Developing a Statewide Lighting Strategy Support Framework

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ABSTRACT

The California Energy Efficiency Strategic Plan set aggressive targets for energy reduction in various sectors and end-uses, including lighting. The plan also calls for more substantial efforts toward market transformation. In support of the plan's lighting goals, the California investor-owned utilities (IOUs) created a statewide Lighting Market Transformation (LMT) program to develop market transformation strategies for targeted lighting technologies.

To inform this market transformation strategy development, the LMT program worked with The Cadmus Group, Inc., to develop an Excel-based planning support tool called the Lighting Solutions Workbook that helps prioritize opportunities for the IOUs to achieve the highest energy savings. The most innovative aspect of the Lighting Solutions Workbook is it makes a wealth of knowledge about market barriers, savings potential, and technology saturation available to planners and decision makers within a logically structured framework that spans major market sectors, applications, and technologies. Cadmus compiled the data populating this tool from multiple sources; the LMT program will update it regularly as new information becomes available.

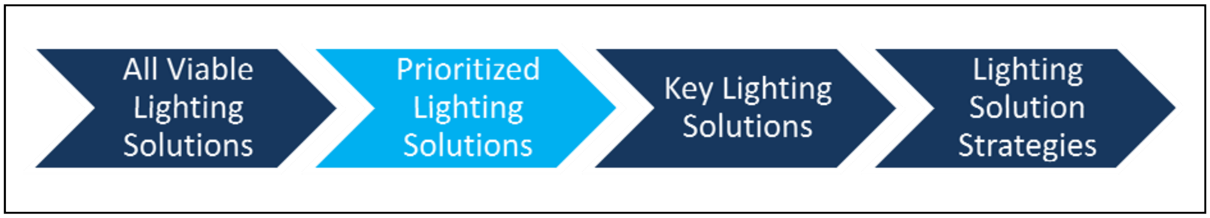
The Lighting Solutions Workbook is the product of a collaborative effort involving lighting experts from utilities throughout North America, Pacific Northwest National Laboratory, California Lighting Technology Center, and other organizations. This paper describes the need for a framework to organize lighting market information, the development of that framework, and the population of the tool with available data. This tool represents a transparent and data-driven approach to planning that can be applied to other regions and end-uses.

Introduction

The Lighting Market Transformation (LMT) program develops and tests market transformation strategies for energy-efficient lighting technologies and practices across key market segments. Representatives from California investor-owned utilities (IOUs) implement this statewide program and are responsible for selecting and prioritizing opportunities within the limited programmatic resources for IOUs. Because lighting is a $100 billion global industry with thousands of existing products and myriad new products entering the market each year, the LMT program uses a process, shown in Figure 1, to select a manageable number of key lighting solutions for further strategy development.

Lighting solutions are prioritized by characteristics such as market needs, energy savings potential, and market barriers. LMT program staff focus on solutions that can most readily attain higher energy and demand savings with fewer resources and risks. From these prioritized solutions, the LMT program identifies a manageable number of key lighting solutions using a set of additional characteristics: availability of stakeholder resources, existing interest and momentum, and level of effort required to affect the market. Finally, the LMT program creates appropriate strategies to target key lighting solutions through programmatic efforts and collaboration with non-IOU entities to the market sectors with the greatest potential for lighting energy savings and market transformation in California.

Figure 1. LMT Program Process



In this paper, we describe the development, content, and use of an Excel-based planning support tool used to prioritize lighting solutions (second step in Figure 1). This tool, the Lighting Solutions Workbook, provides a comprehensive overview of the lighting technology landscape by market sector, built on the foundation of consumers' current usage of technologies across various applications. The workbook is structured in a transparent and logical manner to house the wealth of available information from various studies and industry experts consulted for this project. In developing the tool, the most important objective was to separate lighting applications and technologies with significant savings opportunity from those that are less viable.

The idea for the structure and format of this tool originated when LMT program staff attended a West Coast Utility Lighting Team Meeting in 2010. At this meeting, BC Hydro shared its *Lighting Application Matrix*, which the utility considers to be a global map of all opportunities within a five-year horizon for lighting. BC Hydro was already using its tool to identify which sectors had the greatest savings opportunity, develop a focused action plan, and communicate decisions.

The LMT program staff recognized the potential of BC Hydro's tool, which captured a logical framework for summarizing, in one convenient place, the large diversity of lighting information such as market barriers, savings potential, and technology saturation needed to make strategic decisions. After that meeting, the LMT program staff created the first iteration of its workbook. While it contained most of the basic data the LMT program had hoped to capture, the team understood that with some improvements the workbook could be more useful as a comprehensive view of lighting usage across all major markets. The LMT program staff hired The Cadmus Group to refine the workbook by adjusting its structure to provide an appropriate level of granularity, modifying the types of information housed in the workbook, and by populating the dataset with current information. The workbook captures a comprehensive view of lighting usage across all major markets, and is thus populated by data from a multitude of sources, many specific to California, such as the *2008 Database of Energy Efficient Resources* (California Public Utilities Commission [CPUC] and California Energy Commission [CEC] 2008), the *California Commercial End Use Survey* (Itron 2006), and the *2007 Integrated Energy Policy Report* (CEC 2007). Other data sources include market saturation studies, evaluations, potential studies, and consensus from multiple lighting experts.

Approach

Cadmus and the LMT program staff (the study team) developed the workbook in two phases. In the first phase, we organized the way information was presented across market sectors and technologies, then determined the appropriate types of information for inclusion in the workbook based on our understanding of its intended use and the level of detail available from relevant data sources. We performed the following steps:

- We asked key stakeholders what features, level of detail, types of information, and reporting capabilities the stakeholders hoped the final workbook would encompass.
- We reviewed the literature for data to populate the workbook and then set the level of granularity based on findings from this literature review.

In the second phase, we populated more than 99% of the workbook framework developed in the first phase, making every effort to use up-to-date, California-specific data (where available). We also consulted a couple of lighting experts to provide input on data not readily available in the literature. Because the workbook is meant to be a living document that the LMT program staff can continually enhance and update, we wrote a research plan to complete any data that we were unable to source from the literature or by consulting lighting experts involved in the study. We also suggested opportunities for updating data sourced from older studies through information obtained from future research studies.

About the Workbook Structure

This section describes the main sections of the workbook and their purposes. Supporting data and energy savings calculations are housed with their source(s) noted on worksheets. Data in the supporting worksheets are linked in a primary worksheet, called Market Solutions, where they are organized and summarized. The Market Solutions structure is designed to be flexible, allowing for expansion or aggregation as needed, based on data availability and user preferences. Figure 2 shows an excerpt of the Market Solutions structure; the columns in the table contain either framework data or market data.

- Framework columns, highlighted in yellow dashes, determine the worksheet's structure and dictate the level of data aggregation, at either the sector, subsector, application, technology (current), or technology (replacement) level.
- Market data columns contain information for assessing lighting characteristics germane to a particular application or technology. The data columns are interspersed throughout the framework columns because the level of aggregation varies for different types of data.

Figure 2. Excerpt from Market Solutions Worksheet, Framework Columns Highlighted

	A	B	C	D	E	F	G	H	I	J	K
2	Sector	Sub-Sector	Application	Avg Daily HOU	Active During Peak?	Baseline Use	Current Lighting Practices		Percent Incidence of Current Practice	Replacement Lighting Practice	
3						(GWh/Yr)	Lighting Product	Controls		Lighting Product	Controls
95	Non-Res Exterior	Area Lighting	Covered Parking (Ceiling Mounted)	24	Yes	1,102	Linear Fluorescent	None	20%	High Efficiency Linear Fluorescent T-8/T-5	Occupancy/Bi Level
96							HID (Metal Halide/HPS)	None	80%	LED Fixture	Manual
97										Linear Fluorescent T-8/T-5 HO	Manual
98			Perimeter (Wall Packs)	11	No	336	HID (Metal Halide/HPS) Wall Pack	Photocell/Timeclock	100%	LED Wall Pack	Photocell/Timeclock
99										Fluorescent Wall Pack	Photocell/Timeclock
100										PS MH/CMH	Photocell/Timeclock
101			Public Area (Pathway and Landscape)	12	No	1,015	HID (Metal Halide/HPS)	Photocell	TBD	LED	Photocell/Timeclock
102							Halogen	Photocell	TBD	LED	Photocell/Timeclock
103							Metal Halide	Photocell	34%	PS MH/CMH	Photocell
104										LED	Photocell

Framework Columns

We organized the framework columns based on findings from our research, including interviews with program managers at the IOUs, advice from technical experts, and reports from California and other regions. Most interviewees said they were interested in seeing a market-driven approach to the organization, as opposed to a technology-based approach. Therefore, at the highest level, the framework columns outline the major market sectors for which data are available (residential, nonresidential interior, and nonresidential exterior) and then further specify the subsectors, such as small commercial, agriculture, hospitals, university/college. Each subsector is then broken down into different lighting applications (general lighting, high bay lighting, covered parking, etc.) so that lighting practices and usage can be characterized.

For each application, current and replacement lighting practices are specified for lamps and controls. To develop this part of the framework, we started with information from the original workbook developed by LMT program staff and the BC Hydro Matrix. It was important that the workbook capture information about what is currently installed, and we used various reports, including unpublished data from a residential lighting metering study by KEMA, the *Northwest Commercial Building Stock Assessment* (Cadmus 2009), and the *Sixth Northwest Conservation and Electric Power Plan* (Northwest Power and Conservation Council 2010). The replacement lighting practices were derived from recommendations provided by Cadmus and Pacific Northwest National Laboratory (PNNL) lighting experts. For the residential sector, we assumed that replacement products must have the same base type as the current product; this is not a constraint in the nonresidential sectors.

Market Data Columns

Market data columns contain lighting characteristics germane to a particular application or technology. These columns are highlighted in Figure 3. This part of the workbook includes information the study team and interviewees deemed important for prioritizing lighting solutions.

The first market data column is *Average Daily Hours of Use* (HOU), provided at the lighting application level. HOU is important information about usage, which impacts the energy saving potential for lamps and controls. Although a technology could be much more efficient than the current practice, if it were installed in a location where lights are rarely used, it might not be a good candidate for inclusion in a program.

The HOU column is followed by *Active During Peak?* Identifying measures/applications that are in operation during peak usage periods is essential to the IOUs' efforts to reduce energy use at these critical times. Several interviewees expressed interest specifically in the energy savings potential of end-user behavior changes in response to dynamic and peak pricing.

The *Baseline Use* column indicates how much energy is currently used for a particular lighting application, thus indicating the current market size. The baseline consumption is directly proportional to the savings potential; hence, understanding the lighting end-use consumption by application and market sector is critical.

The next market data column, *Percent Incidence of Current Practice*, shows the current saturation of the current lighting practice in the specified application. For example, Figure 3 shows that incandescent bulbs represent 62% of the interior residential lighting end-use consumption. The values in the *Percent Incidence of Current Practice* column should add up to 100% for each lighting application listed. (Applications with only one current lighting practice, such as LED exit signs, are listed as 100%.) The data that populate this column show the distribution of technologies used in a particular application based on consumers' current usage behavior.

Figure 3. Excerpt from Market Solutions Worksheet, Market Data Columns Highlighted

	A	B	C	D	E	F	G	H	I	J	K
2	Sector	Sub-Sector	Application	Avg Daily HOU	Active During Peak?	Baseline Use	Current Lighting Practices		Percent Incidence of Current Practice	Replacement Lighting Practice	
3						(GWh/Yr)	Lighting Product	Controls		Lighting Product	Controls
4	Residential	All Residential	Interior	2	Yes	14,230	Incandescent MSB	Manual	62%	CFL MSB	Wall Switch Occupancy Sensor
5										LED MSB	Wall Switch Occupancy Sensor
6							CFL MSB	Manual	8%	LED MSB	Wall Switch Occupancy Sensor
7							Halogen MSB	Manual	3%	CFL MSB	Wall Switch Occupancy Sensor
8										LED MSB	Wall Switch Occupancy Sensor
9							Linear Fluorescent	Manual	10%	High Efficiency Linear Fluorescent T-8	Wall Switch Occupancy Sensor
10										LED Panel Lighting	Wall Switch Occupancy Sensor
11							Halogen Pin Base	Manual	6%	LED Pin Base	Manual
13							Incandescent SSB	Manual	8%	LED SSB	Manual
14										Cold Cathode or CFL SSB	Manual

Figure 4 shows the view of the workbook as the user scrolls to the right of the view presented in Figure 2. Columns shown here contain technical savings estimates for replacement of either lamps/ballasts or controls, as well as other market data. Columns L and M show how much energy can be saved—in aggregate across the California IOU service areas—per year for the replacement lamp or control technology over the baseline lamp or control technology. Note that actual savings from replacing both lamps/ballasts and controls are less than the sum of the savings from replacing each individual component separately. For savings purposes, we assume that a high-efficiency ballast would be installed with the new lamp where applicable. We also adjusted the savings to account for applicable codes and standards where they were known, assuming in such cases that the baseline is determined by the relevant code or standard and that no early replacement takes place.

Figure 4. Excerpt Showing Technical Savings Potential, Lifecycle Stage, and Market Barriers[1]

	J	K	L	M	N	O	P	Q	R
2	Replacement Lighting Practice		Lamp (+ Eff Ballast) Tech Savings Potential	Controls Tech Savings Potential	Replacement Lighting Product Life Cycle Stage	Market Barriers for Replacement Practice			
3	Lighting Product	Controls	(GWh/Yr)	(GWh/Yr)		Lighting Primary	Lighting Secondary	Controls Primary	Controls Secondary
95	High Efficiency Linear Fluorescent T-8/T-5	Occupancy/Bi Level	21	50	Maturity	No barrier identified	No barrier identified	No barrier identified	No barrier identified
96	LED Fixture	Manual	413	0	Introduction	First cost	Availability	No barrier identified	No barrier identified
97	Linear Fluorescent T-8/T-5 HO	Manual	323	0	Maturity	No barrier identified	No barrier identified	No barrier identified	No barrier identified
98	LED Wall Pack	Photocell/Timeclock	208	0	Growth	First cost	Reliability	No barrier identified	No barrier identified

The next market data column is the *Replacement Lighting Product Life Cycle Stage*. This column shows the replacement technology's stage (introduction, growth, maturity, or decline) in the product development cycle. This information will guide the activities that utility program managers consider appropriate for a given technology. For example, a technology in the introduction stage will be a strong candidate for emerging technology programs. A technology in the growth stage would be considered for incentive programs as well as marketing and education efforts. A product in the maturity stage should be considered for inclusion in codes and standards; a product in the decline stage should be planned for removal from utility incentive programs, as appropriate.

The workbook also presents *Market Barriers for Replacement Practice*, which has separate columns for lamps and controls. Replacement lighting products and controls each have two columns capturing market barriers: one column for the primary market barrier and a second column for the secondary market barrier. These columns are important because they indicate the obstacles that must be overcome before a technology becomes widely adopted in a given application. Common barriers identified by the study team include cost (incremental cost over the baseline technology), commercial availability, technology performance, technology reliability, customer awareness, and technical feasibility. For example, Figure 4 shows that the replacement lighting technology in row 96 has two barriers: first cost and availability. Multiple stakeholders interviewed for this study indicated that information about barriers was important to

[1] Rows 95 - 97 represent covered parking applications. Row 98 belongs with perimeter lighting.

enhance the document's usefulness as a planning tool. This column and the *Replacement Lighting Product Life Cycle Stage* columns were populated with data obtained from a consensus of lighting experts.

Codes and Standards, another market data column not shown in Figure 4, is populated with the name of the applicable code or standard if it affects a lighting solution's energy savings estimates. Included in the workbook are EPACT 2005 and California Title 20 regulations that:

- eliminate T-12 lights
- require California to adopt EISA requirements earlier than the rest of the U.S.
- effectively require LED traffic lights

If this column is populated, then the energy savings columns are adjusted accordingly. For example, savings from retrofitting incandescent traffic signals with LED signals has been zeroed out as a result of California law. Also, while regulations affecting factors other than energy-efficiency exist, we limit this column to general regulations that affect the savings calculation. This means that the myriad of regulations for lighting in hospitals are noted in the workbook, but are not reflected in the savings estimates. Codes and standards are important because new and existing regulations have an effect on a technology's market application and savings potential. In addition, this workbook provides useful market information to the code and standard development process.

Data Validation

We performed the following checks to ensure that data compiled in the workbook were of the correct order of magnitude (the targeted level of accuracy desired for planning purposes).

(1) Lighting Baseline Consumption Comparison

Cadmus used data from the *2007 IEPR* (CEC 2007) to determine if the lighting baseline consumption in the workbook was the correct order of magnitude. Starting with 281,200 GWh of total electricity consumption across California for all end uses, we determined the total consumption attributed to the California IOUs (Table 1).

Table 1. Electricity Consumption by IOU in California

Electricity Consumption	GWh
PG&E	84,360
SCE	87,172
SDG&E	19,684
IOU Total	191,216
California Statewide Total	**281,200**

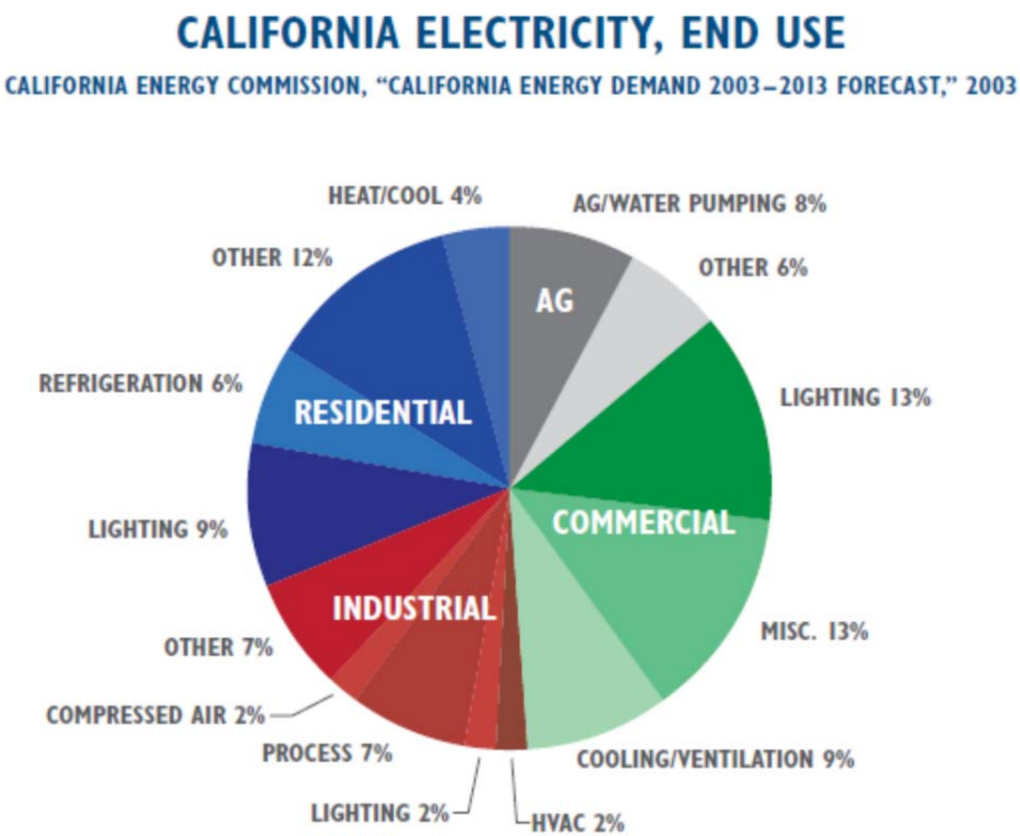
Source: CEC 2007

Next, when we sum the total baseline lighting consumption in the workbook, we obtain a total of 55,432 GWh. Dividing the lighting end-use consumption by the total electricity consumption in the IOU areas yields 29%.

$$\frac{55{,}432}{281{,}200} = 29\%$$

This result is very close to the lighting end-use consumption share across all major sectors shown in Figure 5 from the CEC; the three lighting shares equal 24%.

Figure 5. California Electricity End Use



Source: CEC 2003

(2) Residential Savings Potential Comparison

Cadmus calculated the total interior residential lighting savings potential (lamp replacement only, no controls) from the data in the workbook for each of the current lighting products in the workbook. These results are summarized in Table 2, which indicates a savings potential of 6,220 GWh/yr is possible in the residential sector. Where multiple replacement options were possible (e.g., an incandescent can be replaced by an LED or CFL), we chose to count the CFL replacement because this is more realistic given LEDs currently have very low saturation in the residential market, according to KEMA's unpublished data set. This value is very similar to a result obtained by KEMA.[2] In 2011, KEMA staff presented an analysis in an International Energy Program Evaluation Conference (IEPEC) paper, titled *Residential Lighting: Shedding Lighting on the Remaining Savings Potential in California* (Gaffney, Mahone & Johnson 2011), to determine "order of magnitude" energy savings potential using a separate methodology and came to a result of 6,521 GWh, thus providing an order-of-magnitude validation of our results.

Table 2. Interior Residential Sector Savings Potential

Current Technology	Replacement Technology	Savings Potential (GWh/Yr)
Incandescent MSB[3]	CFL MSB	4,527
CFL MSB	LED MSB	134
Halogen MSB	CFL MSB	245
Linear Fluorescent	High Efficiency Linear Fluorescent T-8	193
Halogen Pin Base	LED Pin Base	509
LED MSB	LED MSB	0
Incandescent SSB	Cold Cathode or CFL SSB	611
Total		**6,220**

Using the Workbook

The Lighting Solutions Workbook better positions the LMT program to identify the market sectors with the greatest savings opportunity as well as the most appropriate technology solutions for those markets. As a living document, the workbook can continually be enhanced and updated as better information becomes available. After a comprehensive review and discussion of the information, the LMT program uses this tool to assess what actions to take regarding particular technologies and the prioritization of those actions, and use the data in the workbook to design and communicate lighting market transformation strategies. The purpose of these strategies is to develop a set of targeted and actionable activities coordinated between the utilities and non-utility entities that will help overcome the key market barriers for the selected lighting solution.

The workbook organizes the necessary information to determine how to best focus limited resources across major market sectors, and it serves as a basis from which the California IOUs can make a concerted effort to transform the lighting market and obtain the highest savings. Although the LMT program and Cadmus created this tool to help the California IOUs plan their lighting strategy, this approach can extend beyond California and beyond the lighting end-use. Using a planning tool such as this workbook, multiple utilities can coordinate efforts transparently; in fact, BC Hydro has a long-term vision to use such a lighting tool to guide all the West Coast utilities to align their efforts and push the market. Additionally, having a planning support tool like the workbook to aggregate and organize a wealth of knowledge in one

[2] Cadmus used KEMA's data set as part of our analysis, although our methodology differed.
[3] MSB stands for medium screw base. SSB stands for small screw base.

convenient resource makes it possible to search for solutions based on numerous program planning criteria and to focus on the most relevant solutions for programs targeting specific markets or market barriers. This tool is a valuable part of the program planning infrastructure in California and British Columbia and could easily be adopted by other program administrators as a way to make transparent and data-driven planning decisions.

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