Quantifying Energy Savings from Market Effects: The Case of High Bay Lighting

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ABSTRACT

This paper presents the methods and results of a major study of the market effects of utility programs to promote energy-efficient indoor high bay lighting in commercial and industrial facilities. The study was sponsored by the California Public Utilities Commission and overseen by the California Institute for Energy and Environment. It focused on quantifying the market effects of the 2006-2008 programs operated by California's investor owned utilities. (KEMA 2010) Using data from vendor and end-user surveys in California and a four-state non-program area, as well as information from the evaluations of the 2006-2008 statewide California programs, the study was able to:

- Estimate the total sales of all high-bay lighting technologies in California during the evaluation period.
- Estimate the baseline shares of various high bay technologies, using the results of vendor surveys in the comparison area.
- Estimate the actual technology shares in California during the evaluation period.
- Estimate the energy savings associated with the higher share of energy-efficient technologies in California.
- Estimate the upper and lower bounds of the portion of those energy savings that could be attributed to the program.

The study found that energy saved through adoptions of efficient high bay lighting "outside the program" that could be attributed to effects of the program (that is, spillover) ranged from 22 to 40 percent of the net savings identified by the statewide evaluations, which did not take spillover into account.

Introduction

In its decision that set out the framework for the 2009-2011 ratepayer-funded energy efficiency programs, the California Public Utilities Commission advanced market transformation as a program strategy. (CPUC 2007) The decision referenced specific market transformation goals such as achieving "Long-lasting sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures" and by providing support for initiatives designed to achieve objectives after the three-year program planning and evaluation cycle had elapsed.

To support the effective adoption of market transformation program strategies, the CPUC commissioned a series of four studies to identify, test, and apply methods to quantify energy savings associated with market effects. Market effects are defined in the California Energy Efficiency Evaluation Protocols as "a change in the structure of a market or the behavior of participants in a market that is reflective of an increase in the adoption of energy-efficient products, services, or practices and is causally related to market interventions," with particular emphasis on quantification of spillover effects. (TecMarket Works 2006) The study summarized in this paper was one in that series.

The High Bay Lighting Market and Efficient Technologies

High bay lighting refers to a diverse group of technologies that are used to light spaces in commercial and industrial facilities with ceiling heights 15 feet and above. The most common types of high bay spaces include warehouses and other active storage areas, gymnasiums, industrial production and assembly areas, and big box retail. According to end-user surveys conducted for this project, high bay spaces are found in 31 percent of California commercial and industrial facilities and account for roughly 9 percent of total floor area in those facilities.

Commercial and industrial lighting differs from many of the end use technologies addressed by ratepayer funded programs in that there is no single product group or performance specification for system components that defines "high efficiency". Rather, lighting system efficiency is typically measured by lighting power density (LPD): the wattage of installed equipment per square foot.[1] High efficiency for lighting a given space can be achieved through many strategies, including fixture selection, fixture layout, use of daylighting, and controls.

Table 1 displays information on those characteristics for each of the most common high bay lighting technologies.

Table 1. Characteristics of Common High Bay Lighting Technologies

Technology	Expected Life (hours)	Efficacy (lm/W)	CRI (1 – 100)	Restrike Time	Lumen Maintenance*	Dimmability	Cost/ Fixture
Probe-Start Metal Halide (Baseline)	7,500 – 20,000	60 – 85	60-70	Up to 10 min	76%	Limited**	$164
High Pressure Sodium	20,000 - 24,000	75 – 130	27	>1 min	93%	Limited**	$135
Pulse-Start Metal Halide	20,000	90 – 110	65-90	Up to 10 min	78%	Limited**	$203
T8 Fluorescent	20,000 – 30,000	86 – 94	70-90	0	98%	Yes	$210
T5HO Fluorescent	20,000	90 – 104	75-98	0	88%	Yes	$283
Induction	100,000	70	80 – 88	0	95%	Yes	n/a

* % of initial light output available after 40% of useful life has elapsed.
** Dimming technologies are available but are difficult and costly to implement.

Energy efficiency in commercial lighting technology is characterized by "efficacy", defined as the light output of a typical lamp per Watt of power input as measured under laboratory conditions. The 2006-2009 California program designs defined probe start metal halide fixtures as the baseline technology and provided incentives for purchase of pulse start metal halide and high bay fluorescent

[1] Most state building codes contain provisions on maximum LPDs in new construction. California's Title 24 Building Codes and Standards also apply to renovation projects in which more than half of the existing lighting fixtures are replaced.

fixtures. The efficacy of pulse start metal halide is 30 to 50 percent higher than the efficacy of probe-start technologies. Fluorescent technologies provide a similar increase in efficacy.

As Table 1 shows, technologies differ strongly in terms of lumen maintenance, that is: the degree to which fixtures perform at their rated efficacy over time. Lighting manufacturers recommend specifying fixture layouts that reflect the "design efficacy" of the technologies used. Design efficacy is measured as lumens per watt after 40 percent of the lamp's effective useful life has elapsed. Not only do fluorescent technologies have higher initial efficacies than metal halide technologies, they maintain their output longer. For the metal halide ballast and lamp combinations, lighting output degrades by 22 percent, compared to 5 – 10 percent for T-8 and T-5 fluorescents.

Lighting designers, installers, and customers take a number of other product attributes into consideration when specifying high bay lighting. The principal attributes are:

- **Expected useful life.** High bay fixtures are often accessible only with lifts and other special equipment. Therefore long expected life is a key product value. The most common high intensity discharge (HID) technologies, such as metal halide and the fluorescent technologies, have useful lives in the range of 20,000 to 30,000 hours. Induction technologies have shown useful lives in the range of 100,000 hours, but their efficacy is low. Potential applications include installation in extremely hazardous and inaccessible areas.
- **Color rendition.** In many high bay applications, such as industrial shops and gymnasiums, color rendition is important for safe and effective use of the lighted space. Color rendition is measured by the Color Rendition Index, with the highest rating (100) associated with incandescent lamps.
- **Control-related attributes.** Energy use in a lighting installation is affected not only by the efficacy of the equipment installed, but by the occupants' ability to match time of use to their needs. The competing technologies differ in terms of restrike time and dimmability.
- **Cost.** The far right-hand column of Table 1 shows the installed costs of a typical 25 – 30 kilolumen fixture for each type of technology circa 2008. These cost estimates are based on data from the "2008 Database of Energy Efficiency Resources (DEER) Measure Cost Documentation", which we validated through comparisons with other industry sources and interviews with market actors. At that time, pulse start metal halide technologies commanded a 23 percent premium over the baseline probe start models. The cost difference between probe start metal halide and T-8 fluorescent technologies was similar. T-5 fixtures were nearly 75 percent more expensive than the baseline technology.

2006-2008 Program Activity

During the 2006-2008 program period, the three California investor-owned utilities (IOUs) operated 12 programs that offered incentives for efficient high bay lighting. Most of these incentives were issued through prescriptive rebate programs. Altogether, those programs provided incentives to 2,983 unique customer accounts. As Table 2 shows, these programs paid over $20 million in rebates to support the purchase of 197,621 fixtures. All of those were fluorescent fixtures, and 93.4 percent of them used T-5 technology. Program managers interviewed for the project reported that contractors took a strong role in promoting the program and generated most of the rebate applications for efficient high bay fixtures. This aspect of program operation is important for understanding the findings of the customer surveys undertaken for the study.

Table 2. Summary of 2006-2008 California Statewide Program Activity for High Bay Lighting

Technology	Fixtures Rebated	Percent of Fixtures	Incentives Paid	Percent of Incent.	Average Rebate/Unit
T-5 Technologies	184,601	93.4%	$18,912,836	92.9%	$ 102
T-8 Technologies	105	0.1%	$ 14,187	0.1%	$ 135
Unspecified Linear Fl.	12,915	6.5%	$ 1,423,995	7.0%	$ 110
Total	197,621	100%	$20,351,018	100%	$ 103

Methods

The specific objectives of the study were to:

- Understand and quantify the cumulative market effects of California's energy efficiency programs on the market for high bay lighting.
- Quantify the kWh and kW savings caused by those market effects, occurring in the years 2006-2008, with particular emphasis on non-participant spillover.
- Support the CPUC's strategic planning efforts by clarifying whether savings from market effects can be quantified with sufficient reliability to be treated as a resource and, potentially, afforded shareholder incentive payments.

Basic Approach and Flow of the Analysis

The study (KEMA 2010) encompassed a broad range of research and analysis, including documentation of the evolution of high bay lighting technology and characterization of the current structure and operation of the market for high bay lighting at the national and regional level. This paper focuses on the quantification of the market effects and related energy impacts of the California program and draws on findings from other elements of the study as needed.

The basic steps in the quantification of market effects and related energy savings were as follows.

1. **Estimate the total number and wattage of all high bay lighting fixtures purchased and installed in California during the program period.** The first component of this step was to estimate the number of high bay lighting (HBL) fixtures purchased in California during the program period and the total wattage associated with those fixtures. This was accomplished by combining the results of the following research efforts:
    - Survey of a representative random sample of commercial and industrial establishments to gather information on the current saturation of high bay lighting and purchases of new equipment during the study period.
    - Survey of a representative random sample of commercial lighting installation contractors to estimate the share of various HBL technologies installed during the study period.
    - Technical data on lighting requirements for various types of commercial space and effective lumen output and efficacy of different HBL technologies.
2. **Estimate the shares of the available HBL technologies purchased in a four-state comparison area.** This was accomplished by fielding a survey of a random sample of commercial lighting contractors in four states where no programs to promote efficient commercial lighting had been operated: Alabama, Mississippi, Georgia, and South Carolina.

The resulting technology mix was used to represent the baseline in California.

3. **Estimate the total baseline wattage of high bay lighting fixtures purchased and installed in California during the program period.** This was accomplished by substituting into Step 1 the technology shares in the comparison area estimated in Step 2.
4. **Estimate the difference in high bay lighting wattage installed between the baseline and actual cases.** This is simply the difference in estimates of total wattage installed generated by Step 3 and Step 1.
5. **Estimate the difference in energy use associated with the difference in technology shares between California and the comparison area.** We estimated energy reduction associated with higher shares of efficient technologies by multiplying the result of Step 3 by average hours of operation for high bay lighting fixtures as determined through end-use metering conducted for the evaluation of the 2006-2008 programs.
6. **Estimate energy savings associated with purchases of efficient HBL made "outside the program", that is: without incentives.** This was accomplished by subtracting the energy savings associated with the IOU programs, net of free ridership, from the results of Step 4. We estimated the "within" program savings using the results of the evaluations overseen by the CPUC of all 2006-2008 programs that promoted efficient high bay lighting. (Itron 2010)
7. **Estimate the portion of savings from purchases outside the program that can be attributed to the effects of the program (spillover).** We estimated the level of spillover based on judgments informed by formal testing of hypotheses concerning alternative influences on promotion and adoption of efficient HBL technologies.

Table 3 shows the data collection efforts that supported the analysis described above. In the remainder of this paper we present details of these calculations and their results. We conclude with a review of lessons learned from carrying out the analysis.

Table 3. Data Collection of the High Bay Lighting Market Study

	Sample Size	
Data Collection Activity	**California**	**Comparison Area**
In-depth interviews: Program Managers, Contractors, CPUC	14	n/a
In-depth interviews: Comm. Lighting Installation Contractors	8	7
In-depth interviews: Comm. Lighting Distributors	9	9
In-depth interviews: Manufacturers	11	
Survey of commercial lighting installation contractors	150	100
Survey of commercial lighting distributors	142	77
Survey of recent HBL lighting purchasers	124	80
Secondary sources including technical manuals, CA program evaluations, CA program participation data bases	n/a	n/a

Detailed Results

Estimation of Market Size and Lumen Output Installed

The first step in estimating the actual and baseline wattage of HBL fixtures purchased and installed by California businesses in 2006-2008 was to estimate the square footage served by those fixtures based on the results of customer telephone surveys. The samples for these surveys focused on manufacturing establishments and commercial establishments such as schools, big box retail stores, and warehouses that are known to contain significant high bay spaces. We used Dun & Bradstreet for the sample frame in California and the comparison area. Table 4 shows the results of the calculations.

The samples of end-users in California and the comparison areas were similar in terms of their distribution across business and building types and number of persons employed. The average California facility appears to be substantially larger than the average facility in the comparison sample. However, this is due largely to the presence of two very large facilities in the California sample. The median size is nearly identical for the two samples, and the difference in the average size is not statistically significant.

Table 4. Estimates of Market Size: Square Feet Served by 2006-2008 Purchases

	MARKET PARAMETERS/Inputs	California	Comparison	Notes/Sources
	NUMBER OF PURCHASERS, 2006-2008			
1	Population of End-Users	59,413	37,608	Dun & Bradstreet Selectory Database: Manufacturing + Selected Commercial NAICS codes
2	% with High Bay Spaces	30.7%**	23.0%	Customer Surveys.
3	Population of End-Users w/ High-bay Spaces	18,252	8,650	Row 1 * Row 2.
4	Percent of end-users w/ high bay spaces who purchased high bay lighting in 2006 – 2008	28.5%	25.5%	Customer Surveys
5	***End users who purchased high bay lighting in 2006 – 2008***	***5,203***	***2,203***	Row 3 * Row 4.
	SQUARE FEET SERVED HBL PURCHASES			
6	Average square feet of purchasers' facilities	203,258	128,880	Customer Survey
7	Percentage of facility sf with ceiling height > 15 f	61%	68%	Customer Survey
8	Average square feet of high bay space	123,987	87,638	Row 6 * Row 7
9	Average percent of high bay space served by 2006 – 2008 purchases	71%	56%	Customer Survey
10	***Total square feet of space served by 2006 – 2008 purchases***	***458.1 million***	***107.8 million***	Row 5 * Row 9 * Row 8

** Significantly different from the comparison area at $p<0.05$.

The next step was to estimate the average lumens required to provide adequate lighting to the estimated 458.1 million square feet served by the 2006-2008 purchases of high bay lighting in California. The steps in this process were as follows:

- Estimate the square footage housed by the various commercial facility types and manufacturing enterprises in the population of HBL purchasers. For commercial facilities we used the results of the *Commercial Energy Use Survey* conducted in California in 2006. (Itron 2006) For manufacturing facilities, we developed square footage estimates based on employment and construction statistics from the Economic Census and the Annual Survey of Manufacturers.

- Estimate the lumens per square foot required in the high bay spaces of the different facility types, based on Illuminating Engineering Society of North America (IESNA) guidelines and Title 24 code requirements.

The weighted average lumens required per square foot based on these calculations was 39.9. Applying this average to total square feet of space served by HBL purchases in 2006-2008, we estimated the total lumens installed for the period at 18.23 billion. Applying rules of thumb for square feet served per fixture found in lighting layout manuals (Ruud 2007), we estimated total fixture purchases in California during the program period at 1.22 million.

Estimation of Technology Shares and Wattage Installed

As mentioned above, we estimated the share of the competing HBL technologies sold in California and the comparison areas during the program period using the results of surveys of representative random samples of installation contractors.[2] To estimate market share we processed the survey results using a combined ratio estimation process that weighted contractor responses by their stratum weight (based on number of employees) and by self-reported volume of units installed in high bay projects. Table 5 shows the technology shares for key HBL lighting types developed by applying these methods.

Table 5. Contractor-reported Technology Shares of 2006-2008 High Bay Lighting Installations

	Contractor-Reported Sales	
Technology Type	**California**	**Comparison**
Fluorescent Tube: T5HO/Electronic Ballast T5HO	65%	29%**
Fluorescent Tube: T-8 /Electronic Ballast T-8	14%	16%
Fluorescent Tube: All other, including T12	1%	11%*
FLUORESCENT TUBE SUBTOTAL	**80%**	**58%**
HID: Pulse-start metal halide	14%	31%*
HID: High-pressure sodium	3%	8%
HID: Other HID: probe-start metal halide	1%	3%**
HID SUBTOTAL	**18%**	**42%**
OTHER: INDUCTION, LED, CFL, INCANDESCENT	**2%**	**2%**

* Significantly different from California at the 90% confidence level (p<=0.1).

** Significantly different from California at the 95% confidence level (p<=0.05).

[2] We also posed questions on technology shares in the customer and distributor surveys. We found that customers were able to distinguish between fluorescent and HID technologies, and that their reported market share for these two large classes of products were very close to those reported by the contractors. However, customers were not able to distinguish effectively between important subcategories such as T-12, T-8, and T-5 fluorescents or the different types of HID lighting. We found that distributors generally lost track of purchases once they left the warehouse and could not provide good technology share breakdowns for equipment used in high bay spaces. We therefore chose to use the contractor technology share estimates for the energy savings analysis.

The differences in technology shares between California and the comparison areas are marked and consistent with the design of the program. T-5 technologies, which received nearly all of the program support, commanded a 65 percent market share in California versus 29 percent in the comparison area. This difference is significant at the 95 percent confidence level. Overall, fluorescent tube technologies account for 80 percent of the high-bay market in California versus 58 percent in the comparison area. In the comparison area, pulse-start metal halides have the highest market share among all HID alternatives, at 31 percent. In both California and the comparison area, the "baseline technology" – probe start metal halide fixtures – are virtually absent from the current sales mix. However, contractors in the comparison areas reported significant numbers of inefficient T-12 fluorescent fixtures in high bay applications.

We estimated the average lumen per watt installed for the California and comparison area fixture sales by applying the results of the technology share analysis to the design efficacy of the various technology types. In some cases, the design efficacies were adjusted to take account of fixture efficiencies reported in various technical manuals and manufacturer specifications. The average efficacy of fixtures installed in California was 62.2 lumens per watt; the average efficacy for fixtures installed in the comparison area was 56.0. Using the estimate of total lumens installed, developed earlier, we estimated the lighting power density for high bay fixtures at 0.62 watts per square foot for California and 0.71 watts per square foot for the comparison area.[3]

Estimation of Demand and Energy Use Reductions: California v. the Comparison Area

Table 6 shows the estimate of the reduction in wattage installed and annual energy use associated with the difference in technology shares between California and the comparison area. If the cohort of HBL fixtures installed in California during the period 2006-2008 had been characterized by the same technology shares as the comparison area, the total connected wattage of those fixtures would have been 326.3 MW versus 293.7 MW, a difference of 32.7 MW.

Table 6. Estimate of Demand and Energy Use Reductions: California versus the Comparison Area

	Item	Value	Notes/Sources
1	Total square feet served by 2006 – 2008 HBL purchases in California	458 mil.	Estimated from CA end-user survey
2	Average Watts per square foot (lighting power density): Program Area Efficacy	0.62 w/sf	Estimated based on technology share results from the CA contractor survey
3	Average watts per square foot (lighting power density): Baseline Efficacy	0.71 w/sf	Estimated based on technology share results from the Comparison Area contractor survey
4	Total MW of high bay lighting purchased: Program Area	293.7 MW	Row 2 * Row 1
5	Total MW of high bay lighting purchased: Baseline Efficacy	326.3 MW	Row 3 * Row 1
6	**Difference in MW installed: Program Area v. Baseline Efficacy**	**32.7 MW**	Row 5 – Row 4
7	**Difference in GWh/Year Usage: Program Area v. Baseline Efficacy**	**97.2 GWh/Year**	Row 6 * average 2,975 annual operating hours per logger studies

[3] Lighting power allowances incorporated in the 2008 Title 24 Building Energy Efficiency Standards range from 0.6 w/sf to 1.6 w/sf depending on space type. These allowances cover all sources of lighting, not just ceiling fixtures.

According to lighting logger studies conducted for the 2006-2008 statewide evaluations, HBL fixtures operated 2,975 hours per year, on average. Applying this figure to the wattage reduction, we estimate the energy savings associated with the more efficient technology mix in California at 97.2 GHW per year.

Savings "Outside the Program" and Attribution to Program Effects

Review of the results of evaluations of all 2006-2008 commercial and industrial energy efficiency programs conducted for the California Public Utilities Commission identified total verified gross savings of 97.2 GWh/Year for HBL measures and net savings of 67.0 GWh/Year. Subtracting the latter from the total energy reduction associated with differences in technology shares between California and the comparison area, we estimate the savings associated with purchases of high bay lighting without program support at 30.2 GWh/Year.

The final, and perhaps most complicated step in the analysis, was to assess what portion of these savings "outside the program" could plausibly be attributed to the effects of the program. Originally, we had hoped to estimate spillover using the results of customer surveys that elicited information on recognition and influence of the programs. Information from other sources could then be analyzed to seek corroboration for those results. However, because the program was driven primarily by contractors, very few customers were able to recall any interaction with it. We therefore assessed the likely level of spillover based on judgments informed by formal testing of hypotheses concerning alternative influences on promotion and adoption of efficient HBL technologies using a wide variety of the information and data collected for the study.

Alternative Hypotheses. Working closely with a committee of advisors who oversaw the execution of this project, we developed a set of four hypotheses to explain the relatively high level of observed savings outside of the program. These were as follows:

1. **Spillover**. Spillover is the influence of the program on HBL purchases made "outside the program". For example, among program participants, spillover may occur if and when they purchase and install energy-efficient products that they learned about and tested through the program, without seeking financial incentives. Among non-participants, spillover may occur if and when they install energy-efficient measures in response to vigorous promotion from contractors who learned about the measures and their technical advantages through the program.
2. **Influence of codes and standards.** The 2008 version of Title 24 contains relatively stringent compliance requirements for lighting power density in high bay spaces compared to IEEE and ASHRAE guidelines, which provide the basis for other state building codes. Energy code enforcement is generally not invoked in replacement projects. However, the most recent revision of California's Title 24 Building Codes and Standards requires code review for renovation projects in which more than half of the existing lighting fixtures are replaced.
3. **Cumulative effects of previous California energy efficiency and information programs on customers' purchase decision criteria and processes.** California IOUs have been offering incentives to commercial and industrial customers to purchase high efficiency lighting equipment continuously for over two decades. In the past decade, these incentive programs have been supplemented with broad-based information programs such as *Flex Your Power*, as well as by an array of focused education and training offerings. Coming into the 2006-2008 program cycle, California customers may have been much more predisposed than their counterparts in the comparison area to be presented with and ultimately select energy-efficient high bay lighting.

4. **Targeting of the California market by manufacturers and large distributors.** Related to Hypothesis 3, it is possible that some portion of efficient high bay lighting sales "outside the program" could be related to manufacturers and distributors focusing marketing effort for those products on California, thus taking advantage of incentives and other public benefit promotions.

Evidence related to the spillover hypothesis. We found strong evidence to support the hypothesis that the program influenced the adoption of T-5 technologies by non-participants, primarily through the influence of installation contractors. Key pieces of evidence to this effect included the following:

- **High presence of the program in the market.** The program accounted for a large portion of the total high-bay market: over 50 percent of all HBL purchasers received incentives through the program. Fixtures that received incentives from the program accounted for 22 percent of all HBL fixtures sold into the program area market. Roughly two-thirds of contractors in the program area reported receiving rebates for HBL from an IOU. Half of those firms reported receiving rebates for more than 25 high bay lighting projects.
- **Focus of program support on T-5 technologies.** The IOU programs focused heavily on supporting T5HOs, which accounted for 93 percent of all fixtures rebated and incentives paid.
- **High portion of total T-5 technology sales occur outside the program.** Despite their high incremental costs, sales of T5HO fixtures outside the program exceeded in-program sales by over 3:1. Out-of-program sales of T5HOs alone accounted for 51 percent of *total HBL* sales. The market share of T5HOs in the comparison area, as reported by contractors, was only 29 percent.
- **Key role of the installation contractors.** The high level of out-of-program sales suggests that program area contractors took a much more aggressive approach to promoting and selling T5HOs than did their counterparts in the comparison area. The contractor surveys provided strong evidence that installers promoted T-5 technology outside of the program. For example, virtually all contractors in California considered T-5 technology to be energy-efficient, while only 21 percent considered pulse start metal halide to be energy efficient. By contrast, 70 percent of contractors in the comparison area considered pulse start technologies to be efficient. Seventy-two percent of program California contractors reported that they recommend energy-efficient HBL for *all* of their projects. One potential reason for strong contractor support of T-5 technology is its high price compared to T-8s, which are similarly efficient. The higher price provides a higher margin when materials mark-ups are taken into account.
- **Reported influence of the program on contractors.** Seventy-nine percent of California contractors rated the importance of IOU programs in their decisions to promote efficient HBL at 8 or above on a scale of 10. Seventy-three percent rated IOU program influence on the market share of efficient HBL technologies at 8 or above on a scale of 10.

Evidence on the influence of Title 24. Lighting replacement projects that affect more than 50 percent of fixtures in an enclosed space are subject to Title 24 lighting power allowance provisions. For projects that use the Prescriptive Area approach to comply with the lighting provisions of the current version of Title 24, it will be easier to attain required lighting power densities using fluorescent technologies rather than pulse start metal halide fixtures. Approaches using primarily fluorescent fixtures deliver required lighting levels at well-below the Title 24 maximum lighting power densities. This finding was echoed in the in-depth interviews with California contractors and distributors.

Despite the major role of Title 24 and associated code enforcement regimes in the California construction market, evidence of its influence on high bay lighting equipment selection and design was relatively sparse. Among the 150 California lighting contractors with whom we completed structured interviews, seven mentioned Title 24 compliance as an influence on high bay specification practice. We concluded from the evidence reviewed above that Title 24 probably did exert some influence on the market share of fluorescent technologies in high bay applications in existing buildings, but that this influence was relatively weak. Our main reasons for this assessment are that:

- Those who did acknowledge the Title 24 influence did so clearly and without prompting in open-ended questions, *but*,
- Only four of the 150 contractors we interviewed identified Title 24 as an influence on their specification practices in existing buildings.

Evidence regarding predisposition of California customers to adopt efficient HBL technologies. Working with the project advisors we identified a number of potential indicators of a predisposition among end-use customers to adopt efficient lighting technologies. These included the share of customers who were aware of those technologies, the portion that employed energy management staff, the level of adoption of various energy management and preventive maintenance activities, and so forth. We found no pattern of significant differences in these characteristics between sample customers in California and the comparison area.

Evidence of differences in promotional effort among distributors. Nearly 90 percent of sample distributors in the comparison areas identified T-5 technology as energy efficient and reported recommending them to contractors as frequently as distributors in California. Thus, evidence gathered conflicted with the hypothesis that distributors in the comparison areas did less than distributors in California to promote T-5s to installation contractors.

Estimates of energy savings associated with spillover. Based on review of the hypothesis testing described above, we set a lower bound of 50 percent for the allocation of savings outside the program to the effects of spillover, and an upper bound of 90 percent. These bounds represent a qualitative judgment based on the relative strength of support for the spillover and alternative hypotheses. Table 7 shows the application of these bounds to the findings of total energy savings associated with adoption of efficient HBL technologies outside the program. The low estimate of savings from spillover effects was 15.1 GWh/Year, or 23 percent of verified net savings estimated without accounting for spillover. The high estimate of spillover was 27.2 GWh/Year or 41 percent of verified net savings.

Table 7. Energy Savings Associated with Spillover

Row #	Calculation Step	Quantity/Outcome
1	Energy savings associated with adoption of efficient HBL technologies, net of baseline adoptions. Conceptually this quantity includes net savings estimated through *Protocol* methods (adjusted gross savings * (1-free ridership rate))	97.2 GWh/Year
2	Net savings estimated via 2006-2008 impact evaluations (program transactions only)	67.0 GWh/Year
3	Savings from out-of-program adoptions, net of baseline adoptions: Row 1 – Row 2	30.2 GWh/Year
4	Low estimate of spillover: savings from out-of-program adoptions, net of baseline, that are attributable to the program: 0.5 * Row 3	15.1 GWh/year
5	High estimate of spillover: savings from out-of-program adoptions, net of baseline, that are attributable to the program: 0.9 * Row 3	27.2 GWh/year

Conclusions and Lessons Learned

The High Bay Lighting Market Effects Study found that the 2006-2008 programs, which featured primarily prescriptive rebates marketed by installation contractors, caused significant market effects, most importantly:

- Strong promotion of energy-efficient T-5 technologies by California contractors, when compared to their counterparts in non-program areas.
- Strong promotion of T-5 technologies to all customers and projects, with and without program incentives.
- Large volume of T-5 fixture sales "outside the program", which led to spillover in the range of 23 to 41 percent of net savings, as estimated by evaluations that did not account for spillover.

From a methodological standpoint, the study demonstrates that it is feasible to conduct a cross-sectional, market-level net savings analysis, including estimation of market size and technology shares, without actual sales data. However, analysts interested in conducting similar studies will need to take into account the following potential complications.

- Previous studies relying on cross-sectional methods involving comparison of program areas to non-program areas show that timing is crucial. Once national markets for efficient technologies begin to take off, differences in technology shares between program and non-program areas quickly become insignificant.
- We are running out of non-program areas. In the latest expansion of ratepayer-funded programs, commercial lighting promotions are active in nearly every state.
- Comparability of the program and non-program areas will always be an issue. Therefore, the kinds of qualitative hypothesis testing used to isolate spillover effects will be required in any study of this type.

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