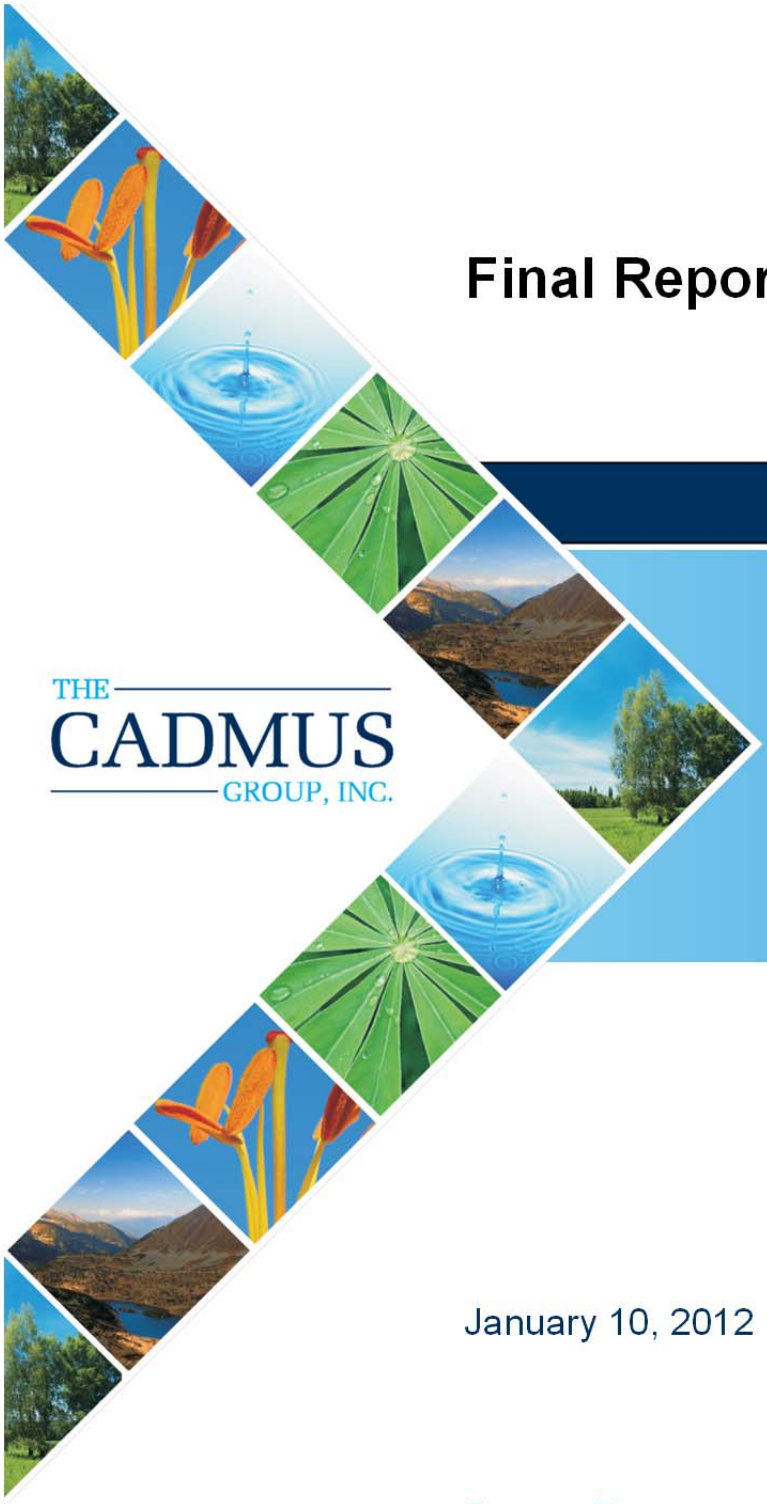

Final Report

CALMAC ID: SCE0308

Development of a Lighting Solutions Workbook for the LMT Program

January 10, 2012

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Executive Summary

The Lighting Market Transformation (LMT) Program is responsible for establishing a process through which the IOUs can develop and test market transformation strategies for the California investor-owned utilities (IOUs). Early in 2010, the LMT program staff developed a process to select key lighting solutions for market transformation strategy development. One of the main steps of this process requires a logically structured planning and design tool that summarizes, in one convenient place, diverse information on market barriers, savings potential, and technology saturation needed to support strategic decisions and prioritize activities based on data rather than limited experience or knowledge. LMT program staff developed the first iteration of this tool, called the Lighting Technology Roadmap.

The original Lighting Technology Roadmap, an Excel spreadsheet, consisted of a technology tab in which data were organized by technology, and a market tab in which data were organized by market sectors. Information in the spreadsheet included the following categories: saturation of emerging technology; market size (GWh and GW); technical savings potential; scalability; influence level; commercialization stage; market adopters; and regulations, codes, and standards.

Initially, the Lighting Technology Roadmap was not at the proper level of granularity for LMT's purposes, and many of its data fields had not been populated. The IOUs engaged The Cadmus Group, Inc., during the second quarter of 2011 to continue developing the Roadmap and to devise an approach for filling in missing data. The most important objective was for Cadmus to create a tool that allows the LMT team to separate the applications and lighting technologies that possess a significant savings opportunity from those that do not. This tool would also need to provide a comprehensive overview of the lighting technology landscape by market sector, built on the foundation of consumers' current usage of technologies and needs across various markets and applications.

Our Approach

Cadmus developed this tool in two phases. First, we optimized its structure by organizing the way information was presented across market sectors and technologies. Then we determined the appropriate types of information for inclusion based on our understanding of the intended use and the level of detail available from relevant data sources. We based this on a two-part assessment of needs and available data obtained through interviews with key stakeholders and a literature review to determine data availability.

In the second phase of this project, Cadmus populated the structural framework developed in the first phase through data collected from the literature and from lighting industry experts. We conducted analysis to verify the data populating the tool were reasonable and consistent with other studies. As the final step in this process, we developed a research plan to obtain additional information and fill in remaining data gaps.

Key Findings from Needs Assessment and Literature Review

The key findings of the needs assessment were:

- The tool should be organized by market sector to reflect end-users' needs.

- Some parts of the original Roadmap were too granular, while other parts were not granular enough.
- Very granular data are typically not available or necessary. It is preferable that data be a more complete set across market sectors and technologies.
- Technical savings potential should: (1) represent annual savings potential (applicable for the next five years) rather than long-term savings potential, and (2) be provided for lamps and controls separately.

The key findings regarding data availability were that complete sets of data across market sectors and technologies were difficult to find, and the level of detail provided in the reports reviewed often differed, even within the same report. This meant that the planning tool would need to be able to accommodate many different types and sources of data.

Final Lighting Solutions Workbook

With input from the IOUs and other stakeholders, Cadmus renamed the Lighting Technology Roadmap the Lighting Solutions Workbook (hereafter referred to as the workbook) to avoid confusion with the original version (the Lighting Technology Roadmap), as well as to avoid misrepresenting the tool as a technology roadmap that documents actions and solutions required to meet specific goals. The updated workbook was reorganized by market sector and application first; from there it branches out to include various applicable technologies. It contains 112 rows and 22 columns of data across all major markets, applications, and technologies. It covers energy savings, market barriers, technology saturation, and other essential information used in strategic planning. This comprehensive tool is populated by data from a multitude of sources, many specific to California (such as DEER 2008 and the 2007 Integrated Energy Policy Report). Other data sources include market saturation studies, evaluations, potential studies, and consensus from multiple lighting experts.

Organization of This Report

This report is divided into four primary sections. The first presents an introduction and overview of the study. The second describes our research and contains the results from the needs assessment. The third section contains a description of the restructured workbook and how it was populated, including a discussion on data quality. The fourth section is the research plan with recommendations on how to complete any outstanding sections of the workbook. Two appendixes are included: a bibliography of the sources used to populate the workbook and the guide used to conduct expert interviews.

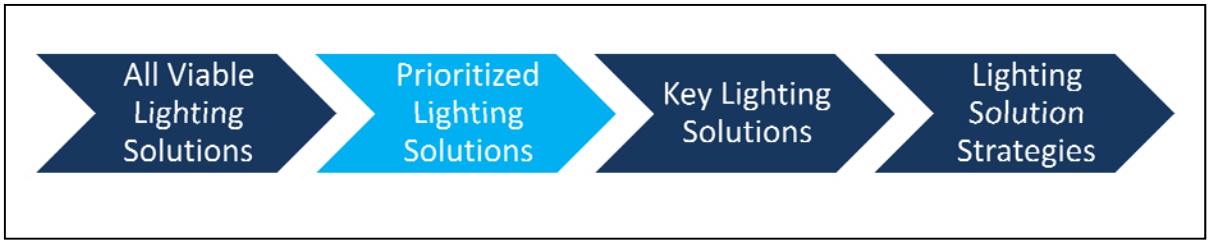
Instructions for Requesting a Copy of the Workbook

The workbook itself is not included in this report. To obtain a copy of the workbook, please submit an e-mail request to David Bend (DDBw@pge.com) or Vireak Ly (Vireak.Ly@sce.com).

Introduction

The Lighting Market Transformation (LMT) Program is a statewide program implemented by a team of Investor Owned Utility (IOU) representatives in California who are responsible for establishing a process through which the IOUs can develop and test market transformation strategies for lighting. Early in 2010, the LMT program staff developed this process shown in Figure 1. Because lighting is a $100 billion industry worldwide with hundreds of products and new products constantly being introduced, the goal of this process is to help select a manageable number of key lighting solutions for market transformation strategy development.

Figure 1. LMT Program Process



The first step in the process is to prioritize lighting solutions by characteristics, such as market needs, energy savings potential, and market barriers, enabling the LMT program and its stakeholders to focus on solutions that can more easily attain higher energy and demand savings with fewer resources and risks. Prioritization should be based on the best information available. The prioritized solutions will serve as a guide for the next step: identifying a manageable number of key lighting solutions. The LMT program will select key lighting solutions based on additional characteristics not incorporated in the prioritization step, which include availability of stakeholder resources, existing interest and momentum, and level of effort required to effect the market for the key lighting solution.

One of the main steps of this process (the step shown in light blue in Figure 1) requires a planning and design tool that provides a logical framework for summarizing, in one convenient place, the large diversity of information, such as market barriers, savings potential, and technology saturation, needed to make strategic decisions. LMT program staff developed the first iteration of this tool, called the Lighting Technology Roadmap (hereafter referred to as the "Roadmap").

The Roadmap, an Excel spreadsheet, consisted of a technology tab in which data were organized by technology, and a market tab in which data were organized by market sectors. Information in the spreadsheet included the following categories: saturation of emerging technology; market size (GWh and GW); technical savings potential; scalability; influence level; commercialization stage; market adopters; and regulations, codes, and standards.

Initially, the Roadmap was not at the proper level of granularity for LMT's purposes, and many of its data fields had not been populated. (These fields used a TBD, or "to be determined," placeholder.) The IOUs engaged The Cadmus Group, Inc., during the second quarter of 2011 to continue developing the Roadmap and to devise an approach for filling in missing data. The most important objective was for Cadmus to create a tool that allows the LMT team to separate the

applications and lighting technologies that possess a significant savings opportunity from those that do not. This tool would also need to provide a comprehensive overview of the lighting technology landscape by market sector, built on the foundation of consumers' current usage of technologies across various markets and applications.

With input from the IOUs and other stakeholders, Cadmus renamed the Roadmap the Lighting Solutions Workbook (hereafter referred to as "the workbook") to avoid confusion with the earlier version (the Roadmap), as well as to avoid misrepresenting the tool as a technology roadmap that documents actions and solutions required to meet specific goals.

Our Approach

Cadmus developed the workbook in two phases. First, we optimized the structure by organizing the way information was presented across market sectors and technologies. Then we determined the appropriate types of information for inclusion in the workbook based on our understanding of the intended use and the level of detail available from relevant data sources. We based this on a two-part assessment of needs and available data:

- We interviewed key stakeholders to gain insight into the features, level of detail, types of information, and reporting capabilities the stakeholders were hoping the final workbook would encompass.
- We conducted a literature review to determine the data available to populate the workbook. We then organized the workbook based on findings from this review.

In the second phase of this project, we populated the structural framework developed in the first phase. Because the workbook is a living document that can continually be modified and updated, Cadmus also provided the LMT program staff with a research plan for filling in any missing data that Cadmus was unable to source from the literature or through consulting lighting experts involved in the study, and suggested opportunities for updates through future research.

Organization of This Report

The following section describes our research and contains the results from the needs assessment.

In the next section of the report, Cadmus describes the structure of the revised workbook. This includes an explanation of each of the worksheets within the workbook, as well as a detailed discussion of the main worksheet, "Market Solutions." The Market Solutions worksheet contains market data and the information we used to identify potential savings. The worksheet consists of framework columns, which outline the structure and organization of lighting technologies, and data columns, which contain information for assessing lighting characteristics germane to a particular application or technology. In this section of the report, we also identify the data sources we used and discuss our data validation process.

Cadmus made every effort to thoroughly populate the workbook with up-to-date, California-specific data. Nonetheless, some of the data currently in the workbook could be simplified further, and some of the data could be updated with more current or with California-specific values. In addition, data for some market sectors are missing.

The final section of this report presents a research plan for filling in missing data and suggests opportunities for updating, localizing, and consolidating data sources through future research.

Two appendixes are included: a bibliography of the sources used to populate the workbook and the guide used to conduct expert interviews.

Background, Interviews, and Literature Review

Background

The creation of the original Roadmap[1] was inspired by BC Hydro's *Lighting Application Matrix*, which LMT team members learned of at a West Coast Utility Lighting Team Meeting in 2010. At the time of its West Coast Utility Lighting Team Meeting presentation, the BC Hydro team was on its 11th version of the Matrix. BC Hydro's Matrix is an Excel workbook focusing primarily on the commercial sector, and BC Hydro was already using their tool to identify which sectors had the greatest savings opportunity, develop a focused action plan, and communicate their plans. At the measure level, it contains information about lighting technology saturation and price; at the subsector and end use levels, it contains information about baseline consumption and savings potential (over a five-year timeframe); and at the market level, the Matrix contains information about pertinent lighting regulations and codes.

The LMT team recognized the potential of a BC Hydro-type Matrix for California and created the Lighting Technology Roadmap as the first iteration of this effort. While the Roadmap contained much of the basic data the LMT team had hoped to capture, the team understood that several improvements were necessary to make the tool more useful. The IOUs hired Cadmus to refine the tool by adjusting its structure to provide an appropriate level of granularity and populate the tool with current, California-specific information.

Interviews

Before restructuring or populating the Roadmap, Cadmus conducted a two-part needs assessment: interviews with lighting experts familiar with the Roadmap, and a literature review.

As shown in Table 1, Cadmus conducted interviews with representatives from Southern California Edison (SCE), Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), Pacific Northwest National Laboratory (PNNL), BC Hydro, and the California Lighting Technology Center (CLTC).

[1] In this report, we refer to the different versions of the planning tool by different names. The Roadmap is the version developed by the LMT team; the Matrix is the version developed by BC Hydro; and the workbook is the version developed by Cadmus.

Table 1. Lighting Experts Interviewed

Role	Organization	Purpose of Interview	Interview Date
LMT Program Manager	SCE	Roadmap Design and History	July 7, 2011
LMT Program Manager	PG&E	Needs Assessment	July 8, 2011
Senior Research Engineer	PNNL	Roadmap Design and Data Population	July 21, 2011 and August 22, 2011
Technology Innovation Manager/Roadmap Designer	BC Hydro	Matrix Design and Data Population	July 22, 2011
Co-Director	CLTC	Needs Assessment/Data Population	July 22, 2011
Program Administrator	PG&E	Needs Assessment/Data Population	Aug 23, 2011
Energy Programs Marketing	SDG&E	Needs Assessment/Data Population	September 1, 2012
Program Manager	SCE	Needs Assessment/Data Population	August 22, 2011

Through the interviews we sought to answer a fundamental question: "Is the Roadmap structured correctly?" The first series of interviews focused on these primary end users of the workbook:

- The LMT Program Managers at SCE and PG&E, who had designed and guided the Roadmap's development;
- IOU program managers consulted CLTC experts during development of the Roadmap;
- The BC Hydro Manager designed the original BC Hydro Matrix
- PNNL is a respected industry expert in lighting technology evaluation and application and has been involved in developing lighting energy codes.

Interview questions addressed the Roadmap's history, purpose, likely usage, and prioritization of data.

Through these conversations we also identified individuals for additional interviews such as program managers and other Roadmap users. In the second series of interviews, we asked for suggestions about the workbook's structure and about the most relevant data to populate it, so that we could optimize the workbook's capabilities and usefulness.

The interviews provided insights regarding the Roadmap's intended uses, particularly how the tool will be used in the statewide LMT Pipeline planning process, and how it should be used to identify market opportunities and technologies with the greatest savings potential. Through the interviews we clarified that the Roadmap is not perceived to be or used as a tracking tool, but rather as a planning document to point users in the right direction. Interviewees expect some variability in the data used to populate the tool; they consider order of magnitude level of accuracy acceptable. The interviewees suggested using expert consensus to generate assumptions for populating missing data, both where data have not been collected or are where they proprietary.

Interviewees' Recommendations for Improvements

The industry experts we interviewed offered many recommendations for improving and redesigning the Roadmap. Below are the most commonly cited recommendations that we received.

Recommendations to Improve the Roadmap

The industry experts we interviewed offered many recommendations for improving the Roadmap. Below are the most commonly cited recommendations and the actions we took in response to those recommendations.

- Relabel the tool: "Roadmap" seems like a misnomer since it implies something other than an Excel workbook.

  Action taken: Cadmus and the LMT team renamed the Roadmap the Lighting Solutions Workbook.

- Organize data by market segment rather than by technology, since efficiency programs are usually based on strategies addressing specific market segments.

- Provide separate technical savings potentials for lamps and controls. While not all respondents agreed with this recommendation, those who did were adamant about this change; those who did not were largely indifferent. All respondents agreed that controls represent a large portion of the potential savings.

- Exclude measures or characteristics that cannot be easily populated with publicly-available data. Industry experts noted that certain types of data (especially very granular data) are generally proprietary and thus likely to be unavailable.

  Action taken: Cadmus recommended the "Current Market Saturation of Emerging Technology" and "Market Size" columns be removed.

- Refocus the technical savings potential from long-term savings to annual savings potential (applicable for the next five years), since the workbook is intended to be updated regularly and program managers need to be able to estimate short-term savings.

  Action taken: the workbook now reflects annual savings potential.

- Structure the workbook so technologies with the greatest savings potential can be identified quickly. Previously, the workbook lacked a summary sheet, so users had to sort through an extensive amount of data.

  Action taken: The workbook now includes a summary worksheet that can be programmed to show potential savings by sector. The summary worksheet can also be updated to show savings by other categories.

- Replace the Roadmap's "Influence Level" column with columns for specific Market Barriers. The new columns would allow users to select barriers such as first cost, availability, performance, reliability, technical feasibility, and consumer awareness, thus enabling filtering by barriers for which the programs can take action.

- Adjust the level of granularity by appropriately reducing or increasing the number of market sectors or technologies covered in the workbook. Where less granularity is needed, aggregate rows by sector and technology to simplify the workbook.

- Use an expert consensus process to populate cells where the data cannot be obtained readily (such as market barriers).

Literature Review

Cadmus began our literature review by soliciting advice from the IOUs and CPUC Energy Division consultants on recommended data sources. We also searched for and obtained relevant reports from California Measurement Advisory Council (CALMAC), the Emerging Technologies Coordinating Council (ETCC), the CPUC, the U.S. Department of Energy (DOE), PNNL, and our own internal library. We compiled these materials into a bibliography, disseminated the bibliography to SCE and PG&E staff, LMT Program Managers, and a PNNL lighting expert, and requested they review it for completeness. The lighting experts provided us with additional recommendations which we appended to our literature review resources.

In addition to these data sources, we reviewed the BC Hydro Matrix and learned that its data were derived from the BC Hydro Conservation Potential Review 2007 (CPR2007), and the energy savings it includes were derived from applying engineering estimates to the lighting baseline consumption in the CPR2007.[2]

Cadmus reviewed all of these secondary reports and assessed the value of each in supplying data that could help us populate the workbook. We included those sources deemed "somewhat valuable" or "highly valuable" in a more detailed review. Table 2 presents the key categories we thought we were likely to include in the workbook, and the "somewhat valuable" and "highly valuable" data sources from which relevant information would come (Table 3 shows the name of the studies referenced in Table 2). Once the workbook's layout was finalized, this table was helpful in guiding us to the appropriate reports for each data component.

[2] Marbek, Resource Consultants Ltd. "BC Hydro 2007 Conservation Potential Review: Commercial Sector in British Columbia." 2007.

Table 2. Secondary Research Matrix

Category	Study*										
	1	2	3	4	5	6	7	8	9	10	11
Lamp											
Compact fluorescent lamp	x						x	x	x	x	
Halogen	x							x			
High intensity discharge			x				x				
Incandescent			x					x			
Light emitting diode	x	x	x	x	x	x		x		x	x
Linear fluorescent			x								
Organic light emitting diode			x		x						
Plasma							x				
Control											
Dimmer	x						x	x			
Occupancy controls	x		x					x			
Daylight controls							x				
Time clock/scheduling							x	x			
Market Data											
Energy consumption of baseline technology	x		x								x
Peak demand of baseline technology	x										
Emerging technology savings potential over baseline technology	x										
Current technology adoption rate in market								x	x	x	
Market barrier	x	x	x		x	x				x	
Scalability/retailer stocking	x		x				x	x			
Codes				x	x	x					
Cost								x			
Region											
CA	x	x				x		x	x		
USA			x	x	x		x	x		x	x
Sectors											
Residential	x		x		x	x		x			
Commercial	x	x	x		x	x	x	x			
Industrial	x		x		x						
Agricultural	x					x					
Outdoor stationary			x		x	x					
Data Age											
1-5 years	x	x			x	x	x	x	x		x
5-10 years	x		x	x						x	

**The table includes only studies assessed to be “somewhat valuable” or “highly valuable.”

Table 3. Secondary Research Studies Referenced in Table 2

Study Number	Name of Study
1	California Lighting Technology Center. "2010 Lighting Technology Overviews and Best-Practice Solutions." 2010.
2	Emerging Technology Associates, Inc. "LED Troffer and Downlight Interior General Illumination Lighting Assessment Final Report." March 19, 2010.
3	Navigant Consulting, Inc. "U.S. Lighting Market Characterization. Volume II: Energy Efficient Lighting Technology Options." September 30, 2005.
4	D&R International, Ltd. "Product Snapshot: LED Replacement Lamps." May 2011.
5	Navigant Consulting, Inc. "Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030." February, 2010.
6	The California Public Utilities Commission. "Statewide Lighting Market Transformation Program Report." June 2011.
7	Pacific Northwest National Laboratory. "Technology Prioritization Scoping Study: Advanced Lighting." February 2010.
8	KEMA, Inc. "Advanced Lighting Baseline Study. Phases 1 and 2 – Draft." June 22, 2011.
9	KEMA, Inc. "Residential Lighting Metering Study. Preliminary Results Presentation." January 29, 2009.
10	Pacific Northwest National Laboratory. "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market." June 2006.
11	Navigant Consulting, Inc. "Energy Savings Estimates for Light Emitting Diodes in Niche Lighting Applications." January, 2011.

As we categorized information from the secondary reports, we discovered many data gaps. For example, although multiple technologies were discussed in a single report, the level of detail provided in that report about each technology often differed. The level of detail also varied tremendously across reports: while one provided the savings potential of specific types of LEDs over the baseline technology, another report presented the savings potential of OLEDs only in broad terms over a five- to 10-year timeframe.

We also found obtaining comparable data across multiple sectors and technologies to be challenging. For example, the Commercial End Use Survey contained good information on lighting baseline usage for the nonresidential sector, but since it did not contain any residential information, we relied upon a California potential study for analogous residential lighting usage data. Hence, the workbook is a "patchwork" of data from numerous sources.

Structure and Population of the Workbook

In this section we discuss the final structure of the workbook and its intended functionality. We also discuss the data sources we used to populate the workbook thus far.

Workbook Structure

Cadmus presented several iterations of the workbook to the project sponsors for input before the final, market-oriented framework was established. The resulting workbook's structure is flexible, allowing for expansion or aggregation, as needed, based on data availability and user preferences. In the remainder of this section, we discuss each of the rows and columns in the workbook and their respective purposes.

In addition to the three tabs (Cover Sheet, Market Solutions, and Summary Sheet) that are visible upon opening the Excel workbook, the workbook has several hidden tabs where data are stored and calculations are performed. These hidden tabs keep the overall appearance of the workbook uncluttered while allowing space for entering information from various sources.

The Cover Sheet (Figure 2) shows the workbook's title, lists the tool developer and clients, discusses the purpose of the tool, and provides the table of contents with links to each worksheet (both hidden and unhidden).

The Market Solutions worksheet contains the workbook's primary data and functionality, and is linked to data in the hidden support sheets.

The Technology Summary sheet pulls data from the Market Solutions sheet and can be programmed to provide summaries by technology and market sector. The Summary worksheet currently contains an overview of baseline lighting consumption across sectors. The Summary worksheet also includes placeholder tables and graphs to demonstrate how the user can compare technologies with one another across all market segments (this functionality was requested by several interviewees). Additionally, as requested by other interviewees, we designed the Summary sheet to enable users to aggregate the data to fit their own programmatic needs.

Specifics of the Planning Workbook

The columns in the Market Solutions worksheet—the main worksheet—contain either framework data or market data.

- Framework columns determine the worksheet's structure and dictate the level of data aggregation. These columns are interspersed throughout the workbook's columns because the level of aggregation varies, becoming finer as the user scrolls towards the right side of the worksheet. Framework columns, highlighted in Figure 3, are: A, B, C, G, H, J, and K.
- Market data columns (D, E, F, I, and L through V) contain information for assessing lighting characteristics germane to a particular application or technology. (These are discussed in more depth in the next section.) The data columns are interspersed throughout the framework columns because the level of aggregation varies among the data columns.

Figure 2. Screenshot of Cover Sheet and Exposed Tabs (Market Solutions and Summary Sheet)

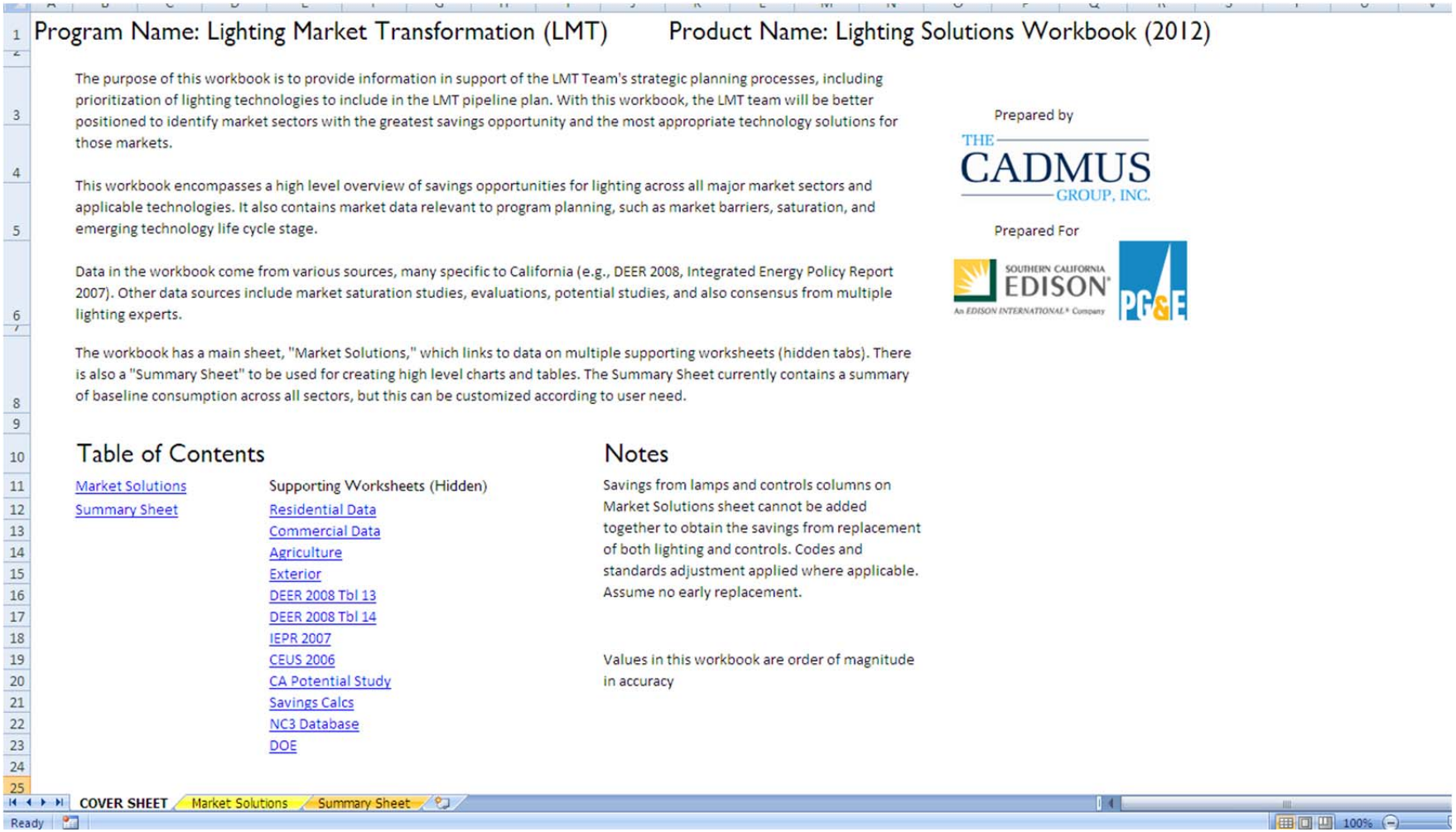


Figure 3. Excerpt from Workbook Showing Framework Columns

A	B	C	D	E	F	G	H	I	J	K
Sector	Sub-Sector	Application	Avg Daily HOU	Active During Peak?	Baseline Use	Current Lighting Practices		Percent Incidence of Current	Replacement Lighting Practice	
					(GWh/	Lighting Produ	Controls		Lighting Product	Controls
Residentia	All Residential	Interior	2	Yes	14,230	Incandescent MSB	Manual	62%	CFL MSB	Wall Switch Occupancy Sensor
									LED MSB	Wall Switch Occupancy Sensor
						CFL MSB	Manual	8%	LED MSB	Wall Switch Occupancy Sensor
						Halogen MSB	Manual	3%	CFL MSB	Wall Switch Occupancy Sensor
									LED MSB	Wall Switch Occupancy Sensor
						Linear Fluorescent	Manual	10%	High Efficiency Linear Fluorescent T-8	Wall Switch Occupancy Sensor
									LED Panel Lighting	Wall Switch Occupancy Sensor
						Halogen Pin Base	Manual	6%	LED Pin Base	Manual
						LED MSB	Manual	0%	LED MSB	Manual
						Incandescent SSB	Manual	8%	LED SSB	Manual
									Cold Cathode or CFL SSB	Manual

.

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 (such as DOE studies and the Northwest Power and Conservation Council's *Sixth Power Plan*).[3] 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 specifies the subsectors, such as small commercial, agriculture, hospitals, university/college, etc. Each subsector is broken down into different lighting applications (general lighting, high bay lighting, covered parking, etc.) so that lighting practices and usage can be characterized at this level

Framework Column A

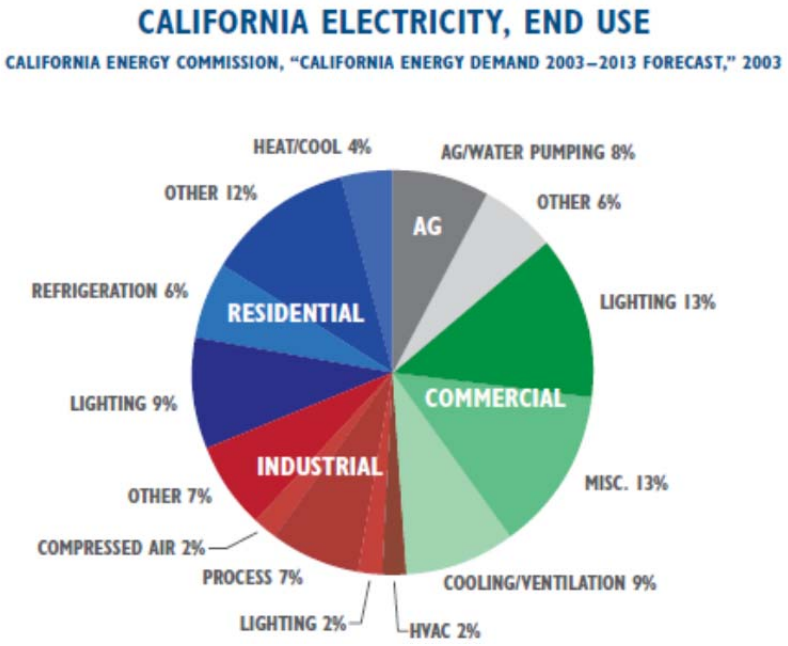
Column A categorizes the market at the sector level: residential, nonresidential interior, and nonresidential exterior. This categorization follows the general sector level division from the original Roadmap. It is also consistent with the end uses listed in the electric usage table in the *California Commercial End Use Survey* (CEUS, Table E-2),[4] which include interior and exterior lighting for a variety of commercial building types.

We combined the agricultural, industrial, and commercial markets into a single nonresidential sector for simplicity. This sector is driven by lighting use in commercial buildings: 13% of California's electricity is consumed by commercial buildings, whereas lighting use in the agricultural and industrial sectors is relatively small (Figure 4). In summary, Cadmus took efforts to ensure that all traditional sectors are represented in the Workbook without introducing unnecessary complexity.

[3] Northwest Power and Conservation Council. "Sixth Northwest Conservation and Electric Power Plan." February 2010.

[4] Itron. "California Commercial End-Use Survey." March 2006.

Figure 4. California Energy Demand 2003-2013[5]



Framework Columns B and C

Column B further divides the main sectors into subsectors (based on interviewee comments[6] and subsectors found in the CEUS). Column C divides those sectors into primary applications. For nonresidential interior lighting, the primary applications are determined by space type (e.g., retail area, food preparation, and restrooms). The use of nonresidential interior space types enables us to capture the occupancy characteristics that drive the data in columns D (hours of use), E (on peak), and F (baseline usage).

The original Roadmap and the BC Hydro Matrix (and some interviewees) supported this level of resolution among nonresidential interior spaces, as opportunities for energy savings vary based upon how these spaces are used.

About the Subsectors and Applications

We describe the subsectors and applications together, since the primary applications are dependent on the subsector.

- **Residential applications** are divided into interior and exterior lighting. This division is based on advice from Cadmus' senior engineering staff and aligns with the many reports we reviewed that support exterior versus interior lighting data granularity. We considered the possibility of separating low-income as a subsector (as suggested by one of the interviewees). However, we determined that sufficient data were unlikely to be available to support this level of disaggregation. As for multifamily, we classified that building

[5] California Energy Commission. "California Energy Demand 2003-2013 Forecast." August 2003.

[6] Multiple interviewees advised us to consider programmatic issues and decision making processes particular to certain subsectors, such as those specific to small commercial, low-income, or K-12.

type as nonresidential and put in the same category as other residences that are not single family housing, mostly because of the decision-making role played by the property owner and because of the presence of common areas.

- For **nonresidential interior lighting**, we begin with the "common to all subsectors" subsector, a best practice from BC Hydro's Matrix. This categorization allows users to capture applications specific to space types that are prevalent in most nonresidential buildings, but that may not pass the 80/20 rule.[7] (The 80/20 rule is used to determine whether a space type or application was significant enough to include in the worksheet for a particular subsector).

  Because multiple interviewees mentioned corridors as an often overlooked, but significant, area for lighting savings, we included the following applications: Exit Signs, Lobbies/Corridors, Stairwells. These applications were also identified in BC Hydro's Matrix.

- For the remaining **nonresidential interior subsectors**, we loosely applied the 80/20 rule to the National Commercial Construction Characteristics (PC^3) data set[8, 9] to identify the top one or two space types for each subsector. We excluded areas that were either common to all or were exterior spaces, and we aggregated spaces that had similar lighting characteristics. We then determined whether the space type was sufficient to define the lighting application or if more specificity was required (e.g., retail applications are either low/medium bay or high bay). The remaining nonresidential interior subsectors include: Small Commercial, Large/Medium Office, Large Retail/Warehouse/Manufacturing, Agricultural, Grocery Store, Hotel/Multifamily/Assisted Living, Hospitals, Restaurants, University, K-12, and Other. For each of these subsectors, we list the most prevalent applications relevant to that subsector (e.g. restaurants have kitchen lighting, menu boards, and dining room lighting).

  Our PNNL contact advised that the breakdown of space types for a subsector is generally universal across North America, so the use of national data is not expected to introduce significant error. For example, an office building in the Pacific Northwest should not be substantially different from one in California in terms of the space types present.

- **Nonresidential exterior lighting** is divided into area and roadway lighting. The exterior lighting subsectors and applications were driven by information from the original Roadmap, BC Hydro Matrix, and the data aggregated in the *Sixth Power Plan*.[10]

  We reorganized the subsectors in the original Roadmap based on areas that primarily have flowing traffic or pedestrian activity.

[7] Interviewees from the first round of research asked us to determine the appropriate use of the 80/20 rule to simplify the workbook. In this case, 20% of space types (e.g., dining area, lobby, office) in a building account for 80% of the floor area.

[8] The data set is used in the following paper: PNNL et al. "National Commercial Construction Characteristics and Compliance with Building Energy Codes: 1999-2007." 2008.

[9] PC^3 is based on 340 buildings in the bid process from 2001 to 2007 across the nation.

[10] NPCC, 2010.

- Area lighting includes parking (outdoor and covered), building perimeter lighting, and public areas such as parks.
- Roadway lighting includes street lights, traffic signals, and signs and billboards.

Framework Columns G, H, J, and K

None of the interviewees expressed great interest in independent information about ballasts so, to simplify the worksheet, we removed the columns for ballast/driver technology that were in the original Roadmap. For savings purposes, we assume that a high-efficiency ballast would be installed with the new lamp where applicable.

For columns G and H (Current Lighting Practices) and columns J and K (Replacement Lighting Practice Lamps), we started with information from both the original Roadmap and the BC Hydro Matrix. For information about what is currently installed (columns G and H), we used various reports, including data from a Residential Lighting Metering Study by KEMA,[11] the *Northwest Commercial Building Stock Assessment* (CBSA),[12] and the *Sixth Power Plan*. The replacement lighting practice (columns J and K) was derived from recommendations provided by Cadmus and 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. This section defines the data columns, explains their importance, and identifies the data sources we used to populate those columns.

Market Data Columns D, E, F, and I

Column D. Average Daily Hours of Use (HOU)

The data in this column is applicable to the specific sectors and subsectors shown. (One interviewee suggested it would be helpful to see this information displayed.)

The value in column D is an average. For example, the average daily HOU for a residential interior space is approximately two hours: although kitchen lights may be on for three or more hours per day, the lights in the bedroom, closet, and hallway are typically on for about one hour per day. All HOU data are a direct reflection of consumer's average usage habits.

Note that we built data validation checks into several columns in the worksheet: in column D, only values from greater than zero to 24 or less can be entered.

Why This Information Matters

Column D is important because it provides information about usage, which impacts the energy saving potential for lamps and controls. Although a technology could be much more efficient

[11] KEMA. "Residential Lighting Metering Study." Unpublished lighting inventory database.
[12] The Cadmus Group, Inc. "Northwest Commercial Building Stock Assessment." December 21, 2009.

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.

Data Sources

Column D is populated primarily by data from the *Sixth Power Plan,* and *DEER.*[13] However, where empirical data were not readily available, the values in column D are based on Cadmus' internal estimates, While California-specific data are ideal, we believe data from other regions in North America provide a useful first-pass substitute.

Column E. Active During Peak?

In this column, the user specifies whether an application is active during California peak demand periods (mid-day Monday through Friday). For simplicity and for data validation purposes, we have built a yes/no drop-down list into the spreadsheet for this characteristic. (In the future, this column could be upgraded from a simple yes/no to actual demand values in GW.)

Why This Information Matters

Identifying measures/applications that are in operation during the peak period is essential to the IOUs' general efforts to reduce peak usage. Several interviewees expressed interest specifically in the energy savings potential of end-user behavior changes in response to dynamic and peak pricing.

Data Sources

The data in this column were populated by Cadmus staff's understanding of whether an application was expected to be active during peak demand periods. For example, we assume that hospitals will have their lights on during the peak demand periods, but that street lights will not turn on until dusk, which is typically after demand has peaked.

Column F. Baseline Use (GWh/yr)

The values in the column indicate how much energy is currently used for a particular lighting application. This tells us about the current market size. In this column, current baseline energy consumption is displayed in GWh per year.

Why This Information Matters

The baseline consumption is directly proportional to the savings potential, hence it is important to understand the lighting end-use consumption by application and market sector.

Data Sources

Data used to populate this column must be California-specific. Sources used include the CEUS (Table E-2 of the CEUS report), DEER, the 2007 Integrated Energy Policy Report from the CEC, and 2006 California potential study.

[13] Database for Energy Efficiency Resources, CPUC and CEC.

Column I: Percent Incidence of Current Practice

This column shows the current saturation of each technology in the specified application. For example, Figure 5 shows that incandescent bulbs represent 62% of the interior residential lighting end-use consumption. The values in the Percent Incidence 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 at 100%). The data that populate this column show the distribution of technologies used in a particular application based on consumers' current usage behavior.

Figure 5. Saturation of Residential Interior Lighting

C	D	E	F	G	H	I
Application	Avg Daily HOU	Active During Peak?	Baseline Use	Current Lighting Practices		Percent Incidence of Current
			(GWh/	Lighting Produ	Controls	
Interior	2	Yes	14,230	Incandescent MSB	Manual	62%
				CFL MSB	Manual	8%
				Halogen MSB	Manual	3%
				Linear Fluorescent	Manual	10%

Why This Information Matters

This characteristic indicates the relative contribution of each lighting practice to the application's overall lighting consumption.

Data Sources

Column I is populated based on multiple data sources including

- KEMA lighting study
- DEER 2008
- Sixth Northwest Conservation and Electric Power Plan
- Northwest Commercial Building Stock Assessment
- U.S. Lighting Market Characterization study
- Solid-State Lighting Research and Development study
- Data from an LED Traffic Signal Survey.

These data sources are described in more detail at the end of this section. Hard-coded cells were populated based on BC Hydro's disaggregation estimates. The values in this column should be estimated California-specific data when they become available.

Characteristic Columns L, M, N, O, P, and Q

Technical Savings Potential

Columns L and M contain the Technical Savings Potential (GWh/yr) for lamps and controls. Column L contains savings for replacements of the lamp/ballast only, while column M contains savings for controls only. Note that actual savings from replacing both lamps/ballasts and controls will be less than the sum of the savings from replacing each individual component separately. We adjusted the savings to account for applicable codes and standards where they were known. To err on the conservative side, we assume in such cases that the baseline is determined by the relevant code or standard and that no early replacement takes place.

Why This Information Matters

These columns show how much energy can be saved—in aggregate across the IOU service areas[14]—per year for the replacement lamp or control technology over the baseline lamp or control technology.

Data Sources

The Technical Savings Potential column is populated by multiplying the following for a specific technology.

$$Technical\ Savings\ Potential = Baseline\ Use * Percent\ Incidence\ of\ Current\ Practice * Applicability * Savings\ Percen$$

The applicability and the savings percent are contained in a hidden worksheet called 'Savings Calculations.' The applicability, 75%, is applied to the technical savings potential for all replacement solutions because we assume some savings may not be attainable for the new technology. It is prudent to discount the savings potential for various reasons such as it might not be physically possible to retrofit the replacement technology in all locations.[15]

For the savings percent, Cadmus consulted these sources of data (all references are also in workbook) to determine the savings percent:

- U.S. Lighting Market Characterization Report for the DOE
- Various manufacturer and program spec sheets (e.g., Mass Save Lighting Table, GE Lighting)
- Studies from the CLTC
- ENERGY STAR
- EPRI

[14] Baseline use data come from sources which are primarily focused on the IOUs (the CEUS also includes SMUD, which has a smaller consumption than any of the IOUs).

[15] Note: BC Hydro used a similar approach for savings.

- Cadmus Lighting Expert Judgment

Note that a few of the cells in this column are either to be determined (TBD) or contain a calculation error. The cells with the calculation error are functional but display an error because the percent incidence of current practice or another calculation input is still to be determined.

Replacement Lighting Product Life Cycle Stage

Column N shows the product life cycle stage to which the replacement lighting technology belongs: introduction, growth, maturity, or decline.

Why This Information Matters

This column helps the user understand a replacement technology's stage in the product development cycle. If a product is in decline, program staff may decide the technology should no longer be pursued. However, a technology that is in its introduction phase alerts program managers to the fact that opportunity exists to further develop the market for that technology.

Data Sources

This column consists of a drop-down list in which the user selects one of the four phases: introduction, growth, maturity, or decline. The column was populated by the LMT program staff in the original Roadmap.

Market Barriers for Replacement Practice

The Market Barriers columns are categorized for lamps (O and P) and for controls (Q and R).[16] These columns are data-validated columns with pull-down menus. Each practice (lamps and controls) has a column for primary market barrier, and a second column for the secondary market barrier.

Why This Information Matters

Market barriers reveal the obstacles that must be overcome before a technology becomes widely adopted in a given application. Common barriers identified by Cadmus and the LMT team include cost (incremental cost over the baseline technology), commercial availability, technology performance, technology reliability, customer awareness, and technical feasibility (e.g., can it fit the socket?).

This column was not a part of the original Roadmap; we included it because interviewee's information about barriers was important to them.

Data Sources

This characteristic is populated based on lighting expert consensus.

Codes and Standards

Column T, Codes and Standards, indicates regulations that have an impact on the savings estimates. These include EPACT 2005 and CA Title 20 regulations that:

[16] Column S is a general column to further comment on market barriers for the replacement practice.

- Eliminate T-12 lights
- Require CA to adopt EISA requirements earlier than the rest of the U.S.
- Effectively require LED traffic lights

While other codes and standards exist, we limit this column to general regulations that affect the savings calculation percentage. For example, savings from retrofitting incandescent traffic signals with LED signals has been zeroed out as a result of California law. However, hospitals have complex regulations for lighting that are not reflected in this workbook.

Why This Information Matters

Codes and standards, which were a part of the original Roadmap, are important because new and existing regulations have an effect on a technology's market application and savings potential. In addition, this workbook can provide useful market information to the code and standard development process.

Data Sources

We used the Appliance Standards Awareness Project Website, the 2010 Appliance Efficiency Regulations report by the California Energy Commission, and internal expert knowledge of codes and standards to assess the extent to which lighting codes and standards would affect savings calculations for the applicable technologies.

Program Action and LMT Ranking

The final two columns in the workbook (U and V) are called Program Action and LMT Ranking. These columns are for internal, LMT team use only. After reviewing and discussing the workbook in its entirety, the team will use these two columns to assess the actions they would like to take regarding particular technologies and the prioritization of those actions.

Data Sources Used

As Cadmus began to populate the workbook, we first identified comprehensive studies that covered multiple technologies or subsectors. After we exhausted these sources, we turned to studies that were narrower in scope. At the end of this process, data were still missing for a few data categories and cells. Cadmus provides recommendations for addressing these missing data and opportunities for updating and strengthening data sources in the Research Plan section of this report.

The following are the key sources Cadmus drew on to populate the workbook (it is not a comprehensive list of all of the data sources we reviewed during the course of designing and populating the workbook).

DEER 2008

The 2008 Database for Energy Efficient Resources (DEER) contains information on selected energy-efficient technologies and measures. The DEER provides estimates of the energy-savings potential for these technologies in residential and nonresidential applications.

We used values from the DEER database to populate the following columns: Average Daily HOU, Baseline Use (GWh/yr), Percent Incidence of Current Practice

California Energy Efficiency Potential Study

This 2006 potential study summarizes the findings of three studies to assess the gross potential for electricity and gas savings in existing residential and commercial buildings in California. Data from this study were used to populate the Baseline Use (GWh/yr) column in the workbook.

California Commercial End-Use Survey (CEUS)

The CEUS is a comprehensive study of commercial sector energy use, primarily designed to support California's energy demand forecasting activities. Almost 3,000 commercial facilities were surveyed to gain information on building systems data, building geometry, electricity and gas usage, thermal shell characteristics, equipment inventories, operating schedules, and other commercial building characteristics. The study was completed in March 2006.

Data from this study were used to populate the Baseline Use (GWh/yr) column in the workbook.

Sixth Power Plan

The Northwest Power and Conservation Council was formed by Washington, Oregon, Idaho, and Montana to give citizens a say in how growing electricity needs of the region would be provided. The purpose of the Council's power plan is to ensure an adequate, efficient, economical, and reliable power supply for the Pacific Northwest. The power plan develops a strategy for the region to meet its future electricity needs.

Data from the Sixth Power Plan are used to populate the Average Daily HOU and Percent Incidence of Current Practice columns in the workbook.

Residential Lighting Metering Study

This study was conducted by KEMA in 2008 and 2009. More than 1,200 homes were visited in which lighting inventory data were collected. Data included details such as number of sockets, bulb wattage, shape, location, and base type. Unpublished data from the study were used to populate the Percent Incidence of Current Practice column for the residential sector.

National Commercial Construction Characteristics (NC^3)

NC^3 is a database developed by Pacific Northwest National Laboratory (PNNL) that contains percentages of space types across various commercial buildings. Data from this study were used to help populate the Baseline Use (GWh/yr) column.

Appliance Standards Awareness Project (ASAP)

ASAP is a coalition of efficiency, consumer and environmental groups, utility companies, and state government agencies that seek to build support for new and updated standards at the national and state levels. The ASAP Website provides a list of legislation that affects different types of lighting products. We used data from this list to populate the Codes and Standards column.

Northwest Commercial Building Stock Assessment

The Commercial Building Stock Assessment was completed in 2003 and is a unique effort that characterized the physical and energy-use characteristics of commercial facilities in the Pacific Northwest by integrating and updating information from several previous regional data

collection efforts. The database is used as a resource for regional and energy planners and researchers. In 2009, the Northwest Energy Efficiency Alliance (NEEA) had the database updated. Data from this study is used to populate the column Percent Incidence of Current Practice.

U.S. Lighting Market Characterization

This study was a multiyear program to evaluate light sources in the United States and to identify opportunities for saving energy. The first phase of the program estimated the inventory of installed lighting technologies for 2001 and their associated energy consumption. This study was sponsored by the U.S. Department of Energy (DOE) and completed by Navigant Consulting. We used data from this study to populate the column Technical Savings Potential.

Solid-State Lighting Research and Development: Multiyear Program Plan

This report is a template for how the DOE plans to create a new, U.S.-led market for high efficiency, general illumination products through the advancement of semiconductor technologies, to save energy, reduce costs, and enhance the quality of the lighted environment. Data from this report are used to populate the column Technical Savings Potential.

Professional Review

Lighting experts at both Cadmus and PNNL reviewed the data in the workbook and provided recommendations for improvements as necessary. We also consulted the LMT program staffs to review the workbook and provide input on columns in need of data. The following columns were completed by Cadmus engineers and reviewed by a lighting expert at PNNL: Market Barriers for Replacement Practice.

Data Validation

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

(1) Lighting Baseline Consumption Comparison

Cadmus used data from the 2007 IEPR to determine if the lighting baseline consumption in the workbook was of 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 IOUs (Table 4).

Table 4. Electricity Consumption by IOU from 2007 IEPR

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

Next, when we sum the total lighting baseline consumption (column F) 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%. This result is very close to the proportion lighting constitutes of statewide end-use electricity consumption shown in Figure 4, which is 24%.

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

(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. Where multiple replacement options were possible (e.g., an incandescent can be replaced by an LED or CFL), we chose the CFL replacement to avoid double counting savings. Our calculation (Table 5) indicated 6,220 GWh/Year savings potential was possible in the residential sector. This value is very similar to a result obtained by KEMA.[17] KEMA presented an analysis in an IEPEC 2011 paper[18] 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.[19]

Table 5. Interior Residential Sector Savings Potential

Base	Replacement	Savings Potential (GWh/Yr)
Incandescent MSB	CFL MSB	4527
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

[17] Cadmus used KEMA's data set as part of our analysis, although our methodology differed.
[18] "Residential Lighting: Shedding Lighting on the Remaining Savings Potential in California" KEMA 2011 IEPEC
[19] Note: these values can be revisited and refined if necessary when Navigant's potential study concludes in 2012.

Research Plan for Completing and Improving the Workbook

The workbook resulting from this study 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 is intended to be regularly updated as better information becomes available. This research plan outlines the activities necessary to completely populate the workbook with the most up-to-date, relevant, and consolidated data sources. The workbook is currently populated with data from multiple sources. We recognize the workbook could be improved with fewer, more comprehensive data sources, or with data that are newer or specific to California. Additionally, some columns are still missing data.

Our plan for improving the workbook is described below by task. Recognizing that time and resources are limited, we list the recommendations in order of importance.

Recommended Tasks

Missing Data ("TBD" in the Workbook)

Cadmus recommends the first task be filling in missing workbook data. The areas with missing data are:

- Percent Incidence of Current Practice data for lighting in colleges and universities,
- The agricultural sector,
- Public areas,
- Lamp Technical Savings Potential column data, to populate the savings for signs and billboards.

We recommend using currently- or soon-to-be-available data sources the LMT team knows of, along with in-house expertise, to populate the missing cells as a low–cost, low-accuracy option. Alternatively, the LMT team could conduct a study with a sample of buildings to determine general saturation levels of different types of lighting in the applicable subsectors. For example, an engineer could audit several agricultural facilities (barns/factories?) and record the percentage of metal halide lights and linear fluorescent lamps. Or, an engineer could go to a nearby college or university and determine the saturation of current lighting practices.

Non-California Data

California-specific data is more crucial in some columns than in others. For instance, savings percent is not region-specific, nor is product lifecycle. However, codes and standards, baseline use, and Percent Incidence of Current Practice can be different from one geographic area to the next. Much of the Percent Incidence of Current Practice data currently in the workbook are from the DOE and Pacific Northwest. These data sources are not adjusted for conditions specific to California. Cadmus encourages the team to discuss these instances and the opportunities for drawing upon more California-specific data sources.

Old Data

The importance of extremely up-to-date data depends on the type of data under consideration. For instance, HOU is unlikely to change over a short period of time. However, Baseline Use or Percent Incidence of Current Practice for certain applications is continually changing and market barriers that were important five years ago may no longer be significant.

We used older (i.e., pre-2008) data that we recommend updating for traffic signals, as well as for baseline consumption data for all sectors and subsectors. Updated studies, such as updated versions of the CEUS, CA Potential study, or DEER, would be excellent sources for replacing the older data, especially if the scopes of these studies can be expanded to include all market sectors and to include a more comprehensive list of lighting applications.

Summary Sheet Functionality

Once all missing data are populated, Cadmus can populate the summary sheet according to user interest. We would conduct another round of interviews to guide our development of summary charts and figures.

Sales Data

During an interim project presentation, one stakeholder recommended Cadmus add a column to the workbook to track sales market share. The current workbook does not contain sales information because these data are usually difficult to obtain, and because none of the stakeholders interviewed during the first part of the project recommended including sales data.

A new column for sales market share can easily be added to the workbook. The challenge lies in obtaining data that covers all market sectors and technologies. A manufacturer organization (e.g., NEMA) may have this information. Alternatively, the information could be gleaned from interviews with manufacturers, or from the CPUC's forthcoming Lighting Sales Tracking studies of the residential and commercial sectors (unfortunately, a formal work plan for this CPUC study was not available within the timeframe of this report).

Codes and Standards Analysis

Both California and federal codes and standards are constantly evolving. Our review found some sources of codes and standards information to be out-of-date. Consequently, we recommend conducting a more thorough review of the status of both state and federal standards to identify the regulations that are scheduled to be implemented in the future. We also suggest developing a set of criteria that can be used in conjunction with the information in the workbook to identify the greatest areas of opportunity for upgrading existing standards.

Program Action and LMT Ranking (for LMT Team)

The last two columns in the workbook, Program Action and LMT Ranking, are reserved for the LMT to complete. Once the workbook has been thoroughly reviewed by the team and updated as much as possible, Cadmus recommends that the team rank the lighting technologies and determine the short-term and longer-term actions that are most advantageous to pursue.

Attributes of Data Sources

Table 6 summarizes the data sources that are currently populating the workbook and points of consideration that contribute to our recommended tasks. For instance, noting which data sources will be updated in the future is important for maintenance purposes.

Future Data Availability

Cadmus queried stakeholders about upcoming lighting studies that may provide valuable information for the workbook. Although the PNNL lighting expert was not aware of any upcoming DOE studies, our SCE and PG&E clients provided a few work orders for studies they are about to undertake for our review. Cadmus' review of the work orders (WO13 and WO 28) showed that the proposed scopes of these studies are limited to specific sectors and products (residential or LEDs). Cadmus is also aware of a California potential study that will be conducted within the next year by Navigant. After reviewing the draft report (Track 1 Draft) released in November 2011, Cadmus concluded that the report in its current form was not granular enough with respect to lighting to support the data needs of the workbook. In the future, the LMT team may consider leveraging existing studies by increasing their scopes to cover more market sectors, or additional technologies within a single market sector. Such expansions could yield comprehensive information that could feed into the workbook.

Estimated Hours to Complete Work

Missing Data

As the lowest cost, lowest accuracy option, some missing data could be filled in through in-house expertise. This could be completed through two conversations with LMT staff facilitated by Cadmus. Cadmus would report on the findings and incorporate them into the workbook. Because most of the cells in the workbook are already populated, completing this work is expected to take 20 hours.

Missing Percent Incidence of Current Practice data for lighting in colleges and universities, the agricultural sector, and public areas can also be populated through site visits, which would result in improved accuracy. Cadmus recommends conducting, at minimum, ten site visits at five hours each, per sector. This work would also involve additional hours for preparation, travel to various site locations, analysis of the data collected, and updating the workbook.

Non-California Data

The workbook currently includes a great deal of national, rather than California-specific, data. Replacing that data with California-specific information would be very expensive and time–consuming, as it would require data collection though site visits. However, it would be possible to piggyback on another study or have a facilitated conversation in which national data are reviewed and determinations are made about whether the data match expert opinion.

Table 6. Data Sources and Characteristics

Data Source	Data Contribution	Year Published	CA Data?	Future Updates?
National Lighting Inventory and Energy Consumption Estimate, Navigant	Avg. Daily HOU	2002	No	Unknown
Residential Lighting Metering Study Database, KEMA	Percent Incidence of Current Practice Technical Savings Potential	2008-2009	Yes	Probably
Database for Energy Efficiency Resources, CPUC and CEC	Avg. Daily HOU Baseline Use Percent Incidence of Current Practice	2008	Yes	Yes, in 2011
Long-Day Lighting in Dairy Barns, University of WI.	Avg. Daily HOU	2000	No	No
Sixth Northwest Conservation and Electric Power Plan, Northwest Power and Conservation Council	Avg. Daily HOU Percent Incidence of Current Practice	2010	No	Probably in 2015
California Energy Efficiency Potential Study, Itron, Inc.	Baseline Use	2006	Yes	Probably
National Commercial Construction Characteristics, PNNL	Baseline Use	1997-2007	No	Probably
California Commercial End-Use Survey, Itron, Inc.	Baseline Use	2006	Yes	Probably
Lighting Expert Consensus: The Cadmus Group and PNNL	Baseline Use Technical Savings Potential Life Cycle Stage Market Barriers	n/a	n/a	n/a
Northwest Commercial Building Stock Assessment, The Cadmus Group	Percent Incidence of Current Practice	2009	No	2012/2013
U.S. Lighting Market Characterization, Navigant Consulting, Inc.	Percent Incidence of Current Practice	2002	No	Continually updated
Solid-State Lighting Research and Development: Multi Year Program, DOE	Percent Incidence of Current Practice	2011	No	Probably
Appliance Standards Awareness Project, Website	Codes and Standards	Continually updated	Yes	Unknown
LED Traffic Signal Survey Results, CEC	Percent Incidence of Current Practice	2005	Yes	Probably

Old Data

Baseline consumption information in the workbook could be updated through information from new studies, once available. If data from newer studies were to become available, we estimate

that carefully reviewing the data (including understanding its underlying assumption) and updating the entire workbook would require 50 hours.[20]

Summary Sheet Functionality

For this task, Cadmus recommends first convening one or two client meetings, perhaps with several shorter follow-up phone calls, to discuss the desired summary sheet's functionality. During the discussions we would strive arrive at consensus on the data that will be pulled in, the formulas necessary to build the summary, and the "look and feel" of the summary information's presentation. We would then develop/program the Summary Sheet's functionality. This is anticipated to be a meticulous process that would require quality review by several technical advisors before presentation to the client. This work is estimated to take 60 hours to complete.

Sales Data

Sales data might be collected through several means. Although difficult to obtain, one possibility is to interview manufacturers and ask them to provide data. Another potential alternative could be to contract with a manufacturer's association, such as NEMA, to collect sales data from its members. Because these data are highly proprietary, we cannot give an estimate for this task.

Codes and Standards Analysis

To determine whether any additional codes and standards should be captured in the workbook, Cadmus recommends conducting a facilitated conversation on the topic with in-house codes and standards experts. Completing this work and applying it to the workbook would require approximately 50 hours. Subsequent to completion of this task, we recommend the process be repeated every two years.

[20] Note: this estimate could be affected by the amount of data that need to be reviewed, the quality of the data, and whether the data significantly deviate from current values in the workbook.

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Appendix B: Interview Guide

Introduction Talking Points

- We appreciate the time you are setting aside to contribute to this project. As you know, Cadmus was hired by SCE and PG&E to optimize the Roadmap and determine how to best populate the refined Roadmap.
- Your familiarity with the LMT Roadmap and your insights into the Roadmap's development and use is very important. We will ask you about how the Roadmap came to be, ideas to improve it, and how to best populate the Roadmap.
- This interview is expected to take one hour.

Warm Up Questions

1. As I understand it, you are a [FILL IN PERSON'S ROLE] for LMT. How did you get involved?
2. What are your responsibilities?

Roadmap History

3. What was the original impetus for the Roadmap's development?
4. Who designed it and what were their specific roles?
    - Did all of the Roadmap designers have the same vision and objectives for the Roadmap?
    - Can you provide their contact information (name, organization, phone #, e-mail address)? I will send you a follow up e-mail requesting this information.
5. What is your understanding of how the Roadmap will be used? (The link between market data in Roadmap and which market transformation activities would be pursued.)
6. How was the Roadmap's structure developed?
7. What reference documents and assumptions were used to develop it?
8. What were the challenges and trade offs in developing the Roadmap?
9. Who are the primary users? (Will ask for name, organization, role, and contact info in a follow-up e-mail.)

10. [Ask for any users who weren't already mentioned as Roadmap designers above.] Were these users involved in the creation of the Roadmap? If so, what were they mostly interested in?

Current Roadmap structure and contents

11. The Roadmap includes many combinations of measures and existing technologies, as well as ballasts and controls. Are energy-efficient lighting programs structured to take advantage of this level of granularity?

12. Do you see any advantages or disadvantages to breaking out the savings by measure (i.e., ballasts, controls, daylighting would count as measures)?

13. The Roadmap also has multiple market segments and applications. How do you see energy-efficiency programs making use of this level of granularity?

14. Now I'd like to review several of the Roadmap's columns with you and get your thoughts about how each will be used:

    - Influence level – how is this determined? Would it be useful to have a column for barriers? (e.g., cost, availability, size, components, etc)
    - Commercialization stage
    - Market adopters
    - Current saturation
    - Market size
    - Savings Potential

15. What data sources were used to populate the current version?

    - CA centric data or national market data?
    - Is your organization currently tracking the transformation of the lighting market? If so, how and with what metrics?

Roadmap challenges and future progression

16. What do you like most about the current Roadmap structure?

17. What are your biggest concerns with the current Roadmap structure?

18. Do you have any ideas about how the Roadmap could be simplified?

19. Are there any metrics or technologies that are not currently part of the Roadmap that you think should be added?

20. What criteria should be used to prioritize data population (e.g., by technology or by column)?

21. What criteria should be used to evaluate the quality of data in the Roadmap?

Wind Down

22. Is there anyone else you recommend we speak with to get additional perspectives on the Roadmap and further our understanding of its history, design, and use? [Note to interviewer: get name, organization, and contact info. Also, ask why respondent thinks this person's perspective would be helpful].

23. Are there specific documents you highly recommend we review as part of this process?

24. Should we have additional follow up questions, would you mind if we contacted you again?

Thank you for your time today. We look forward to working with you on this important project.