Baseline Study for Assessing the PG&E Daylighting and Lighting Exchange Programs

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Abstract

This paper describes an assessment of the daylighting design market in Northern California. The assessment is based on 30 one-to-one interviews and surveys of building professionals in Northern California. The assessment was done to provide a market and evaluation baseline in support of PG&E's efforts to develop and disseminate six building design and information tools that it believes will stimulate greater interest in efficient lighting and daylighting.

The paper presents a conceptual model for understanding and analyzing daylighting practices. In addition it provides an example of the decision structure for commercial chain stores and an example of how decision making occurs when an electrical engineer is the key decision maker determining lighting specifications. The paper describes the penetration of selected daylighting practices among professionals in the commercial buildings market. Finally, the paper presents estimates of the target population's interest in the PG&E tools.

Introduction

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%, 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, Pacific Gas and Electric Company (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 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
- encourage others to become partners in the continuing development of these products and the market.

The tools are now in advanced stages of development. This paper reports on a market evaluation designed to describe the structure of the market, the target audiences, current market practices (a market baseline), and to develop data that could be used to help develop strategies for transferring the tools to the market place. This paper presents a brief description of the tools, a description of the framework to be used in analyzing the market place, and some of the results of the study.

The Product Offerings

PG&E, through the Pacific Energy Center (PEC), has set out to create a suite of information and design tools that will enable designers and specifiers to obtain good product and design information and to increase the amount of analysis that is used in decisions that effect the performance and appearance of daylit spaces. The tools are Desktop Radiance, Artificial Sky, SkyCalc, Daylighting Prospector, the Lighting Exchange Dialog, and the Lighting Exchange Product Database.

Desktop Radiance builds upon an earlier tool, Radiance, which produces a high quality 3-D rendering of a spatial location. Desktop Radiance links a widely used computer aided drafting (CAD) package, AutoCAD, to Radiance, thereby eliminating the need to laboriously enter data by hand into Radiance and making Radiance a practical user tool. 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 is a physical sky simulator facility that is being rehabilitated and upgraded. The upgraded facility will allow users to create accurate and repeatable hemispherical light distribution patterns to simulate standard skies that can be used with physical models to evaluate light and shadow effects in buildings. Because lighting conditions are repeatable, one can experiment with design elements and options under the same conditions.

SkyCalc allows 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 uses roof top measurements of illumination, light level measurements taken in a specific location within a building, and information about lighting and control hardware to determine the cost effectiveness of alternative daylighting control systems. The 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.

In addition to the analytic tools, PG&E has recognized that there are significant gaps in the flow and movement of lighting information. To meet this need, PG&E is developing a Web site that will allow users to exchange information with one another, locate manufacturers' data, and access tools that facilitate equipment comparison and selection.

The **Lighting Exchange Dialog** is a Web based moderated discussion list designed to provide timely and technically accurate lighting design information to users. Users who participate in the dis-

cussion list submit questions and receive answers about lighting products and design issues. The difference between this and most other discussion lists is that a moderator and a panel of experts screen the answers to insure that responses are technically accurate. Responses to questions are maintained in a database that users may search. A goal of the system is to provide some response to a query within 24 hours and a technically correct answer as soon as it is feasible.

The **Lighting Exchange Product Database** provides data from manufacturer catalogs in a searchable database. Users may search by type of equipment and retrieve catalog specifications from a cross section of manufacturers supplying that type of equipment.

A Conceptual Framework for Analyzing the Market

In prior research conducted for PG&E (Cooper, 1998a, Cooper, 1998b), 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. However, features such as advanced glazing, controls for limiting the use of electric lights, light shelves, and alternative window locations and sizes are not considered. Architects using the conventional approach may develop physical or computer generated models of the structure but they are principally used for presentation to clients and are seldom used to evaluate the effects of natural and electric light in space. Computer models are not used 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 design accordingly. 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 not typically specified. Models or computer simulations are not used to analyze 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 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 estimate that a majority of architects take the conventional approach (59 percent), about a third (36 percent) do limited customization, and 6 percent use a customized approach.

While the idea of levels is a good one it actually combines two concepts. It may be more useful to conceptualize daylighting in two dimensions, one that deals with practices related to the physical characteristics of buildings as these bear on the entry of natural light into the building and a second dimension relating to practices associated with artificial light. Figure 3 illustrates how the concepts can be joined to form a two dimensional space. We describe these as the intentional components of daylighting because the goal of PG&E's programmatic efforts is to increase the intentionality with which daylighting is used.

For purposes of definition, we can define the upper right hand quadrant as representing daylighting practice. 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 into working spaces nor the use of natural light is intentionally examined in the early stages of design. The result may be a situation in which neither the natural or electric lighting systems 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. Building designs in this quadrant may or may not have quality electrical lighting but they do have naturally well lit spaces. From a logical standpoint, it is difficult to believe that one would find many cases in this quadrant. If a designer pays attention to details that result in a building that takes good advantage of natural light, then it is difficult to believe that that same designer would fail to ensure that the artificial lighting was made to compliment the natural lighting component. Still, it is a possibility.

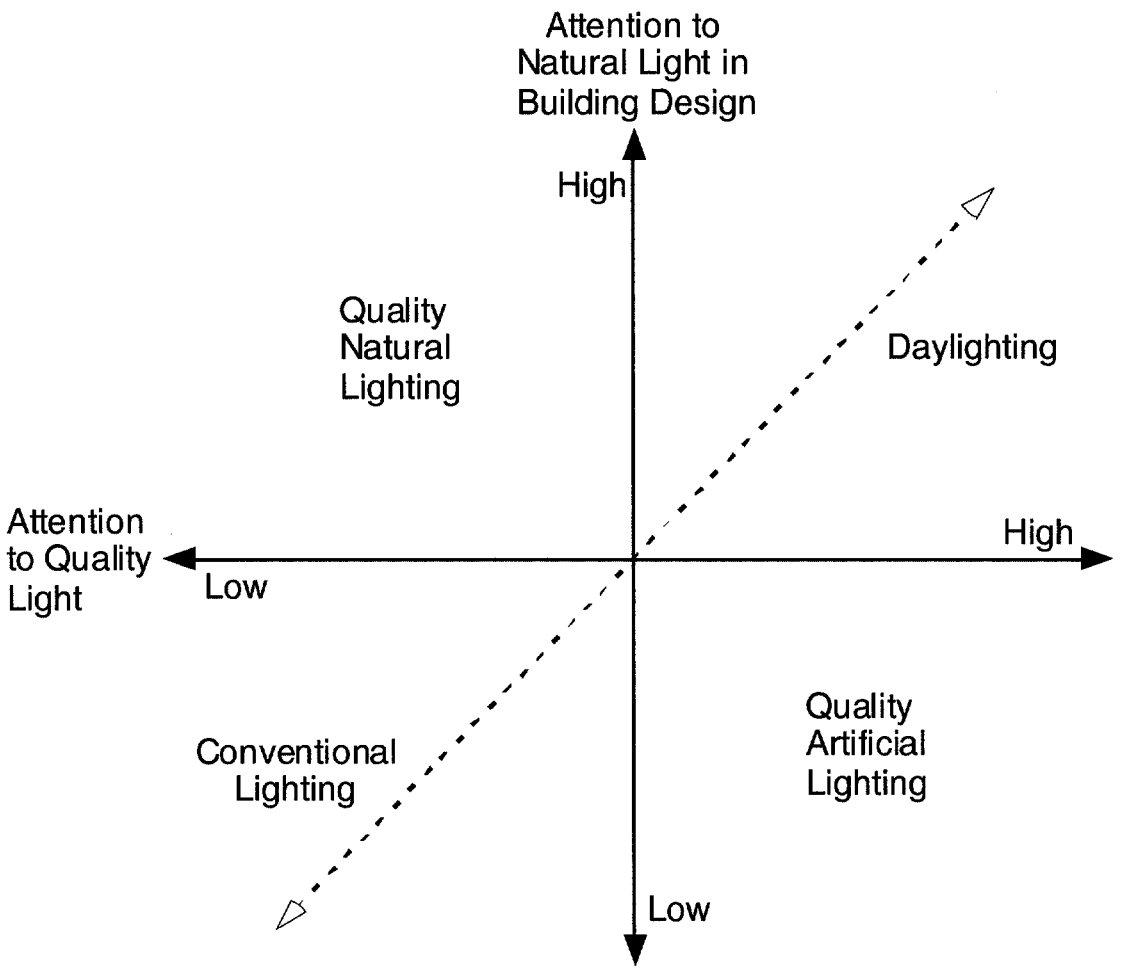

Figure 1 Components of intentional lighting design

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 is less well considered. Buildings resulting from this process may or may not make use of natural light. Buildings that have been retrofitted or renovated may appear in this quadrant. In these instances, structural changes and alterations to the building may not be possible. Even so, lighting design can be optimized for efficiency and comfort in relation to the existing structure.

The are at least two clear advantages to this approach. 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. 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. Thus for example, we might observe changes in the field of lighting but see that building design is static. Further, we may see advances in the use of efficient lighting equipment but not necessarily in the use of dimming controls. This approach also allows us to examine whether lighting and building practice are evolving and are being carried out in relation to one another.

Table 1 lays out some key indicators of intentional design with respect to daylighting practice. The indicators identified here are illustrative. 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 in the survey were designed to determine 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 out giving much thought to good daylighting design. Most architects will tell you that they do daylighting. 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 size and placement of windows and / or skylights on internal light and shadow effects
Analyze the effects of glazing on internal light and on shadow effects
Investigate architectural elements such as external light shelves and shading devices as a way to influence internal light and shadow effects
Investigate the use of skylighting
Attention to quality and efficiency of lighting
Consider and analyze alternative fixtures and lamps and their placement in relation to efficiency, comfort, and customer value
Analyze designs to optimize the perceived quality (comfort and value) of the lighting while minimizing energy use
Analyze lighting levels to establish the need for controls or natural light

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 the 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. The Lighting Exchange should help to increase the movement along the horizontal and vertical dimensions by providing product information and improved design through the exchange of ideas. 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.

Methods Used in this Research

Three basic data collection methods were used in this research. The first is the analysis of secondary data. These data were 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. These data were used to develop a sampling frame and understand the general characteristics of the population.

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 one-to-one interviews were conducted on-site at the respondent's 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 data source is a random survey of 201 building professionals. The survey was conducted by telephone using trained professional interviewers. As many as ten attempts were made to contact respondents. The telephone interviews lasted from 18 minutes to as much as 50 minutes.

Estimating the Potential Market

One of the important issues in a market assessment is to identify the key market segments and to estimate the size of the target audiences. The audience is some subset of architects, engineers, lighting designers, and professionals from other disciplines. The problem is identifying the subsets.

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 may work outside the area of lighting design and for companies that are not involved in commercial new construction.

As an alternative way of identifying the target audience, 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 could be used, we attempted to select commercial retail, office and warehousing type 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 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 1 to 50 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 3 shows the distribution of firms and the number of projects reported in the F. W. Dodge data. About 20 percent of the firms complete slightly more than half of the projects.

Table 2 Projects meeting criteria by type in Northern California in 1997 and 1998 (N = 1908)

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

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

What we can say about the target audience at this point in time is that once we include other disciplines and out of state firms, the total number of target firms may be in the neighborhood of 1,500 to 2,000 firms. The number of individuals is probably somewhere between 5,000 and 10,000.

We should point out that there are significant limitations in the data that are available. We know from our interviews that some firms have been involved in many more projects than are identified in the F. W. Dodge data. One likely explanation is that firms may be playing a supporting role and may not be listed as a 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, we should point out that it is almost impossible to identify the unlicensed technical staff in firms through publicly available records. There are often several unlicensed technical staff per licensed staff member.

The Structure of Key Market Segments

In the preliminary interviews we identified three basic types of decision making structures, design / build for chain stores, general design / build, and traditional architecture. There are more but most are 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. To illustrate the point we describe the design-build environment for chain stores. Descriptions of the other two environments are detailed elsewhere.

Figure 2 shows the decision making structure for a design / build environment that is 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 architects and engineers who are responsible for property acquisition and development and construction management.

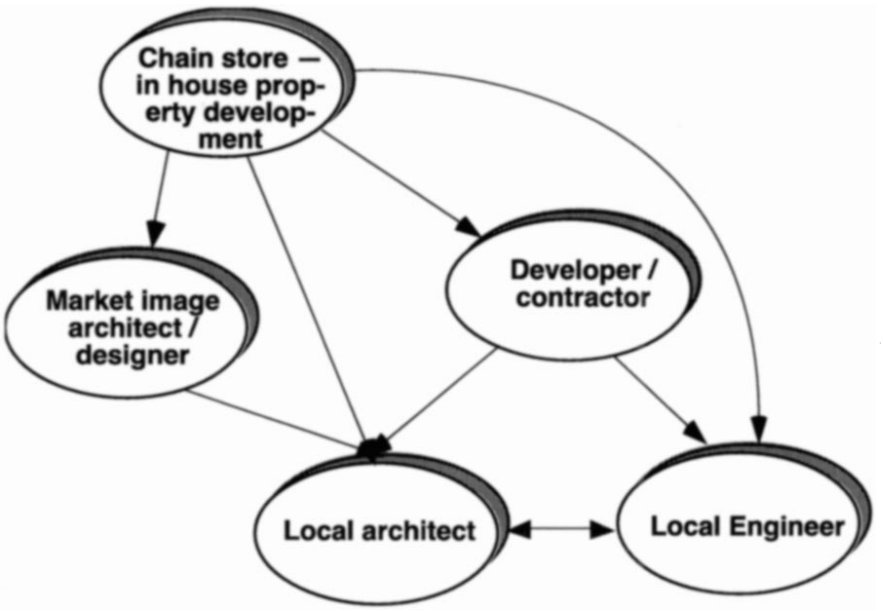

Figure 2 Commercial building decision making model for a national or regional chain

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 usually 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 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.

The Decision Makers

In our survey, we asked the respondents who the key decision makers were with respect to each of the major decisions we identified in Table 1. Table 4 shows decision makers by decision type. Architects are clearly the key decision makers for the decisions having to do with features of the buildings. The architects are also the key decision makers with respect to lighting placement in a near majority of projects, but it is the engineers who are the key decision makers with respect to lighting specifications and dimming controls.

Table 4 The primary decision makers for different types of decisions

	Owner	Architect	Lighting designer	Electrical engineer	Other	DK/NA	Total
Exact orientation of building	12	73			7	8	100
Size / placement of windows	8	82			1	9	100
Glazing material	6	78	1		5	9	99
Use of architectural elements	5	83	2	1	4	5	100
Use of skylights	12	76	1		5	5	99
Lighting location / placement	3	47	17	24		5	99
Lighting specifications	4	24	19	42		6	99
Dimming controls	9	24	18	38		7	99

N=201

In our analysis, we were able to identify who the primary as well as the supporting decision makers are. Figure 3 shows the case for electrical engineers as the primary decision makers for lighting specifications. In this case, architects supported electrical engineers in their decision making 68 percent of the time.

In our overall analysis of decision making we found that architects are clearly in the driver's seat when it comes to the physical design aspects of the building. The data show that lighting design professionals have influence over aspects of building design that would lead to quality lighting in a relatively small percentage of cases. Further, when we asked about the criteria that would lead to quality daylighting designs, we found that they were viewed as relatively unimportant compared to other criteria.

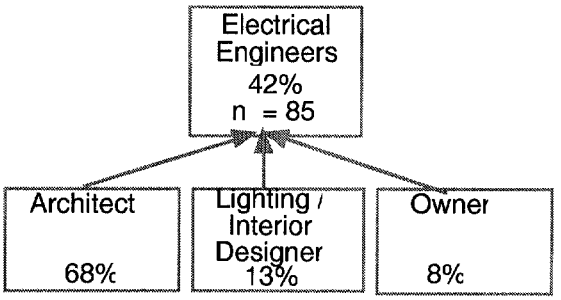

Figure 3 Supporting actors when electrical engineers are the primary decision makers for lightng specifications

Baseline Practices Related to Daylighting

Earlier we identified two dimensions of daylighting and some indicators of lighting design practice. Table 5 presents selected results for eight measures. These selected measures show that practices associated with daylighting are not widely observed in Northern California. For instance, only 18 percent of projects involve a team in examining architectural elements to control natural light. Only 15 percent of projects use computer models to assess internal light and shadow effects. While a significant percentage of projects use bi- and tri-level lighting (45 percent) and about half that number make use of motion sensors, less than a seventh of all projects are using dimming ballasts and lighting controls in main work areas. While 34 percent of all building professionals use rendering only eight percent render internal spaces and in only four percent of the projects professionals are actually using rendering to analyze light and shadow effects. Fifteen percent of all projects are making use of skylights in general work areas.

The evidence strongly suggests that daylighting has not deeply penetrated the California market and that for the most part most building professionals and projects are in the quadrant of Figure 1 that we labeled conventional design.

Table 5 Baseline estimation of selected measures of daylighting practice in Northern California

	Percent of projects
Work with team to examine architectural elements to control natural light	18
Use of physical computer models to assess internal light and shadow effects	15
Use of bi-level and tri-level lighting controls	45
Use of motion sensors	25
Use of dimming ballasts and lighting controls in main work areas	13
Render internal designs	8
Use rendering to analyze internal light and shadow effects	4
Use skylights in general work areas	15

Baseline Practices Related to Internet Use

We investigated Internet use among building professionals because low levels of Internet use might represent a significant barrier to using the Lighting

Exchange Dialog and Product Database tools. We found that 89 percent of respondents use e-mail and 85 percent use the Internet in relation to their work. We found that the majority of users (53 percent) use the Internet a small amount, from one to three hours per week in relation to their work. Finally, we discovered that 89 percent of building professionals say that one of the reasons they use the Internet is to locate product information.

Market Readiness for the PG&E Tools

We also asked respondents about their interest in the PG&E Daylighting Design and Information Tools packages. Table 6 shows their response. Building professionals have the greatest interest in the Internet product database followed by the moderated discussion group. There is also considerable interest in the daylighting tool, the rendering tool and the tools for evaluating skylighting. Although we do not show the data here, there was enough "significant" interest in each of the tools to believe that they can be successfully introduced to the market.

Key Findings about Diffusing Tools into the Market

Table 6 Percentages of respondents expressing some or significant interest in the PG&E tools

Tool	Percent
Lighting Exchange Product Data base	86
Lighting Exchange Dialog	76
Daylighting Prospector	68
Desk Top Radiance	62
SkyCalc	58
Artificial Sky	29

N = 201

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The key findings are:

- There are probably fewer than 2,000 firms in the target market.
- The patterns of decision making and the key decision makers are quite diverse. PG&E will have to target the audience and the messages carefully.
- There is substantial evidence that only a small part of the market, perhaps as little as a seventh, is currently using quality daylighting in their projects. There is substantial opportunity for the tools to impact the market.
- There is significant interest in the PG&E tools and they are likely to find acceptance among building professionals. The Lighting Exchange Product Database elicits the most interest among potential users while Artificial Sky evokes the least.

- The conceptual model for daylighting provides a powerful tool for collecting and analyzing the data.
- The data that has been gathered should provide a good baseline for the evaluation of the impact of the tools on the market.

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