	42		42	

In general, the architects are most likely to have used skylights in the various ways discussed above and do so more than any other professional group. However, architects do not have the highest average percent of skylight use for projects.

Future expectations for skylights

When we asked professionals if they thought their use of skylighting would increase, decrease or remain about the same, the majority of respondents told us that that they though it would remain about the same (Table 46). However, energy consultants and lighting designers were more likely to say they expected to see an increase in the use of skylighting than architects and engineers. This, taken with some of the earlier observations about skylighting, suggests that the energy consultants and lighting designers may be more activist about skylighting than architects and electrical engineers.

Table 46 Future expectations, regarding skylight usage, among those already using them

Respondent type	Percent decreasing	Percent remaining about the same	Percent increasing	Percent Total	N
Architects	1	88	11	100	73
Electrical Engineers	6	78	17	100	18
Lighting Designers	18	46	36	100	11
Energy Consultants	13	50	38	100	8
Average	5	79	16	100	

Among those who have not specified skylights, over two-thirds have discussed their use with other professionals (Table 47).

Table 47 Have respondents who have not specified skylights discussed their use with other professionals?

Respondent type	Percent Yes	Percent No	Percent Total	N
Architects	32	68	100	31
Electrical Engineers	24	76	100	25
Lighting Designers	25	75	100	16
Energy Consultants	40	60	100	10
Average	29	71	100	

We also found that sixty-one percent of respondents who have not yet specified skylighting on projects have sought and obtained product information regarding their use. Architects and energy consultants are much more likely to have done this than others (Table 48).

Table 48 Have respondents who have not used skylights obtained product information about their use?

Respondent type	Percent Yes	Percent No	Percent Total	N
Architects	87	13	100	31
Electrical Engineers	40	60	100	25
Lighting Designers	38	63	100	16
Energy Consultants	70	30	100	10
Average	61	39	100	

Summary

Based on the data in this chapter we conclude that:

- Low rise office buildings make up the largest group of new commercial buildings in the market area followed by educational buildings and big box retail structures.
- Building designers of all types report to architectural firms, building owners and building developers and contractors for most of the new buildings in the market area of which about four-fifths are designed for a know tenant.
- Lighting systems are specified using a wide range of analysis methods and selection criteria including the analysis of task needs and the analysis of color quality among others.
- A majority of building designers specify some form of advanced lighting systems or controls for some projects, but their presence in the market is low for most projects and the use of advanced control and systems in not pervasive.
- The use of AutoCad is widespread but is predominately used for 2 dimensional work.
- Some form of rendering is used by a large segment of the market, but these segments to not represent a majority of the design community. Most rendering is done in-house.
- Physical models and mock-ups are not used for the vast majority of building projects.

- Skylights are routinely specified in the market, but only show up in about 14 percent of structures. Advanced lighting controls are rarely specified with skylights.

Chapter 9 The Market Potential for the Daylighting Design Tools

Introduction

In this chapter we examine what market actors say about the likelihood that they will adopt and use the Daylighting Design Tools. We answer four basic questions:

- What is the level of interest in the Daylighting Prospector, Desk Top Radiance, SkyCalc, and Artificial Sky?
- What motivates interest in the Daylighting Design Tools?
- Why do some market actors not have an interest in the Design Tools?
- What is the likelihood that these tools will be adopted and used?

Market potential

In order to evaluate the market potential for these products, we directly asked our survey respondents about their interest in the products. We read a brief description about each product and the information it provides and then asked respondents if the product would be of significant interest to them or their firm, of some interest, of little interest, or of no interest. If the respondent indicated conditional interest in the product or its potential application, the response was coded as "depends." The "depends" option was not read to the respondent. This technique allows the respondent to consider their response and indicate their level of interest while providing those who are unsure an optional category that allows them to qualify their response.

Sixty-six or more percent of the respondents expressed some interest in three of the four tools. Of the four tools, Desk Top Radiance elicited the highest level of significant interest (46 percent) followed closely by Daylighting Prospector (Table 49). SkyCalc also elicited much interest, but the number expressing significant interest was 17 percent less than for the Desk Top Radiance. The interest in Artificial Sky was half that of the Daylighting Prospector or Desk Top Radiance.

The percentage of respondents who felt that they had no potential use for the product was also recorded. More than half of the respondents felt they had no use or interest for Artificial Sky. One-fifth do not believe that they have a use for Desk Top Radiance. Three to four percent of the respondents felt they had no use for the Daylighting Prospector and SkyCalc.

Table 49 Percent of market that is interested in daylighting design tools

	Significant interest	Some interest	Depends	Of little interest	No interest	No potential use	Total
Daylighting Prospector	43	35	2	9	7	4	100
Desk Top Radiance	46	24	2	5	3	20	100
SkyCalc	29	37	2	17	12	14	101
Artificial Sky	12	20	2	11	4	50	99

Note: Includes all respondents, N = 201.

In market terms, the initial adopters are most likely to come from those who express a significant interest. Those with less interest are likely to wait until later in the adoption cycle when they can see the experiences of those who adopt. Based on the number expressing significant interest, the results of the PG&E survey indicate that there is strong market potential for Daylighting Prospector, for Desk Top Radiance, and (to a somewhat lesser degree) SkyCalc. If these products provide benefits following their introduction, it is likely that they will be adapted and used by a significant number of these respondents.

As we report later in this chapter, there is a small segment of the market for which Artificial Sky can provide significant advantages for testing a design concept, "selling" a design, and / or overcoming interest group resistance to design recommendations. Overall, there will be lower levels of acceptance for Artificial Sky than for the other products. There are a variety of reasons why this may be the case. There is a limited need for design professionals to "test" their designs under a simulated sky. The time and costs associated with using the facility are likely to outweigh the benefits for many projects. The Artificial Sky facility will be used as a technical and political problem-solving facility.

Daylighting Prospector

We examined interest in each of the tools in more depth. We did this by determining who might be interested in the tools and by analyzing what people told us about the perceived benefits of the tools and the perceived barriers to their adoption.

Interest in the Daylighting Prospector is strongest among electrical engineers (Table 50). Fifty-three percent of the electrical engineers have significant interest in Daylighting Prospector. Lighting designers are also interested with 48 percent indicating strong interest followed by energy consultants, 50 percent of whom expressed a strong interest. Architects have the smallest percentage, 39 percent, expressing significant interest.

The high level of interest among electrical engineers and energy consultants is consistent with their roles. The functions provided by Daylighting Prospector are basically engineering functions involving estimating lighting levels and selecting control strategies and control equipment. The slightly lower levels of significant interest among lighting designers can probably be traced to their greater interest in aesthetics than hardware. Because architects are often less involved with specifying lighting systems or in designing operational controls for lighting systems it is not surprising that they would have the lowest level of interest for the Daylighting Prospector.

Table 50 Percent interest in Daylighting Prospector by profession

	Significant interest	Some interest	Depends	Of little interest	No interest	Total	N
Electrical engineer	53	33	0	9	5	100	43
Energy consultant	50	22	6	11	11	100	18
Lighting designer	48	26	4	15	7	100	27
Architect	39	44	2	7	8	100	100

Note: Includes professionals who reported a level of demand for product

We asked respondents who indicated some level of interest in Daylighting Prospector about their primary motivations for wanting to use the program. Respondents could suggest as many reasons as they wanted. We received 282 comments from individuals. The most common responses (Table 51) were to save money for clients; to help with the analysis of different designs; options and decisions; or to service the client and provide greater customer satisfaction, reflecting the view of 27 percent, 25 percent and 22 percent of the respondents respectively. Saving energy or being more energy efficient was a frequently cited reason with 20 percent of the respondents providing this comment. Seventeen percent of the respondents said that they wanted to provide a higher quality product and the same amount said they wanted the tool to help demonstrate concepts and designs to clients.

The remaining responses covered a wide range of subject areas including: meeting Title 24 codes, to learn, to do better buildings and to increase sales among other reasons.

Table 51 What is your motivation for wanting to use Daylighting Prospector

Comment	Percent of Cases
Save money for clients	27
To help with the analysis of different designs, options and decision	25
Serve the client / customer satisfaction	22
Save energy / more energy efficient	20
Provide a high(er) quality product	17
Demonstrate to clients	17
To meet the Title 24 code	8
Learn about the program / gain knowledge	7
To do better buildings, offices, surrounding	7
Increase sales	6
To save time in the analysis	6
Modernize, improve our designs	5

N=282; only categories with five percent or more of responses are presented.
Total exceeds 100 percent because respondents could provide more than one answer.

We also examined why some respondents express little or no interest in Daylighting Prospector (Table 52). Fifty-six percent of those with little interest said they do not get involved in these aspects of building designs. The next largest group, making up 25 percent of these respondents, said that there is no client interest in daylighting, and 13 percent said that daylighting has little impact on their projects or that it is not important. Another 13 percent said they do this without the need for software. A few said that using the tool is not part of their standard practice or that there is no time for this activity.

Table 52 Why is Daylighting Prospector of no or little interest

Comment	Percent of cases
Not our line of work / not what we do / don't do Title 24 calculations	56
No interest in this from our clients / no demand for this / no market.	25
Not a significant impact on our projects / not important	13
We do this without the need for software	13
Not part of our standards or way of doing things	6
No time for this activity	6

N=30 responses; only categories with five percent or more responses are presented.
Total exceeds 100 percent because respondents could provide more than one answer.

Desk Top Radiance

Interest in Desk Top Radiance is most pronounced among lighting designers with 67 percent indicating strong interest in the software (Table 53). This is undoubtedly related to their interest in aesthetics and being able to visualize the product that they are producing in advance. Electrical engineers and architects also have a strong interest in Desk Top Radiance with 64 percent and 55 percent indicating significant interest respectively. Energy consultants expressed the lowest levels of interest with 36 percent indicating a significant interest. With the exception of the energy consultants, the percent of professionals having significant interest exceeds the percent reporting "some" interest, indicating that this software has the potential to capture the interest of a majority of the design community.

Table 53 Percent interest in Desk Top Radiance by profession

	Significant interest	Some interest	Depends	Of little interest	No interest	Total	N
Lighting designer	67	19	0	5	9	100	21
Electrical engineer	64	30	0	6	0	100	36
Architect	55	30	6	5	4	100	89
Energy consultant	36	37	0	27	0	100	11

Note: Includes professionals who reported a level of demand for product.

Respondents were asked what motivated their interest. The primary reason (Table 54) is to show designs to clients in order to demonstrate what a room or building will look like (43 percent) or to see the effects of different lighting designs (26 percent). Another 15 percent provided the closely related comment of wanting to evaluate or analyze different lighting options. Respondents provided a wide range of additional responses that seem to center on working with the client, saving time, energy or money, providing better products and services and working with clients. It is clear from these responses that Desk Top Radiance is seen as a tool to help improve designs, but also as a marketing and customer interaction tool to help with market competitiveness.

Table 54 What is your motivation for wanting to use Desk Top Radiance

	Percent of cases
Show designs to clients	43
To see the effect of different designs	26
Evaluate and analysis different lighting options and configurations	15
Save time on rendering	10
Increase sales	8
Reduce the cost of rendering	7
If it is easy to use, must be very easy	7
To do designs and renderings	6
To improve or make more realistic renderings	6
Increase customer satisfaction	6
To save energy / energy efficiency	5
Because it is free	5

N=228; only categories with five percent or more responses are presented.
Total exceeds 100 percent because respondents could provide more than one answer.

For the few people who are not interested in this program (Table 55), the primary reasons are that they do not use AutoCad (29 percent) or that they do not do lighting projects (29 percent). Eighteen percent of respondents said that they do too few projects where rendering is required or needed to warrant using the tool. The remaining responses included lack of time to learn it, rendering by hand or having different kinds of computers, etc.

Table 55 Why is Desk Top Radiance of no or little interest

Comment	Percent of cases
Don't do lighting.	29
Don't use AutoCad / don't use these programs.	29
Too few projects to need this type of tool.	18
No time to learn it / not enough time for this.	12
We render by hand.	6
This is not important to us / not a big concern.	6
We have different kinds of computers / doesn't work on our systems.	6
Our hands are tied with T-24 / we have no choice or options on this.	6

N=19; only responses with five or more are presented in the table
Total exceeds 100 percent because respondents could provide more than one answer.

Desk Top Radiance is designed to work with AutoCad version 14.0. AutoCad has had 3D capability for several years beginning with version 9.0. For this reason there may be a substantial segment of the market using 3D AutoCad capable versions that are incompatible with the Desk Top Radiance add-on. In the short term this may impact the market potential for Radiance limiting its use to those who have version 14.0 of the software or who are willing to up-grade their current versions to 14.0 at a current cost of about $3,000. In the longer term there will be newer versions of AutoCad and most users will eventually upgrade to take advantage of new features and a wide variety of products that are available in the after market. The ultimate challenge may be to keep Desk Top Radiance compatible with the new versions of AutoCad.

SkyCalc

Interest in SkyCalc is strong across each of the professional groups (Table 56) although not as strong as Daylighting Prospector or Desk Top Radiance. Lighting Designers had the highest percentage of respondents expressing significant interest in SkyCalc (38 percent) followed by energy consultants (35 percent), architects (29 percent) and electrical engineers (28 percent). It is interesting that energy consultants show one of the highest interest levels in this tool. This may be because skylighting is an option that can result in significant savings which allows more flexibility of design in other areas. It may also be that energy consultants are the one profession which might champion the idea of skylights.

Table 56 Percent interest in SkyCalc by profession

	Significant interest	Some interest	Depends	Of little interest	No interest	Total	N
Energy consultant	35	41	0	12	12	100	18
Lighting designer	38	23	4	8	27	100	27
Electrical engineer	28	44	0	23	5	100	43
Architect	29	40	3	18	10	100	104

Note: Includes professionals who reported a level of demand for product

Respondents indicated that they are interested in SkyCalc for a wide variety of reasons. When asked about the motivations (Table 57) for using SkyCalc, 27 percent of the respondents provided reasons having to do with analyzing, designing and testing ideas. Eighteen percent of the respondents said that they wanted to save energy, 11 percent wanted to increase customer satisfaction and service, and ten percent each said that cost savings could be increased by the use of natural light.

Table 57 What is your motivation for wanting to use SkyCalc

Comment	Percent of cases
Evaluate and analyze, help us design, test ideas and performance	27
Save energy / energy efficiency	18
Increase customer satisfaction and service	11
Look at the cost savings	10
Increase the use of natural lighting, better natural lighting	10
Improve the lighting of the building	10

N=178; only categories with five percent or more responses are presented in the table.
Total exceeds 100 percent because respondents could provide more than one answer.

Among those who expressed little or no interest in SkyCalc (Table 58), the primary reasons for little interest was that they do not do skylights in their work (51 percent) or that they are not the decision maker with respect to skylighting (14 percent). Others said that the decision is simple and there is no need for a computer to make these decisions or that there is no time for this type of analysis. Others provided a range of single response answers that reflect a wider range of opinions, such as that the clients are not informed, energy is not important, lighting has to be installed anyway, and others.

Table 58 Why is SkyCalc of little or no interest

Comment	Percent of cases
Don't do this/ no need for this.	51
We are not the decision maker	14
Don't need software for this decision / not that complex	14
It is not mandatory analysis	7

N=64; only categories with five percent or more responses are presented in the table.
Total exceeds 100 percent because respondents could provide more than one answer.

Artificial Sky

Interest in the Artificial Sky facility is strongest among electrical engineers. Each of the remaining three professions show much lower levels of interest (Table 59). Architects show two-thirds of the level of significant interest that electrical engineers do and lighting designers show about half the level of significant interest. Energy consultants only show "some interest".

Table 59 Percent interest in Artificial Sky by profession

	Significant interest	Some interest	Depends	Of little interest	No interest	Total	N
Electrical engineer	38	22	0	31	8	100	13
Architect	26	39	5	22	8	100	64
Lighting designer	17	39	11	22	11	100	18
Energy consultant	0	100	0	0	0	100	4

Note: Includes professionals who reported a level of demand for product

By a wide margin, designers said that they would use this facility to test or model the performance of their designs or to configure new or different designs and observe their performance. This response was provided by 80 percent of respondents (Table 60). Twenty-four percent said they would use the facility to show clients how their designs perform, while 13 percent said they would use the facility to improve their designs and eight percent said they would use it to save energy or increase the energy efficiency of their designs. In addition, five percent said they would use the facility to acquire general information or knowledge.

Table 60 What is your motivation for wanting to use the Artificial Sky facility

Comment	Percent of cases
Too model, or specify a design, test designs, confirm designs.	80
Show to our clients our designs and performance of designs.	24
To improve our designs.	13
Energy efficiency / save energy.	8
For general information and knowledge	6

N = 89; only categories with five percent or more responses are presented in the table
Total exceeds 100 percent because respondents could provide more than one answer.

We asked those who expressed a lack of interest why the Artificial Sky facility is of little or no interest to them. The primary reasons for the lack of interest is that the facility is not located near where they work (31 percent) or that they do not do a lot of work where such a facility is needed (24 percent) (Table 61). Fourteen percent said the facility is not needed in their work. Others indicated that the added cost cannot be accounted for within their existing projects (13 percent) and that these decisions are not that complex (seven percent).

Table 61 Why is the Artificial Sky facility of no or little interest

Comment	Percent of cases
Too far away from where we work.	31
Not a lot of that kind of work in this area.	24
Don't need it in our work.	14
Too expensive to do or use.	13
Our decisions are not that complex.	7

N=33; only categories with five percent or more responses are presented in the table
Total exceeds 100 percent because respondents could provide more than one answer.

Summary

Based on the data in this chapter we conclude that:

There is strong market interest in Daylighting Prospector, Desk Top Radiance, and SkyCalc.

We believe that this market interest will translate into use of the tools.

In the short term, the lack of AutoCad version 14.0 may reduce interest in Desk Top Radiance. However, we expect this issue to go away in the long term if Desk Top Radiance is compatible with later versions of AutoCad.

Artificial Sky will be used to a lessor degree, but can serve a valuable niche position by helping the building design community move toward better designs that can incorporate daylighting components among other design concepts.

There are differences in who is likely to use the tools. SkyCalc seems to have the greatest appeal among energy consultants, Desk Top Radiance among lighting designers, Daylighting Prospector among electrical engineers, and Artificial Sky among engineers. The evidence we have suggests that the tools will be a tougher sell to the architectural community. The data from the one-to-one interviews suggest that architects do not necessarily see the intended purpose of the tools fitting with their view of their role. For example, architects often told us that analysis that would be performed by SkyCalc or Daylighting Prospector was really in the province of the electrical engineers. One implication of this is that it may take longer to penetrate the architectural market with these tools.

The key motivations for using the design tools are to:

- model, test, and confirm designs,
- design, evaluate, analyze, and test ideas and their performance,
- show and demonstrate designs to clients, and
- save energy and / or money.

Reasons for not using design tools are because:

- respondents do not do that kind of work,
- respondents do not use design tool software, and
- there is a lack of client interest.

Should the lighting design tools be developed, deployed and supported in a way that provides significant relative advantages compared to current practices for the building design community, they will experience positive market acceptance and lead to transformation effects.

Chapter 10 Tracking the transformation of the market

Introduction

One of the goals of the research is to identify methods for measuring the transformational impacts of the Daylighting Design Tools. In this chapter we sketch out a methodology for measuring change.

Conceptual underpinnings

A basic design for conducting a market transformation assessment for a project such as this one is presented in Chapter 3 (see Figure 3). This design calls for a series of measurements to be made over time starting with a market and program baseline and a market characterization in a comparison area. This document represents the Time 0 measurements for the market and program baseline in Northern California. If the market transforming effects of this program are to be assessed based on this model, then periodic data collection activities are required once the programs are in the field and marketing efforts are underway.

There are two issues that need to be resolved with this design. The first is whether the measurements should be based on a panel design in which the same respondents are contacted at later points in time or whether measurements are to be drawn from new sample each time. The study would be stronger with a panel design because changes are tracked for specific firms and individuals and direct linkages can be made between changes in behaviors and adoption and use of program products. In a discrete sample design (different sample at each point in time), these linkages will have to be inferred. The panel design requires tracking and contacting the same respondents at subsequent points in time. This can be an expensive and time consuming process. In a panel design there is also the issue of respondent willingness to be interviewed more than once or twice and there is the issue of dealing with attrition among respondents.

The second issue with this design is the identification of a comparison area. From other studies we know that firms in the Northwest are quite similar to those in Northern California but the Northwest Energy Efficiency Alliance and the Lighting Design Laboratory are operating in that area and may very well encourage the adoption of these or similar tools. Thus, the Northwest is probably not a good area for a comparison. Other areas of the country that might be used for comparison purposes are Texas or the Washington, D.C. area. There is high growth in both of these areas and both have similar types of high technology industries and large numbers of architects.

It should be kept in mind that these tools may impact the market outside of California. Architecture is practiced regionally, nationally, and internationally. To the best knowledge of the investigators, there are presently no plans to limit the distribution of the tools to Northern California. If the tools are well received, it is likely that building professionals outside of California will become aware of the tools and some may become users of the tools. These cases need to be taken into account.

What needs to be measured and tracked

In order to determine if the Daylighting Design Tools are influencing the market, the following categories of data need to be collected either continuously or at discrete points in time in the future:

- Awareness of the Daylighting Design Tools and similar tools
- Contacts with sources of information and training with respect to the tools
- People / firms who have received the Daylighting Design Tools
- People / firms that have tried the Daylighting Design Tools
- People / firms that are regularly using the Daylighting Design Tools
- Proportion of projects in which people are using the tools
- Motivations for using the tools
- Characterization of selected professional design practices in key selected areas (see below)
- Objective measures of building efficiency from California Title 24 data
- Firmographics

These data can be collected through a tracking system and participant and non-participant surveys. Table 62 lists the categories of data by the participant status.

Why the data are important

Part of what needs to be known in order to evaluate the market transformation effects of the tools is the amount of marketing that is done and the audiences to which marketing efforts are targeted. Individuals and firms must be aware of the tools in order to adopt them. It is also important to know (by tracking if possible) what information and training people may have received with respect to the tools and the source of that information.

It is also important to continuously track who has actually requested and received copies of the tools. This information is vital for efficient follow-up. If possible, small amounts of demographic and firmographic information should be requested as part of the request fulfillment process. This information can be analyzed and compared to the baseline to understand who the adopters are and who is responding to any marketing efforts on a continuing basis.

At various future points in time surveys can be used to determine:

- who is aware of the tools

- why people have or have not adopted the tools
- how much the tools are being used

Ultimately the question is one of whether the tools cause design practices related to daylighting to change. Questions about design practices can be repeated from survey to survey and changes in the levels of practice can be tracked against use of the tools. If the tools are influencing the market, then there should be greater levels of change in practice among those who have used the tools than among those who have not.

Table 27 in Chapter 8 presents a series of questions about lighting and design issues. These baseline questions are appropriate for inclusion in follow-up studies. In the follow-up studies, the amount of change can be assessed by determining how the distribution of daylighting practice at the time of the follow-up study has changed from current practice as represented in Figure 18. The use of the daylighting model is very powerful because change can be tracked along both the lighting and physical design dimensions which allows us to understand where change is occurring. Further, with just two or three sets of additional data points, we can begin to estimate how things are moving with diffusion curves.

Table 62 Categories of data to be collected by participant status

		Data to be collected continuously or at intervals		
	Data in the current baseline (This report)	Participants (N. California and elsewhere)	Non participants (N. California)	Non participants in a comparison area (Texas / Virginia)
Awareness of Daylighting Design Tools and similar tools	Yes	Survey		Survey
Contacts with sources of information and training with respect to tools		Survey		
People / firms who have received the tools	Assumed to be zero	Tracking system	N/A	N/A
People / firms that have tried the tools	Assumed to be zero	Survey	N/A	N/A
People / firms that are regularly using the Daylighting Design Tools (percent of projects)	Assumed to be zero	Survey	N/A	N/A
People / firms are regularly using similar tools (percent of projects)	Yes	Survey	Survey	Survey
Motivations for using the Design Tools	Yes	Survey	N/A	N/A
Motivations for using the similar tools	Yes	Survey	Survey	Survey
Professional design practices in key selected areas	Yes	Survey	Survey	Survey
Extent to which practices have been influenced by Daylighting Design Tools	Not applicable	Survey		
Title 24 data for efficiency of buildings	Not applicable	Data from Title 24 compliance	Data from Title 24 compliance	Not applicable
Firmographics	Yes	Survey	Survey	Survey

Chapter 11 Key Findings and Lessons

This chapter summarizes the major findings of the research and suggests potential directions for the future.

Program Overview

Currently, PG&E is attempting to address daylighting technology and diffusion issues by developing analysis and information tools that will enable building professionals to increase the energy efficiency, occupant comfort and value of commercial buildings they design and build. PG&E's goal is to create and deliver tools that will find acceptance in the day-to-day world of practitioners. Greater use of such tools should provide architects and designers with increased confidence in their evaluation of lighting design and daylighting options which, in turn, is expected to lead to changes in design practice. PG&E’s intent is to transfer these tools to users in order to effect changes in design practice that will increase the use of efficient lighting and daylighting in designs. PG&E's short term objectives are to:

- create a viable set of products and an allied set of educational offerings,
- transfer the products to the marketplace, and
- encourage others to become partners in the continuing development of these products and the market.

The tools are now in advanced stages of development or are currently being introduced into the market. This study provides a market evaluation to understand the structure of the market, the target audiences, and to help fine-tune strategies for transferring the tools into the market place. In addition this study establishes a daylighting practices market baseline so that PG&E can track the penetration of the tools and assess the effects of the tools in the market place.

Purpose of study

The purpose of this study is to examine the operations of the daylighting market in Northern California and to characterize the baseline operations of that market. However, because daylighting is not a single product but a concept integrating several related building decisions, characteristics, and components, there is actually no “daylighting” market as one would traditionally think of a product market. Instead daylighting is a purposeful way of incorporating and integrating lighting concepts that use natural light to offset the use of artificial light. As a result, a baseline study for daylighting is actually a building practices baseline for the decisions and product uses that go into creating a day-lit environment. The purpose of this study is to baseline the operations of the market for the aspects that impact the integration and use of daylighting, including:

- Building design and orientation practices relating to daylighting,
- The design and use of glazing systems to allow for the entry of artificial light,
- The integration and use of lighting, fixtures and controls,
- The use of design practices and tools that influence daylighting, and
- Actors' daylighting decision making criteria and current patterns of influence

In addition, this study examines the market potential for four daylighting design tools developed by PG&E to help speed the transformation of the daylighting market toward greater use of daylighting in commercial buildings. The purposes of this study for the Daylighting Design Tools are to identify:

- Current market practices so that changes to the market resulting from the introduction of PG&E's tools into the lighting market can be assessed
- Barriers to the introduction of these products
- The potential for these products to influence the market
- The potential for these products to be adopted in the market
- Market effects measures that will allow changes in the use of these products to be tracked in the future
- The target audiences, particularly the types, number and characteristics of actors interested in the Daylighting Tools
- The functions of the Daylighting Design Tools

Methodology

There are primarily three methods being used in this research. The first is the analysis of secondary data. These data are primarily from F. W. Dodge and represent data about construction activity in Northern California in 1997 and 1998. In addition, we have obtained and examined the lists of architects and electrical engineers registered in California in 1998.

The second source of data is 30 one-to-one interviews with architects, electrical engineers and lighting designers. The respondents are from a stratified random sample of firms representing four different levels of participation in the market based on the 1997 and 1998 F. W. Dodge data. The interviews were conducted on-site at the respondents' premises. The interviews lasted from 30 minutes to an hour and a half. The interviews were open-ended but were conducted using a protocol.

The third source of data is a random telephone survey of 201 building professionals focusing on the design and specification behaviors of key players in the market, their interest in the Daylighting Design Tools, and demographic and firmographic information.

This report presents the synthesis and analysis of these assessment efforts and provides a baseline of the operations of the daylighting market in order to track market changes associated with the use of the daylighting tools.

Characteristics of the target audience

The largest group included in the study sample is architects and the next largest is electrical engineers. The most frequent occupational title among the respondents is owner / partner which reflects the many small firms in the sample as well as the way in which the sampling frame was constructed.

The most common level of education is the bachelor's degree. About the same number of people have additional education through and including a master's degree with some additional education.

The size of the firms range from the very small, with one or two employees and a few projects, to large firms, with multiple offices, hundreds of projects, and hundreds of employees. All of these firms primarily do business in Northern California. The firms complete projects for a broad range of building types. The type of structure common to most firms are low-rise offices, educational buildings and retail stores that are not of the big box type.

Nearly every firm works directly for building owners but most complete projects for a wide variety of other actors including developers, contractors and other architectural and engineering firms.

Key findings about diffusing tools into the market

Based on the market baseline assessment, we estimate that there are probably fewer than 2,000 key firms in Northern California that should be the target of PG&E's Daylighting Design Tools marketing efforts.

There are some basic types of decision making structures within the market. Depending on the type of structure the key decision makers will vary. For example, if the goal is to encourage retail chain outlets to make greater use of skylighting, then the key targets will be the in-house staff of the retail chain and the firm or firms that are responsible for the design of the market image for the chain's buildings. These firms should be an important target audience for both the message about skylighting and for use of the software. The market image firms may often be located outside of California.

Chains use local architects and engineering firms to insure that buildings meet state and local codes and to ease the local permitting process. These firms can influence the process but their influence is minimal. They should also be a target audience for the message about skylights and the software because of their supporting role. These firms are frequently responsible for finalizing the designs and for seeing that buildings meet specifications.

In the design build environment, the customer and the firm responsible for managing the overall construction, frequently a construction contractor, are the key to changing practices with respect to daylighting. Therefore, they should be the primary targets of efforts to introduce daylighting concepts into new construction. These audiences may be less interested in the tools than in information and data demonstrating that daylighting may lead to increases in productivity and may represent effective life cycle cost solutions. In these settings architects and engineers can play a “pull” role in bringing the technology into the market and they need to have the tools and training to use the tools. If they have both, they may be able to exert some influence on the clients.

In the more traditional, architect driven environment the architects are key players. However, their interest in daylighting concepts, the complexity of the configurations and controls, the use of Title 24 standards as a target rather than as a threshold, and the pressures to design low-cost buildings as fast as possible provides a marketing challenge for introducing daylighting systems.

We have presented a model for understanding daylighting. Daylighting is the intentional integration of elements of building design, artificial lighting and natural lighting to provide visually comfortable environments that optimize the use of natural and artificial light while minimizing energy consumption. We defined a physical dimension and a lighting dimension that must be intentionally integrated for good lighting design to occur. In our preliminary analysis we found that in Northern California:

- Building orientation and siting is seldom done in response to lighting requirements.
- Architectural elements that provide shading currently are not widely used.
- Architects attend to the size of windows and glazings because of the need to comply with Title 24 requirements.
- Architects probably use learned rules of thumb to determine the size and placement of windows.
- It is the engineers who do the heat load analysis. Unless there are significant problems in meeting Title 24 requirements, engineers will specify solutions that are within their purview and that do not require changing the physical elements of the structure.
- Architects see their role as one of dealing with physical and aesthetic aspects of design. Generally they view lighting as being outside of the range of their responsibilities.
- Architects see engineers and lighting designers as being responsible for designing lighting systems.
- Engineers are providing lighting solutions that meet Title 24 requirements.
- Except for motion controls in selected areas, automated lighting controls are not generally being specified.
- Engineers cited the cost of control systems (particularly the costs of ballasts) as being a key barrier to the adoption of lighting dimming systems.
- Engineers think life cycle cost data might help overcome the resistance to control systems but they were unsure of their ability to influence the process.
- There are some buildings, usually those for high tech customers, where controls are being specified as a way to give staff more control over their environments.
- Many architectural firms are now using 3D CAD rendering for presentation purposes.
- Architects would welcome a rendering tool that is easier to use than the ones they are currently using for presenting designs.

- Architects see the use of a rendering tool to examine illumination levels as being an engineering function.
- Architects are more likely to use a rendering tool to examine light and shadow effects in special settings where lighting is critical to the aesthetic of the space.
- Many firms are incorporating some skylights into buildings.
- Most skylighting is minimal and done for aesthetic and comfort reasons.
- The evidence suggests that when skylighting is being done, lighting and lighting control systems are being considered to form a comprehensive integrated solution only about half the time.

There is little current evidence that the physical and lighting elements of design are being intentionally integrated to form good daylighting solutions. A major barrier to integration is the definition of disciplinary boundaries by the players and the timing of analysis, which act to prevent integrated solutions. Several people suggested that a simple tool that would allow analysis of lighting patterns early in the process might increase the potential for integration.

It is clear that effectiveness of PG&E's efforts to diffuse these technologies will be much enhanced if the target audiences are segmented and targeted separately. Initially, it may be important to target engineers and lighting designers for these tools because they are the ones who are most likely to use them first.

Decision Making

We examined eight decision areas to determine who makes the decisions and the criteria that are important to selected decisions. The eight areas are the exact orientation of the building, size / placement of windows, glazing material, use of architectural elements, use of skylights, lighting location / placement, lighting specifications, and dimming controls.

One finding that is very clear is that compliance with Title 24 is a strong factor in decision making. From the standpoint of improving overall energy efficiency, Title 24 is clearly working. However, there may be a downside. Throughout the survey and the one-to-one interviews, we detected a driving interest in meeting Title 24 requirements, sometimes to the exclusion of considering alternatives that would yield even greater energy efficiency. One of the benefits of the design tools is that they may help to increase the ability of professionals to more than meet the requirements of Title 24.

Architects are clearly in the driver's seat when it comes to decisions about physical design issues. It is fairly clear that they seek the assistance of professionals who can assist them with Title 24 compliance issues. Further, the data seem to show that lighting design professionals only have influence over aspects of design that would lead to quality daylighting in a relatively small percentage of cases. Also based on the relative importance of the various criteria, it appears that decision making criteria that would lead to quality daylighting designs are viewed as relatively less important.

With respect to decision making about the use of architectural elements to create transmission and shadow effects and the use of skylights, the data suggest that for relatively small percentages of cases, there may be integration of decision making across disciplines.

Current baseline practices and the state of the market

With regard to the market baseline of the market, we found that low-rise office buildings make up the largest group of new commercial buildings in the market area followed by educational buildings and big box retail structures.

Building designers of all types report to architectural firms, building owners and building developers and contractors. Over three-quarters of buildings are designed for a known tenant. This suggests that split incentives are potentially a problem in a small proportion of buildings.

Lighting systems are specified using a wide range of analysis methods and selection criteria including the analysis of task needs and the analysis of color quality among others. A majority of building designers specify some form of advanced lighting systems or controls, but their presence in the market is low for most projects and the use of advanced controls and systems in not pervasive.

The use of AutoCad is very strong but it is predominately used for two dimensional work.

Some form of rendering is used by a modest segment of the market but this segment does not represent a majority of the design community. Most rendering is done in-house. Physical models and mock-ups are not used in the vast majority of building projects.

Skylights are specified in the market, but only show up in about 13 percent of structures. Advanced lighting controls are specified with skylights about half the time.

Market potential for Daylighting Design Tools

There is strong market interest in Daylighting Prospector, Desk Top Radiance, and SkyCalc. However, lack of AutoCad version 14.0 may serve as a barrier for the use of Desk Top Radiance.

Artificial Sky will be used to a lesser degree but can serve a valuable niche position by helping the building design community move toward better designs that can incorporate daylighting components among other design concepts.

The key motivations for using the design tools are to:

- model, test, and confirm designs,
- design, evaluate, analyze, and test ideas and their performance,
- show and demonstrate designs to clients, and

- save energy and / or money.

Reasons for not using design tools are because:

- respondents do not do that kind of work,
- respondents do not use design tool software, and
- there is a lack of client interest.

Should the lighting design tools be developed and deployed in a way that provides significant relative advantages for the building design community, they will experience positive market acceptance and lead to transformation effects.

Based on the data from the telephone survey and the commentary in the interviews, we believe that these three lighting design tools, Daylighting Prospector, Desk Top Radiance, and SkyCalc, have the potential to become important resources for building professionals.

Daylighting Design Tools Market Barriers

One theme identified in the market transformation literature is the need to identify market barriers in order to be able to design programs that overcome the barriers and speed the adoption of energy efficient innovations in the market. This report identifies and discusses a number of market barriers within the contextual framework of the operations of the daylighting market and in the discussions pertaining to the daylighting tools. This section of the report brings these barriers together.

Market operations barriers

Rules of thumb rule the roost

In order to speed their work professionals develop rules of thumb. For example, an architect may have a rule about the percentage of a wall that can be glass of a certain type in order to meet Title 24 guidelines. Analytic tools must compete with the ease of use of rules of thumb if they are to be adopted. If they take longer than rules of thumb, then tools must have offsetting advantages that will make it easy to adopt them.

Design in a one way street

The physical design of buildings is often “frozen” before lighting designers and electrical engineers are included in the design process. Thus, many of the decisions about building orientation, window size and placement, and glazing materials are made with minimal input from lighting designers and electrical engineers. This limits the potential for integrated daylighting options.

Cheaper, faster, better,

Building professionals report that time frames are short, budgets are competitive, and performance in getting the building completed is paramount. There are negative incentives if the pace of work is slow and costs are increased by exploring alternative lighting designs or conducting analysis to determine if daylighting is appropriate. This market is receptive to changes that help get the job done, cheaper, faster and better, but not at the expense of reliability or client satisfaction. To the extent that the design tools can speed the design process, they will be embraced.

The responsibility gap

Members of each discipline have strong perceptions about their responsibilities and the responsibilities of others. The key issues in daylighting are often interdisciplinary and require coordination and communication. Unless someone takes responsibility for resolving the interdisciplinary issues, professionals fall back to their perceived disciplinary boundaries. The result is that no one is responsible for looking at alternative designs that can save money and energy in a significant number of new buildings.

Reliability, Reliability, Reliability

Experience has taught professionals that reliability is important, more important than component life times and more important than hardware costs. Professionals are looking for reliable systems that can be rapidly specified and installed. Lack of experience with advanced fixtures and controls translates to lack of confidence in their performance. Building professionals do not want to take risks that require them to spend additional time or money fixing a problem that would not have occurred by using more traditional fixtures or controls. Daylighting must be seen as a reliable low maintenance alternative.

Title 24 improves efficiency but limits innovation

Title 24 is used by the building design community as a design target rather than a minimum performance threshold. Many professionals see the code as a barrier to getting buildings completed and often hire specialized consultants to review their plans to assure that their designs will obtain code approval. They focus on creating designs that pass the code rather than creating design alternatives that may exceed the code. Alternative designs are avoided because building professionals perceive that the risk is in creating a design that will not pass.

Lighting designers focus on thermal load more than lighting needs

Many professionals reported that a major decision factor in their decisions about windows and glazing materials is their impact on building thermal loads. Thermal loads are a significant factor in meeting Title 24 requirements. Many professionals are reluctant to try daylighting designs because of the cost associated with developing the designs and the possibility that they that might not meet Title 24.

Sensors and lighting controls are for bathrooms and boardrooms

Many building professionals use lighting sensors and controls in their structures. However, most professionals say they use them in specific areas of the building such as bathrooms, board rooms, meeting rooms, storage rooms and areas where people typically do not spend a lot of time. Professionals are reluctant to use them in high use areas because of cost and the potential for problems.

Cost of daylighting design more an issue than fixture or control costs

The cost and complexity of the design process is the issue for many market actors. The design process must be fast, resulting in a design that works the first time and requires no on-going relationship with the building or the building owner. Designers are looking for ways to streamline the design process. They are reluctant to use anything that will increase design costs unless there are off-setting advantages. On the other hand, professionals are telling us that the cost of the lighting equipment and controls is not nearly as important as Title 24 compliance, product reliability, systems appearance, and ease of maintenance. Daylighting services must help reduce or minimize design costs to be successful at transforming the market.

Skylights are for looking good not for reducing electric consumption

Skylights are used in many buildings constructed in northern California. However, they are most often used for to improve the aesthetics of the environment. Their use to reduce energy consumption is seldom considered. The locations in which many skylighting systems currently are used do not lend themselves well to the use of lighting controls.

The market is small and segmented

The daylighting design market in Northern California is probably 2,000 firms. The identification of the actors is relatively easy. However, the market is comprised of many different segments each of which perceives different issues and different benefits from using tools. The trick will be getting the right messages to the right actors in the right segments. Finding firms that can employ daylighting design in a significant number of their projects will be challenging. This report provides significant assistance in that effort but it also points out that the demand for daylighting tools and assistance initially will be strong for a small subset of the market.

Barriers associated with the tools

Rendering is beneficial but AutoCad use will impact adoption

Many professionals see rendering as a positive development in the market. Designers think they can use rendering to demonstrate designs to clients and to see what designs will look like or how changes will effect performance. CAD software programs change often and are expensive to purchase. The current version of AutoCad is version 14. Programs that encourage the use of rendering as a design tool may need to help clients see the benefits of purchasing or upgrading to version 14 in order to run Desk Top Radiance. Maintaining Desk Top Radiance so that it will work with the latest versions of software will be a significant factor in its continued acceptance and use.

Training is the key to tool use

Many professionals indicated that the development of the design tools represents a move in the right direction. However, during the interviews, most professionals asked about training. Many indicated that training, including the cost, convenience and quality will be important in their decision to adopt the tools. Many firms solve their training problem by hiring junior staff who are already trained. It may be important to seed the tools to colleges and universities and to CAD user groups and firms that offer CAD training.

Ease of software use important for design professionals

A repeated message was the need for tools that provide point and click operations and crystal clear instructions. Software documentation concerns were expressed by some indicating little tolerance for program software that has poor documentation or on-screen help messages. Software support is critical. Software that works as advertised is essential. Given the size of the market and the amount of communication with the market, negative reviews in the first months of implementation could well doom the software.

Improving client value important for software acceptance

Potential users of the design tools report that customer satisfaction and value is key to the use of the software. Added value encompasses a wide range of attributes including customer satisfaction, design adoption, cost reductions for both the design firm and the client, among others. Design professionals reported that the tools must provide help to them and their clients. It must be a win-win situation. Professionals indicate that software that improves the design process or provides added value to their clients will be used. Daylighting program managers will want to structure the services to clearly show better value in the market for both the design professional and their clients.

Need to demonstrate and support design decisions

The building design community wants tools that will help them explore and present reliable cost-effective alternative designs and options to their clients. Many professionals reported that the tools discussed will be beneficial if they provide a low-cost method of providing design options to their clients and if they allow designers to quickly and cost-effectively examine the impact of different designs. The daylighting design tools must be ready to demonstrate these characteristics in the market.

Conclusion

This study provides a detailed assessment of the operations of the building design community in Northern California and baselines daylighting related design practices. In addition, the study provides an assessment of the market potential for the Daylighting Design Tools.

Daylighting is present in the Northern California market but its use is not widespread and the use of tools designed to integrate daylighting with building lighting control is infrequent. Architects rarely consider daylighting in their design practices and often indicate that this task is the job of electrical engineers or lighting designers.

Title 24 drives most all lighting decisions and most lighting professionals treat Title 24 as the target rather than a minimum threshold. Daylighting is rarely seen as a method of obtaining or surpassing Title 24 requirements.

Many professional incorporate skylights in their designs, but these designs are typically specified for reasons other than to gain additional lighting and lighting controls are frequently integrated with skylights.

There is significant interest in the Daylighting Design Tools being developed and introduced by PG&E, especially Daylighting Prospector, Desk Top Radiance, and SkyCalc. There is also some limited interest in Artificial Sky. The interest in Artificial Sky is focused on testing and developing new designs and in overcoming technical or design acceptance problems.

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Appendix B Interview Protocol

Lighting Controls Issues

Have you done commercial projects (offices and other types of buildings) with significant amounts of side lighting? How many in the last year?

If yes, do you incorporate advanced lighting controls (e.g., lighting sensors and dimmers) into those projects? About what percentage of your projects incorporate advanced controls?

> If yes, what determines if advanced lighting controls are used?
>
> What kinds of lighting controls do you use on your projects? Occupancy sensors? Daylighting controls?
>
> If you think of projects as having stages such as concept, design, construction, commissioning, etc. At what stage in the project is the decision to use advanced controls usually made?
>
> Who decides whether controls will be used?
>
> What criteria are used to decide what kind of controls to use and how to place them? What types of analysis are done to help decide if controls are used? Do you use try to estimate lighting levels by some method or do you follow some rules of thumb? Are software packages used? Which ones?
>
> If there were tools or information that could help you do a better job of evaluating the use of lighting controls in projects, what would you like to have? How would they work?
>
> What are there barriers to more extensive use of advanced lighting controls either in terms of using controls in more projects or using more controls in existing projects?
>
> If cost or customers perceptions of cost are a problem, is there data or information that would help overcome those issues? What about other issues such as lighting quality, maintenance cost, reliability issues, user problems?
>
> Where do you currently get information about advanced lighting controls?

If no, can you tell me why you don't use lighting controls

If there are cost issues, what data might be helpful in overcoming the problems?

If you were going to search for data about advanced lighting controls where would you look? What kind of data would you look for?

Daylighting prospector

This tool is designed to help identify opportunities to use lighting controls in existing or new buildings. It uses an estimate or an actual reading of natural lighting reaching the roof of a building, information about the orientation of the building, and either an estimate or a reading of the natural lighting at a location inside the building, that then allows the user to evaluate the cost effectiveness of lighting equipment and control options for that location. The program is designed to let you try different equipment options and configurations. The program is designed to be user friendly and allow multiple runs with changes..

Could you see your firm making use of such a tool in its projects? Under what conditions might you use it? Who would use it? What level of personnel would use it?

If you had someone using the tool for a modest sized office building, say 30,000 square feet, and it takes a few minutes per location within the building to evaluate lighting control options, how many labor hours would you be willing to put into using the tool to evaluate the building?

Who in the firm would use the tool?

Thinking about some of your recent projects, what reasons would you have not for not using such a tool?

What should be in the outputs of such a tool? How would the outputs be used? Who do you imagine might use the outputs?

Equipment lists by location?

Comparisons of energy use with and without controls?

How would you use the outputs? Mostly as a basis for design? For use with clients to convince clients that they should use controls? What?

Desktop Radiance related questions

Still thinking about buildings that use side-lighting, I would like to explore structural and façade design practices that may influence the entry of natural light into the building.

Think back over the kinds of buildings that you have been involved with recently? How much attention do you give to orientation of the building? Typically what drives the orientation of the building. What factors are a priority?

What about the size and placement of windows? What factors really drive the decision making? What are the priority factors?

What about glazing choices? What currently drives your practice in this area? What technologies are you currently specifying

Do you typically consider or talk with clients about architectural elements such as light shelves, shading devices? Under what circumstances do you talk about this with clients?

When you make decisions about issues of orientation, window size and placement, and glazing choices what types of analysis do you use to support your decisions?

When all of these elements are considered what are the most important factors? Where do issues of the quantity and quality of external light fit into the list?

Are the levels of interior illumination analyzed at this stage? If so, what tools are used to do this? What is the purpose of the analysis?

Do you use physical models? For what purpose do you use them? How often are they used? Do you ever use physical models to analyze the light and shadow effects of natural light on interior spaces?

Do you use 2D and 3D CAD in this office? Who is responsible for the CAD? What CAD package is used? Do you have full-time staff devoted to CAD operations? Do staff use CAD directly?

Do you use 3D renderings or imaging software? When and under what circumstances do you use them? What software do you use?

Desktop Radiance is a software package that works with Autocad files to produce 3D renderings of interior spaces. Desktop Radiance produces accurate estimations of illumination levels that can be used as a basis for lighting design. In this sense it differs from other products in this category such as Lightscape. It also allows one to quickly compare the effects of different configurations and designs?

Do you think you would be likely to use a product such as radiance? Under what circumstances? What would you expect the characteristics of the package to be?

Do you use facilities that allow you to test physical models with respect to solar orientation? How often? Why? If you don't use these facilities, why don't you use them? If such facilities were available to you at no cost, would you use them. How often?

Big Box Section

Do you ever get involved in the design of large retail or warehouse structures that are typically referred to as "box" or "big box"? Such buildings usually have a few windows at the front and the rest of the building is roof and walls.

If yes, what types of clients have you done these types of buildings for, individual owners, developers, chain stores?

Can you tell me a little bit about how the design process works in relation to the client?

How much control do you have over the designs when you do these types of buildings? Does the client provide fairly rigid specifications? How much latitude is there in the design work?

Have you done any such buildings with skylights or have you considered skylights as an option in such buildings?

(Considered it) If you have considered it but not done it, what caused you not to do it?
If you have done skylights, what type of skylighting system did you use?

How extensive was the use of skylights?

What led to the decision to use skylights

What sorts of analysis was done to support the use of skylights in the design?

Did your analysis include an examination of lighting fixtures and lighting controls to compliment the skylighting?

Did you use any special software or programs in the analysis

If you were going to do more skylighting what kinds of tools and information would you like to have?

For those who have not done it or just considered it?

Do you think there is potential to get clients to consider skylighting in "box" buildings? What would it take to convince clients that skylights would be a good idea?

If you had a tool that would allow you to evaluate skylighting options what would you want the tool to do?

Spacing

Structural support

Patterns of light and shadow within the building

Lighting layout and controls

Comparisons of different approaches to skylighting

SkyCalc is a tool for evaluating the potential for skylighting. What SkyCalc does is allow one to determine the number and placement of skylights using different skylighting designs buildings to get \ levels of illumination at the floor level. This information is integrated with lighting and controls information to provide cost effectiveness calculations.

Would such software be of use to you? How often would you use it? How would you use it?

Are there reasons why you wouldn't use it?

Internet use

Do the members of this firm use the internet for work related purposes? What proportion of the staff use it? Who typically uses it?

What sorts of things do the staff use the internet for?

Professional discussions groups?

Search for manufacturer information?

Search for design information?

Search for other types of data?

Training

Do you have a vision of how the internet might be used in the future?

Do you have ideas for ways in which Internet services could aid you professionally?

The PEC is establishing a website that will provide a single location to get product information from lighting equipment vendors. Do you think you might use such a site? How often do you think you might use such a site? What information would you want to get from such a site?

The PEC is establishing a moderated list service where professionals will be able to ask design questions and receive timely answers that have been reviewed for technical correctness. There will also be a library of previous asked questions and the response to them? Do you think you would use such a service? How often? Under what circumstances?

Can you think of other internet services that would aid you professionally?

The firm

Roughly what proportion of your business (in dollar volume) would you characterize as new construction and what proportion would you characterize as additions, remodels/renovations?

New construction

Remodels / renovations

What proportion of your work would you describe as low rise office, high rise office, commercial retail that might be described as "big box."

For the projects you have done recently, have you been the primary designer or have you worked with plans provided by the client?

Do you team with other firms? What is the composition of the team? Does it vary by the type of project? Do you usually team with the same firms? How are the responsibilities divided? Who typically interacts with the clients?

I would like to get some idea of what role your company plays in projects and what aspects might be done by others. With respect to the projects you have done since January 1997, have you

Specified or help to specify the building foot print position or orientation?

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Specified or helped to specify the placement and or size of openings

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Specified or helped to specify glazing materials?

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Design or help to design lighting systems?

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Specify lighting fixtures and control systems?

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Supervise the installation of the lighting systems

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Install lighting fixtures and controls

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Oversee or complete the commissioning of lighting system and controls

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Re-commission lighting systems or controls

☐ Never ☐ For some projects ☐ All projects or nearly all projects

Appendix C Questionnaire

PG&E Market Baseline Survey Questionnaire

Respondent Information (pre-filled)

1. Name: ______________________ ___ ________________________

2. Title/Position:____________________________
3. Company name: ___________________________________
4. Address 1: _______________________________________
5. Address 2: _______________________________________
6. City: __________________________ State: ______ Zip __________________
7. Telephone: (___) ____ - ____ Telephone 2: (___) ____ - ____
8. Fax:(___) ____ - ____

Contact log

Date month, day, year mm dd yy	Time in (24 hour clock) h h m m	Time out (24 hour clock) h h m m	Result: 1. Complete, 2. Callback, 3. No answer, 4. No contact, 5. Wrong number, 6. Refusal, 7. Moved known, 8. Moved unknown, 9. Other (describe) <u>Write in call back date and time</u>	
9.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________
10.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________
11.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________
12.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________
13.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________
14.a.___ ___ ___	b. __ __ __ __	c. __ __ __ __	d. ______	________________________

Good (morning / afternoon). My name is __________________. I am calling on behalf of Pacific Gas and Electric Company. May I speak with Mr./Ms. ______________________.

❏ Yes → Continue with survey
❏ Is at a different phone number → Obtain new number and call (_____) ________________
❏ Not in at this time → Schedule call back Date ___/___/1999, Time: ____am/pm
❏ No longer works here → Thank them and terminate call
❏ Other: → Reason: ____________________________________
❏ No answer → Leave message

Good (morning / afternoon)Mr ./ Ms. ________________. My name is _________________.

I am calling on behalf of PG&E. I would like to speak to << >>

If asked reason for call reply as follows:

> We are trying to obtain some information that will allow us to provide better services to the building design community.

If person is not available, establish when would be a good time to call back or (if you think it will work) give them a call back number.

If the person is no longer at this firm, ask for the next person on the list from that firm if available. Otherwise terminate and substitute a new case.

- If the person you are calling

I am calling on behalf of the Pacific Gas and Electric Company. PG&E is trying to get a better understanding of current design practices among building professionals and how building professionals interact with each other. Also, PG&E is developing and implementing some no cost software and Internet tools for buildings professionals and would like your help in understanding who the most likely users of these tools might be and how they might meet user needs. These tools, which will be available at no cost, include a 3D rendering package, a tool for evaluating the potential for skylighting, a tool for evaluating the potential for daylighting, an Internet tool to locate products particularly lighting and glazing products, and a tool that will permit professionals to give and receive advice from other professionals.

According to our records you and your firm are involved with the design and / or construction of commercial projects located in Northern California. I would like to complete a 15 minute survey about the building design market and the use of these new no-cost services. The survey focuses on your practices and how your firm might use the tools. Your responses will be anonymous.

May I proceed?

15. ❑ Yes ❑ No ❑ DKNA

Call back

Refuses to participate. Thank and close

Wrong person

16. Is there someone else within your firm with whom I could talk?

❑ Mr./Ms. _________ at Ext./Phone/etc. ❑ No one here does that
❑ DKNA

I am sorry to have bothered you. We must have gotten your name in error. Thank you for your time and patience. *Terminate and record data in log*

If transferred to another person or making a new call, go back to Good (morning/afternoon).

❑ Call back

I would be more than happy to call back. Can you suggest a time?

Hour_______AM/PM Month _______ Day _________

Thank you very much for speaking with me. I will call again.

Terminate and transfer information to call log

Next page

Professional responsibilities

I'd like to start by asking you a couple of questions about you and your firm?

- If the CATI system has an occupation in the occupation field start here. Else skip to 18.

Our records indicate that your are an <<***occupation*** >>

17. Is that correct? ❑ No ***Go to 18*** ❑ Yes ***Go to 19***

The CATI system should fill one of these.

Architect	Electrical engineer	Title 24 specialists
Interior designer	Lighting designer	Building contractor
Graphics CAD specialist	Lighting contractor	Facility manager
Energy consultant	Electrical contractor	Electrician
Lighting specifier		

18. What is your profession? ____

Do not prompt? Code into one of the following. If unsure, use this list to probe.

❑ Architect	❑ Electrical engineer	❑ Title 24 specialists
❑ Interior designer	❑ Lighting designer	❑ Building contractor
❑ Graphics CAD specialist	❑ Lighting contractor	❑ Facility manager
❑ Energy consultant	❑ Electrical contractor	❑ Electrician
❑ Lighting specifier	❑ Other	

19. What is the principal business of your firm? ____

(Interviewer: enter what the person says then code one of the following. You may use the following categories to probe. If not sure, leave the answer for later coding. If the respondent indicates that they are a contractor or engineering firm, ask what kind. If the respondent indicates that the firm is manufacturing, distributor or retailer, ask if they manufacture or sell building related equipment or if they manufacture or sell something else.)

❑ Architectural design
❑ Interior Design
❑ Lighting Design
❑ Engineering
Would that be?
  ❑ Electrical / Lighting
  ❑ HVAC
  ❑ Both

❑ Contractor
Would that be?
  ❑ General
  ❑ Electrical
  ❑ HVAC
  ❑ Both
❑ Property Owner / Management
❑ Manufacturer

❑ Developer
❑ Distributor
❑ Retailer
❑ Other; ________________
____
____

During the last 12 months can you tell me roughly how many different commercial and industrial projects your firm has completed? 20. # ________________.

(If the respondent says that there are no commercial and industrial projects, that they only do residential. Thank them and close the interview.)

About how many of these were in Northern California (*Interviewer: We define Northern California as that part of California that is north of a line from Monterey to Fresno*)? 21. # _______

I am going to read a list of different types of building projects. For each type, can you to tell me approximately what percentage of your firm's projects are of that type. If you have no projects or just an occasional project of a type just indicate "none."

What percentage of your projects are . . .	None	Percent	DKNA
22. Low rise office structures from 1 – 3 floors	❏	______%	❏
23. Higher rise office structures of four or more floors	❏	______%	❏
24. Big box retail structures including retail food stores (*if they ask what "Big Box" means, say 10,000 square feet or more with minimal sidelighting)*	❏	______%	❏
25. Other types of retail	❏	______%	❏
26. Warehouses	❏	______%	❏
27. Manufacturing facilities	❏	______%	❏
28. Educational buildings	❏	______%	❏
29. Health facilities / hospitals	❏	______%	❏
30. Other public buildings	❏	______%	❏
31. Other ________________	❏	______%	❏

Building professionals may take direction and report to many different kinds of firms such as developers, retail chains, independent retailers, building owners, general contractors, etc. I am interested in finding out who typically directs your work and to whom you typically report. This may be different than who writes the checks. For example, you might get paid by a retail chain but provide services to a general contractor. In this case it is the contractor that directs the work. If you never or almost never work for the type of firm mentioned you can say none.

In what percentage of your projects do you work directly for. . .	None or almost none	Percent	DKNA

32.	a developer	❑	_______%	❑
33.	a retail chain store	❑	_______%	❑
34.	a building owner other than a developer	❑	_______%	❑
35.	a general contractor	❑	_______%	❑
36.	an architectural firm	❑	_______%	❑
37.	an engineering firm	❑	_______%	❑
38.	Some other type of firm, please specify _______________?	❑	_______%	❑

Can you tell me what percentage of your firm's projects are completed for :

What percentage are completed for . . .		None or almost none	Percentage	DKNA
39.	a known tenant	❑	_______%	❑
40.	lease or occupancy by an unknown tenant	❑	_______%	❑

Developers, owners, tenants, architects, electrical engineers, general contractors, and lighting designer are all important decision makers in building projects. I am going to list some important decisions that are made during the construction process. Thinking about the projects that your firm does, please tell me who the key professional typically is for each type of decision. Then please tell me what other professionals play key supporting roles in that type of decision. (*Interviewer: you may read the list once or twice to help the respondent get the idea? After that, just ask the question?*)

		a. For your projects, who typically is the primary decision maker with responsibility for determining:	c. What other professionals or firms play key supporting roles in determining:
41.	the exact orientation of the building	❑ Developer	❑ Developer
		❑ Owner	❑ Owner
		❑ Tenant	❑ Tenant
		❑ Architect	❑ Architect
		❑ Lighting designer	❑ Lighting designer
		❑ Interior designer	❑ Interior designer
		❑ Electrical engineer	❑ Electrical engineer
		❑ Electrical contractor	❑ Electrical contractor
		❑ HVAC engineer	❑ HVAC engineer
		❑ General contractor	❑ General contractor
		❑ Other contractor	❑ Other contractor
		❑ Other _________	❑ Other _________
		❑ No one / Don't do this	❑ No one
		❑ Don't know	❑ Don't know
42.	the size and placement of windows	❑ Developer	❑ Developer
		❑ Owner	❑ Owner
		❑ Tenant	❑ Tenant

	❑ Architect	❑ Architect
	❑ Lighting designer	❑ Lighting designer
	❑ Interior designer	❑ Interior designer
	❑ Electrical engineer	❑ Electrical engineer
	❑ Electrical contractor	❑ Electrical contractor
	❑ HVAC engineer	❑ HVAC engineer
	❑ General contractor	❑ General contractor
	❑ Other contractor	❑ Other contractor
	❑ Other _________	❑ Other _________
	❑ No one / Don’t do this	❑ No one
	❑ Don’t know	❑ Don’t know
43. the glazing material	❑ Developer	❑ Developer
	❑ Owner	❑ Owner
	❑ Tenant	❑ Tenant
	❑ Architect	❑ Architect
	❑ Lighting designer	❑ Lighting designer
	❑ Interior designer	❑ Interior designer
	❑ Electrical engineer	❑ Electrical engineer
	❑ Electrical contractor	❑ Electrical contractor
	❑ HVAC engineer	❑ HVAC engineer
	❑ General contractor	❑ General contractor
	❑ Other contractor	❑ Other contractor
	❑ Other _________	❑ Other _________
	❑ No one / Don’t do this	❑ No one
	❑ Don’t know	❑ Don’t know
44. the use of architectural elements such as light shelves and shading devices	❑ Developer	❑ Developer
	❑ Owner	❑ Owner
	❑ Tenant	❑ Tenant
	❑ Architect	❑ Architect
	❑ Lighting designer	❑ Lighting designer
	❑ Interior designer	❑ Interior designer
	❑ Electrical engineer	❑ Electrical engineer
	❑ Electrical contractor	❑ Electrical contractor
	❑ HVAC engineer	❑ HVAC engineer
	❑ General contractor	❑ General contractor
	❑ Other contractor	❑ Other contractor
	❑ Other _________	❑ Other _________
	❑ No one / Don’t do this	❑ No one
	❑ Don’t know	❑ Don’t know
45. the use of skylights	❑ Developer	❑ Developer
	❑ Owner	❑ Owner
	❑ Tenant	❑ Tenant
	❑ Architect	❑ Architect
	❑ Lighting designer	❑ Lighting designer
	❑ Interior designer	❑ Interior designer
	❑ Electrical engineer	❑ Electrical engineer
	❑ Electrical contractor	❑ Electrical contractor
	❑ HVAC engineer	❑ HVAC engineer
	❑ General contractor	❑ General contractor

		❏ Other contractor	❏ Other contractor
		❏ Other _________	❏ Other _________
46.	lighting location or placement	❏ Developer	❏ Developer
		❏ Owner	❏ Owner
		❏ Tenant	❏ Tenant
		❏ Architect	❏ Architect
		❏ Lighting designer	❏ Lighting designer
		❏ Interior designer	❏ Interior designer
		❏ Electrical engineer	❏ Electrical engineer
		❏ Electrical contractor	❏ Electrical contractor
		❏ HVAC engineer	❏ HVAC engineer
		❏ General contractor	❏ General contractor
		❏ Other contractor	❏ Other contractor
		❏ Other _________	❏ Other _________
		❏ No one / Don't do this	❏ No one
		❏ Don't know	❏ Don't know
47.	lighting specifications	❏ Developer	❏ Developer
		❏ Owner	❏ Owner
		❏ Tenant	❏ Tenant
		❏ Architect	❏ Architect
		❏ Lighting designer	❏ Lighting designer
		❏ Interior designer	❏ Interior designer
		❏ Electrical engineer	❏ Electrical engineer
		❏ Electrical contractor	❏ Electrical contractor
		❏ HVAC engineer	❏ HVAC engineer
		❏ General contractor	❏ General contractor
		❏ Other contractor	❏ Other contractor
		❏ Other _________	❏ Other _________
		❏ No one / Don't do this	❏ No one
		❏ Don't know	❏ Don't know
48.	Dimming controls	❏ Developer	❏ Developer
		❏ Owner	❏ Owner
		❏ Tenant	❏ Tenant
		❏ Architect	❏ Architect
		❏ Lighting designer	❏ Lighting designer
		❏ Interior designer	❏ Interior designer
		❏ Electrical engineer	❏ Electrical engineer
		❏ Electrical contractor	❏ Electrical contractor
		❏ HVAC engineer	❏ HVAC engineer
		❏ General contractor	❏ General contractor
		❏ Other contractor	❏ Other contractor
		❏ Other _________	❏ Other _________
		❏ No one / Don't do this	❏ No one
		❏ Don't know	❏ Don't know

Now I am going read the same list of decisions and ask for what percentage of your projects you firm plays the primary role for that type of decision.

For what percentage of your projects does your firm have the primary responsibility for determining:	None	Percentage	DKNA
49. the exact orientation of the building	❑	_______%	❑
50. the size and placement of windows	❑	_______%	❑
51. the glazing material	❑	_______%	❑
52. the use of architectural elements such as light shelves and shading devices	❑	_______%	❑
53. the use of skylights	❑	_______%	❑
54. lighting location or placement	❑	_______%	❑
55. lighting specifications	❑	_______%	❑
56. Dimming controls	❑	_______%	❑

If 49 is greater than "none" then go to 57 else go to 63

I am going to read a list of criteria that people use in making decisions about building orientation. As I read each criterion, please rate the importance of the criterion on a scale of 1 to 10 where 1 means not at all important and 10 means a most important criterion in terms of your decision making.

For building orientation, how important is:

	Criterion	Score	DKNA
57.	Meeting code requirements	_______	❑
58.	Visual presentation of the building	_______	❑
59.	Maximizing the use of the available ground space	_______	❑
60.	Solar orientation	_______	❑
61.	Access and egress to the building	_______	❑
62.	Parking	_______	❑

(63) If 51 is greater than "none" then go to 63 else go to 70

I am going to read a list of criteria that people use in making decisions about the choice of glazing materials. As I read each criterion, please rate the importance of the criterion on a scale of 1 to 10 where 1 means not at all important and 10 means a most important criterion in terms of your decision making.

For glazing materials, how important is:

	Criterion	Score	DKNA
63.	Meeting code requirements	_______	❑
64.	Aesthetics	_______	❑
65.	Maximizing the amount of glazing	_______	❑
66.	Daylight or visual transmittance	_______	❑
67.	Cost	_______	❑
68.	Insulating ability	_______	❑
69.	Heat reflectivity	_______	❑

(70) If question 55 is greater than "none" then start at 70 else go to 87.

You said you or your firm plays a primary or key role with respect to lighting specifications. Could you tell me for what percentage of your firm's projects you or someone in your firm does each of the following. If almost none, just say none.

For what percentage of your firm's projects do you or someone in your firm:	None or almost none	Percentage	DKNA
70. analyze the amount of artificial illumination needed in relation to task needs	❑	_______%	❑
71. recommend or implement measures for reducing glare	❑	_______%	❑
72. analyze lamps and fixtures in relation to color quality needs	❑	_______%	❑
73. use physical or computer models to assess internal light and shadow effects.	❑	_______%	❑
74. work with others on the design team to examine potential façade design elements to control natural light	❑	_______%	❑

75. commission or inspect lighting systems or controls	❑	_______%	❑

I am going to read a list of criteria that people use in making decisions about lighting specifications. As I read each criterion, please rate the importance of the criterion on a scale of 1 to 10 where 1 means not at all important and 10 means a most important criterion in terms of your decision making.

For lighting specifications, how important is:

		Score	DKNA
76.	Meeting the code requirements	_______	❑
77.	Initial equipment cost	_______	❑
78.	Reliability	_______	❑
79.	Ease of maintenance	_______	❑
80.	Visual appearance of the fixture or equipment	_______	❑
81.	Energy efficiency	_______	❑
82.	Color of the light	_______	❑
83.	Potential for glare	_______	❑
84.	Ability to work with control systems	_______	❑
85.	Life time of the components	_______	❑
86.	Functional lighting requirements	_______	❑

Lighting controls:

(87) If question 56 is greater than "none" then start at 87 else go to question 105.

Previously you said that you have used dimming controls. For what percentage of the projects that your firm has completed in the last year did you use the following. If the answer is almost none, just say none.

for what percentage of the projects that your firm has completed in the last year did you use	None or almost none	Percentage	DKNA
87. Motion sensors			
88. bi-level or tri-level lighting			
89. dimming ballasts with sensors in just a few special areas	❑	_______%	❑
90. dimming ballasts with sensors in the main work areas	❑	_______%	❑

If 90 is greater than none go to 91 else go to 105

For those projects in which you have installed dimming controls for what percentage did you: (*You can say none or none or almost none.*)	None	Percentage	DKNA
91. analyze different dimming equipment options	❑	_______%	❑
92. establish control zones based on cost effectiveness calculations	❑	_______%	❑
93. establish control zone boundaries based on common use areas	❑	_______%	❑
94. examine potential sensors locations to see if they will work with carpet and furniture in the proposed locations	❑	_______%	❑
95. establish a protocol for commissioning of sensors	❑	_______%	❑
96. commission the sensors	❑	_______%	❑

I am going to read a list of criteria that people use in making decisions about lighting controls As I read each criterion, please rate the importance of the criterion on a scale of 1 to 10 where 1 means not at all important and 10 means a most important criterion in terms of your decision making in the last year.

For lighting controls, how important was:

	For lighting controls, how important was:	Score	DKNA
97.	Meeting code requirements	_______	❑
98.	Initial equipment cost	_______	❑
99.	Reliability	_______	❑
100.	Ease of maintenance	_______	❑
101.	Visual appearance of the fixture or equipment	_______	❑
102.	Energy efficiency	_______	❑
103.	User controlability	_______	❑

104. Do you think that the number of projects in which you will use dimming controls in the next two years will increase, decrease, or remain about the same?

❑ Decrease ❑ Remain about the same ❑ Increase ❑ DKNA

Why?____

Go to question number 108

105. Have you recommended or considered using dimming controls in your projects?
❑ No ❑ Yes ❑ We just don't get involved with controls (**Go to 120**)

106. Have you talked to other users, manufacturer representatives, or attended seminars or classes in order to learn about dimming controls?

❑ No ❑ Yes

107. Have you obtained product information about dimming controls?

❑ No ❑ Yes

108. Have you attempted to sell customers on the potential for dimming controls?

❑ No ❑ Yes

109. What is the likelihood that you will use dimming controls in at least some of your projects within the next two yeas? Very unlikely unlikely neither likely or unlikely likely very likely

Very unlikely	Unlikely	Neither unlikely nor likely	Somewhat likely	Very likely	DKNA
❑	❑	❑	❑	❑	❑

I am going to read a list of things that might keep decision-makers from choosing dimming controls. For each item can you tell me whether it is not important, somewhat important, or a very important reason for not using controls?

		Not important	Somewhat important	Very important	DKNA
110.	First cost	❑	❑	❑	❑
111.	Equipment reliablity issues	❑	❑	❑	❑
112.	Potential for maintenance headaches	❑	❑	❑	❑
113.	Customers' lack of awareness of dimming controls	❑	❑	❑	❑
114.	Customers' lack of information about dimming controls	❑	❑	❑	❑
115.	Are there other reasons for not using controls? ______________	❑	❑	❑	❑

Daylighting Prospector Questions

116. If PG&E made available at no cost a program that would allow you to estimate natural lighting levels for interior spaces and would also allow you to evaluate the cost effectiveness of various dimming and control options, would such a program be

- ❑ Of significant interest to you or your firm
- ❑ Of some interest to you or your firm
- ❑ Depends (Do not read)
- ❑ Of little interest to you or your firm, or
- ❑ Of no interest.
- ❑ DKNA

117. Can you tell me why?

____

____

Go to 120

118. Under what circumstances would the program be of interest?

____

____

Got to 120

119. What would your motivation be for using such a program?

____

____

120. Do you or anyone in your firm use CAD?

❑ No ***Go to 122*** ❑ Yes

121. Which 2D Cad programs do you use

- ❑ AutoCad
- ❑ Microstation
- ❑ Archicad

122. Do you use 3D CAD programs to generate images of interior or exterior building spaces

❑ No ❑ Yes

skip to130

123. What software do you use to generate the 3D images?

- ❑ 3D Studio
- ❑ Visio
- ❑ (Other)_______________

For what percentage of projects do you use rendering to:

		None or almost none	Percentage	DKNA
124.	present **external** design features to clients and code officials	❏	______%	❏
125.	present **internal** designs to clients	❏	______%	❏
126.	to analyze such things such as **internal** light and shadow effects	❏	______%	❏

127. Of the projects you render, what percentage do you do in-house ___________

128. Do you think that your firm's use of renderings will increase, decrease or remain about the same over the next two years?

❏ Increase ❏ Decrease ❏ Remain about the same

129. Why?

____

____

Go to 132

130. What are the primary reasons why you don't use renderings?

______________________________ ________

131. Do you think your firm will use renderings in the future?

❏ No ❏ Yes

Skip to138

132. What do you think are the most important advantages of using renderings in your profession?

____

____

133. What are the most important disadvantages of using renderings in your profession?.

____

134. If PG&E made available a rendering program without cost that works easily with Autocad and Autocad files and produces photographic quality renderings that provide accurate readings of the levels of illumination anywhere in the image, would this program be…

- ❑ of significant interest to you or your firm
- ❑ of some interest to you or your firm
- ❑ depends
- ❑ of little interest to you or your firm, or
- ❑ of no interest.
- ❑ DKNA

135. Why would this program be of little or no interest to your firm?

____

____

Go to 138

136. Under what cicumstances would the program be of interest?

____

____

Got to 138

137. What would be the primary reason you or your firm would use such a program?

____

____

138. Do you use physical models or mock-ups in your work?

❑ No ***If no go to 144*** ❑ Yes

For what percentage of your projects do you :

		None or almost none	Percentage	DKNA
139.	use physical models to present designs to clients and local code officials	❑	_______%	❑
140.	use physical models to analyze such things as interior light and shadow effects	❑	_______%	❑
141.	use **mock-ups** to the effects of artificial and natural light in interior designs	❑	_______%	❑

Artificial Sky Questions

142. If PG&E were to provide in the San Francisco Bay area a facility where models of buildings or parts of buildings could be evaluated under artificial skies to see how they would perform in different solar conditions or different models under the same conditions,

.

- ❑ Of significant interest to you or your firm
- ❑ Of some interest to you or your firm
- ❑ Depends
- ❑ Of little interest to you or your firm, or
- ❑ Of no interest.
- ❑ DNNS

143. Why would this facility be of little or no interest to your firm?

____

____

Go to 146

144. Under what cicumstances would the facility be of interest?

____

____

Got to146

145. What would be the primary reason you or your firm would use such a facility?

____

____

SkyCalc Questions

(146) If question 53 is greater than none then 146 else go to 153.
Earlier you said that you or your firm had used some skylights in projects. In what percentage of the cases were:

		None or almost none	Percentage	DKNA
146.	skylights for a few selected or special spaces within the building	❑	_______%	❑
147.	general skylighting in a substantial proportion of the building designed to provide light in work spaces	❑	_______%	❑

If 147 is greater than none then 148 else 153

In designing for the skylighting, For what percentage of your projects did you:

		None or almost none	Percentage	DKNA
148.	base the number, size and position of skylights on the location of structural elements	❏	_______%	❏
149.	determined size and number of skylights based on illumination requirements	❏	_______%	❏
150.	specify controls for electric lighting in response to natural light entering the space		_______%	
		❏	_______%	❏

151. During the next two years is your use of skylights in projects likely to increase, descrease, or remain about the same.

❏ Decrease ❏ Remain about the same ❏ Increase ❏ DKNA

152. Why?____

Skip to 156

153. Have you investigated the use of skylights for large general work areas by talking to other professionals, manufacturer representatives, or attending classes?

❏ No ❏ Yes

154. Have you obtained product information about skylights?

❏ No ❏ Yes

155. What is the likelihood that you will use skylight in large general work areas for at least some of your projects within the next two years? Very unlikely, unlikely, neither likely or unlikely, likely, very likely?

Very unlikely	Unlikely	Neither unlikely or likely	Somewhat likely	Very likely	DKNA
❑	❑	❑	❑	❑	❑

I am going to read a list of reasons why decision makers might decide not to use skylights. For each item can you tell me whether the reason is not important, somewhat important, or a very important reason for not using skylights

		Not important	Somewhat important	Very important	DKNA
156.	Customers perceive that first cost is too high	❑	❑	❑	❑
157.	Clients think skylights cause security problems	❑	❑	❑	❑
158.	Perceived to be a potential maintenance problem	❑	❑	❑	❑
159.	Too difficult to control the light	❑	❑	❑	❑
160.	Customers aren't aware of potential productivity improvements from usingskylighing	❑	❑	❑	❑

161. If PG&E were to provide a computer program that would allow you to determine the number and placement of skylights based on illumination levels and the number, type and placement of lighting fixtures with dimming controls in relation to skylights, would this program be. . .

- ❑ of significant interest to you or your firm (→ 164)
- ❑ of some interest to you or your firm (→ 164)
- ❑ depends (don't read) (→ 163)
- ❑ of little interest to you or your firm, or (→ 162)
- ❑ of no interest.
- ❑ DKNA

162. Is there some reason?

____

____

Go to 165

163. Under what circumstances would the program be of interest?

____

____

Got to 165

164. What motivates your interest in such a program?

165. Thinking back over the various issues we have discussed, can you think of any data or computer software tools that the PEC might supply that might aid in physical or lighting design?

Lighting Exchange Questions

166. Do you use e-mail in your work

❑ No ❑ Yes

167. How about the Internet, do you use it in relation to your work?

❑ No ***Go to question 173*** ❑ Yes

168. About how many hours a week do you use the Internet in relation to your work?

❑ 1 - 3 ❑ 4 - 5 ❑ 6 - 9 ❑ 10 - 15 ❑ 15+ ❑ DKNA

169. Please tell me if you typically use the internet, do you use it to… (*read all and check all that apply*):

a. ❑ visit manufacturer web sites
b. ❑ locate product information
c. ❑ locate design information
e. ❑ participate in professional discussion lists
f. ❑ get information about current events in your field
g. ❑ seek information about competitors

170. Are you aware of the inter-light site that has the database that allows you to search for manufacturers that have certain types of products?

❑ No ❑ Yes

Have you used the site?

❑ No ❑ Yes

171. What about PG&E's Pacific Energy Center Site, are you aware of it?

❑ No *Go to question 174* ❑ Yes

Have you used the site?

❑ No ❑ Yes

172. About how many times you have been there?

❑ Once ❑ 2 to 5 times ❑ 5 – 10 ❑ more than 10 times

SKIP to 174

173. Do you think that you are likely to become an internet user in the next two years?

❑ No ***go to 184*** ❑ Yes

174. If PG&E were to provide an Internet site where you could search for and retrieve the specifications for products meeting a certain set of criteria, what sorts of products would you want to be able to search for. . . (check all that apply)

❑ lamps
❑ ballasts
❑ controls
❑ fixtures
❑ glazing
❑ sustainable materials

175. If this site were to exist, do you think that it would be

❑ Of significant interest to you
❑ Of some interest to you
❑ Depends (do not read)
❑ Of little interest to you
❑ Of no interest.
❑ DNNS

176. Can you tell me why?

____

____

Go to 179

177. Under what circumstances would the site be of interest?

____

____

Got to 179

178. What is your motivation for using the site?

____

____

179. PG&E is working on a web site to provide a moderated discussion list for design information. The site allows a person to post design questions to which technical experts respond. All questionsand responses are reviewed by technical experts to insure that the responses are technically correct. The responses are also to be posted in a database that can be searched. Would such an expert site be:

- ❑ of significant interest to you
- ❑ of some interest to you
- ❑ depends (do not read)
- ❑ of little interest to you or your firm, or
- ❑ of no interest.
- ❑ DKNA

180. Can you tell me why?

____

____

Go to 183

181. Under what circumstances would the site be of interest?

____

____

Got to 183

182. What is your motivation for using the site?

____

____

Go to 183

183. Can you think of any internet services that you might find useful that PG&E might be able to provide?

____

____

Firmographics

184. About how many offices or locations does your firm have?

❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5-10 ❑ 10+ ❑ DKNA

254. For all locations of your company about how many full-time employees are there?

❑ <10 ❑ 10-19 ❑ 20-29 ❑ 30-49 ❑ 50-100 ❑ 100-499 ❑ 500+

185. About how many full time employees are at your office or location

❑ <10 ❑ 10-19 ❑ 20-29 ❑ 30-49 ❑ 50-100 ❑ 100-499 ❑ 500+

Personal Information

186. What is your job title?____

(Interviewer: enter what the person says then code one of the following. If you are not sure use the following categories to probe. If not sure, leave the answer for later coding.)

❑ Owner / Partner
❑ President
❑ Executive vice-president
❑ Senior manager
❑ Manager
❑ Senior engineer
❑ Engineer
❑ Senior architect
❑ Architect
❑ Senior designer
❑ Designer
❑ Other:

187. Do you supervise the work of others?

❑ No ❑ Yes

188. How long have you been in your current position?

_______ Years

189. How long have you been doing this kind of work?

______ Years

190. What is your highest level of education?

❑ high school or less
❑ Associates degree
❑ Some college
❑ Bachelor's degree
❑ Bachelor's degree and some additional education
❑ Masters degree
❑ Masters degree with some additional education
❑ Ph. D or its equivalent