CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

2008 CEC Title 24 Building Energy Efficiency Standards Rulemaking Proceeding
July 6, 2006

Hardwired Standby Loads: Lighting Controls

This report was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission.

Table of Contents

Document information

Category: Codes and Standards

Keywords: PG&E CASE, Codes and Standards Enhancements, Title 24, nonresidential, 2008, efficiency, lighting controls

Overview

This CASE proposal addresses the standby energy loads from hardwired lighting controls – specifically sensors that regulate usage of non-residential and high-rise residential lighting fixtures and systems. Several types of sensors were evaluated as part of this CASE study including hardwired motion/occupancy sensor and photocell sensors interconnected with lighting systems for indoor and outdoor buildings applications. Automated controls or advanced lighting controls – systems which combine sensors and/or time clocks with microprocessors and relays to regulate lighting for large areas or whole buildings based on astronomical patterns (other than day/night), preset schedules or other complex settings are outside the scope of this research.

The lighting controls and sensors evaluated in this CASE study are used for smaller, defined commercial spaces such as hallways, rest rooms, conference rooms, storage rooms, copy rooms, open office areas, and private offices, as well as outdoor building perimeter lighting. They may be wall or ceiling mounted as individual units, or they can be integral to a lighting switch, all are readily available from a variety of retail and wholesale distribution channels. The three primary categories of hardwired sensor technologies evaluated include: infrared, ultrasonic, and dual-technology (a combination of infrared and ultrasonic technologies). The two components of the control device that have an effect on standby loads include the sensor itself and the power pack that powers it. The technologies employed to perform the control functions vary by manufacturer and thus potential efficiency gains were examined on a product category basis.

The definition of standby used to develop this proposal is the period when the control device is operating but the lighting system is in "off" mode (some commercial sensors also operate while the lights are on to determine whether the occupant is present). The standby load draw of these technologies has not been extensively measured and appears to vary widely, depending on manufacturers' implementation. Further, little existing research has been conducted on this issue. Thus, the key elements of this two-phase proposal are to:

- Require standardized measuring/labeling/reporting of standby energy load for devices on product specification sheets and packaging, and then, after a period of data collection enabled by this requirement,
- Identify sensors categories or device types with high savings potential, as applicable.
- Regulate the maximum standby loads from hardwired lighting controls associated with commercial lighting systems.

The analysis conducted as part of this research indicates that an improvement in lighting control device efficiency could save California approximately 1,000 to 3,000 MWh per year. This research was limited to the savings from device-level efficiency improvements. However, an investigation of the interactions of control devices within an overall lighting system may indicate the potential to yield greater standby energy savings benefits than efficiency improvements in the devices alone.

Description

Lighting controls and sensors are hardwired into building lighting circuits and are designed to remain active when the lighting circuit is switched on. As such, they consume varying standby loads (depending on their design) during the majority of their installed and useful life. Currently, Title 24 standards address and encourage the use of these controls, but do not address their standby loading. Because the current standards do not apply to the controls associated with commercial lighting systems, one of the primary barriers is likely to be the process of introducing a new standard for a previously unregulated device. Manufacturer resistance to proposed measures is anticipated to be relatively high since the introduction of a new standard in California would potentially increase the costs associated with testing, reporting, design, materials, and manufacturing. However, given that lighting controls are mandated for many applications in California, it is reasonable to address the efficiency of the devices themselves. While individual standby loads of lighting control devices are low, reducing the collective standby loads of these hardwired devices installed in new commercial buildings would result in important energy savings for California.

Examples of lighting controls are illustrated in Figure 1 . As shown, these include an outdoor motion sensor, an occupancy sensor wall switch with a photocell, and a ceiling-mounted occupancy sensor.

Figure 1:Example Lighting Controls[1]

<u>Recommendations</u>

We recommend a two-phase process for implementing code changes associated with the standby loads from hardwired lighting controls. Phase One would mandate a "test and list" requirement for all lighting controls to be established in the 2008 Title 24 standards. Phase Two would evaluate the establishment of minimum efficiency (or alternatively a maximum load per unit or per system) requirements. Any Phase Two requirements will be developed based on the device specifications and function. The evaluation of this minimum efficiency -- or load requirement -- would begin after Phase One's two-year data collection period.

No manufacturing changes are required under the "test and list" proposal. However, product testing and additional information on the package and specification sheets would be required. The potential benefits of this Phase One recommended code change are: an increased awareness of product power consumption, and more product options for specifiers and buyers. For our estimates, we assume that a small upward shift in the average efficiency and a downward shift in demand of these devices would be observed as a result of this Phase One test and list mandate, due to increased industry awareness and competition. We also expect that the mandated data disclosure may spur component manufacturers to offer more variety in size and capacity of their components, so that sensor manufacturers could optimize their products' power demand profiles.

Phase Two of this recommended approach entails evaluating the development of mandated efficiency levels for specific device types or technologies. For example, device types could include indoor photosensors and outdoor motion sensors. Since no data is currently available on which to base specific recommendations, any Phase Two code changes would follow a two-year Phase One reporting period (anticipated 2008-2010) and would likely be included in the next Title 24 update or a future Title 20 proceeding. With new data available from manufacturers, well-informed recommendations for minimum efficiency code changes should be possible.

In the case of this analysis, our data indicate that lighting controls will require alternative minimum standby requirements by function. Section 119 of the current Title 24 standards maintains specific language for eight different sensor categories. A mandatory minimum efficiency requirement would require similar specificity. The Phase One period of product standby load testing and listing will ensure that the highest impact and most cost-effective requirements are mandated.

Throughout the remainder of this report, Phase One refers to the "test and list" proposed code change and Phase Two refers to potential proposed minimum efficiency code changes. Phase Two is included in this analysis to

[1] Control devices shown in Figure 1 are manufactured by RAB, Hubbel Wiring Devices, and Lutron (from left to right)

suggest that a minimum efficiency standard would be possible based on the indications from preliminary research that cost-effective opportunities to reduce standby load of lighting controls do exist.

Energy Benefits

Energy benefits were calculated based upon achievable standby load savings from the introduction of higher efficiency devices. Specifically, we measured and researched the standby power demand (in watts) from a variety of lighting controls and power packs to determine standby energy levels. We estimated the total energy benefits based on the incremental watts per unit that would be saved as a result of a new standard. The total energy benefits were calculated by estimating the forecasted statewide population multiplied by the estimated lighting controls for new commercial and high rise residential buildings. The estimated energy benefits for each proposed code change are shown in Table 1.

Table 1: Estimated Energy Benefits for Lighting Controls Code Changes

Device	Type of Code Change	Per Unit Savings in Watts (average)	Estimated Annual New Controls in CA Non-Residential Buildings	Estimated Annual New Controls CA High Rise Residential Buildings	Estimated Annual CA Retrofit Installations	Hours per Year in Standby	MWh Savings after 1 Year (average)	Estimated Annual Savings (kW)
Lighting Controls	Test & List	0.05	458,600	357,000	40,800	6,760	300	40
Lighting Controls	Minimum Efficiency	0.33	458,600	357,000	40,800	6,760	1,900	280

Our results from the measurement of the standby loads of several device samples indicate that Phase Two potential minimum efficiency requirements would need to be specified by device type or technology. Figure 2 and Figure 3 illustrate that outdoor motion sensors and photo sensors are potential areas to focus on in Phase Two.

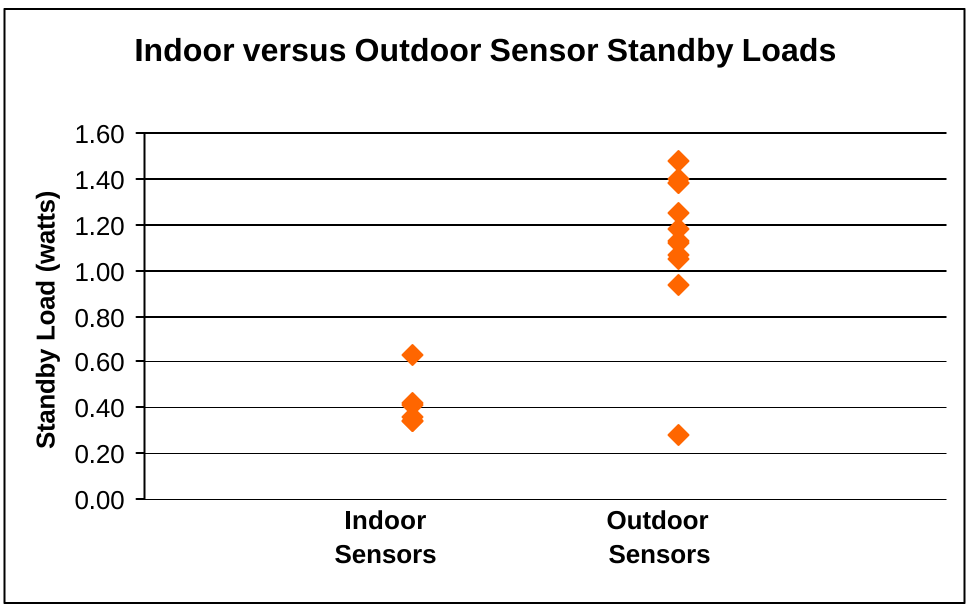

Figure 2: Standby Loads of Indoor versus Outdoor Lighting Control Devices

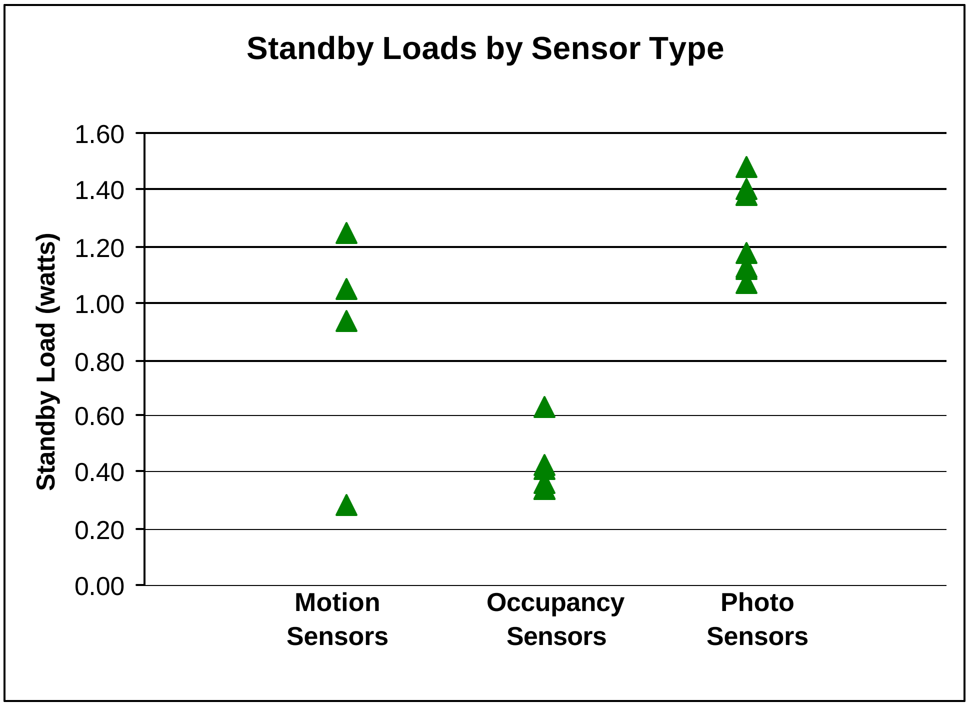

Figure 3: Standby Loads by Type of Lighting Control Devices

Non-energy Benefits

Measurable non-energy benefits are not anticipated with this proposed standard. However, there may potential product lifetime or reliability benefits to be gained from using more efficient systems or components. The intent of this proposal is to maintain current performance standards with lower standby energy loads from control devices.

Qualitative Assessment

At present, there are no real incentives for manufacturers to design for higher standby efficiency in the lighting controls market. Rather the product design incentives, primarily driven by market demand, include quality, reliability, and low cost. The lack of market demand for standby efficiency dictates that natural market adoption will not occur in either the short or long term, absent the proposals included in this report.

The assumed benefits of the proposed standards are based on full compliance from manufacturers. The timelines for the Phase One "Test and List" and the Phase Two Mandatory Efficiency Standard development are proposed to accommodate necessary changes in the design, testing, manufacturing, and distribution processes. There will likely be a gradual industry movement toward compliance with the 'test and list' standard and full compliance with a mandated efficiency level will be supported through the initial listing Phase One. A gradual industry movement toward compliance is expected because it is difficult to measure compliance with, much less enforce, a 'test and list' standard without undue expense. However, after any specific efficiency standards identified in Phase Two, product labels can be checked during inspections to ensure reasonable compliance levels.

Based on this expectation, the installation rate will be consistent with the assumptions laid out in the *Statewide Energy Impacts* section of this report. Installation rates consistent with full compliance are particularly important given that individual devices have minimal standby loads but the volume of devices sold into California's market sufficiently justifies this effort on a cost-benefit basis.

Specific testing procedures are integral to these proposed standards. The project team employed the IEC 62301 testing protocol for this initial effort but an agreed upon testing procedure that is widely accepted is important. If the IEC protocol is adopted, moderate effort will be required to develop new methods for future analysis of product standby loads. One key issue is whether California ultimately intends to mandate minimum standby efficiency on a device level or lighting system basis. Even if a standard is set at the device level, some lighting control devices such as photo sensors, will require a test method to establish standby load levels under different ambient light conditions. As such, it is expected that for the mandatory minimum efficiency standard – for device or lighting system – significant research and stakeholder input will be required to develop the testing protocol for a widely accepted mandated level of efficiency.

The development of this CASE report involved primary research and preliminary testing, industry interviews, market analysis, and stakeholder participation. Despite the openness of this process, the research effort was limited by the lack of extant data or prior research in the development of efficient lighting control devices. Industry experts on this subject have participated in the stakeholder process to date but a more thorough testing and a more involved stakeholder process is necessary to establish the appropriate design criteria for lighting controls efficiency. Currently, there are no efficiency standards for hardwired standby devices, which would make California a leader through this continued effort.

Statewide Energy Impacts

An initial analysis found that the first year's implementation of the lighting controls maximum standby load requirements would reduce electricity energy consumption by approximately 1,900 MW/hr per year. This estimate assumes the installation of one average lighting sensor device per 300 sq ft. and is expanded up to the population of one year's new construction, which is estimated to be 156 Million square feet per year for all nonresidential building types and 35,000 new high rise residential buildings. Note that the evaluation of minimum efficiency requirements would start after a two-year data collection phase.

Table 2: Estimated Statewide Impacts from Two Lighting Controls Code Changes

Device	Type of Code Change	MWh Savings after 1 Year (average)	kW Savings after 1 Year (average)	Year 1 Million sq. ft. (Non-Residential)	CA High Rise Residential Buildings
Lighting Controls	Test & List	300	40	156	35,700
Lighting Controls	Minimum Efficiency	1,900	280	156	35,700

Environmental Impact

The team assessed the potential environmental impact for both proposed code changes for lighting controls including Phase One Test and List and Phase Two Minimum Efficiency. In both cases, the environmental impact is expected to be very low. For the Phase One Test and List proposed changes, there are no anticipated adverse environmental impacts outside the existing practice. This proposed change does not require any measurable adjustments to current manufacturing processes, materials, or installation practices and thus the environmental impact of this change is assumed to be zero.

Any Phase Two proposed code changes requiring a minimum efficiency for categories of sensors could have environmental impacts relative to current practices. If manufacturers need to employ alternative materials, the potential for a greater environmental impact exists. Similarly, if manufacturing processes are adjusted to comply with this proposed code change, a negative environmental impact could result. All other processes, including packaging, shipping, and installation will not change as a result of the code change. However, at present, the team estimates that the overall environmental impact will be negligible.

The primary environmental impacts from the code changes proposed in this CASE study would result in reduced emissions. These environmental impacts are based upon air emissions reductions from power plants due to electricity savings as shown in Table 3 below.[2] Estimates of annual reduced emissions resulting from proposed standards changes calculated using these emission factors are shown in Table 4.

Table 3: Factors used to calculate the air emissions reductions resulting from end-use reductions in electricity

Emissions factors	NOx	CO	CO2	PM10
Electricity, Western States (lbs/MWh)	0.383	0.23	1200	0.06

Table 4: Estimated reduced emissions resulting from proposed code changes

Annual Emissions Savings (lbs/year)	NOx	CO	CO2	PM10
Lighting Controls: Phase One Test & List	103	62	323,000	16
Lighitng Controls: Phase Two Min. Efficiency	722	433	2,261,300	113

Type of Change

As described above, the team is recommending a tiered, two-phase process for code changes related to the standby loads associated with hardwired lighting system controls. To date, standby loads have not been one of the design criteria for lighting control manufacturers. Thus, the first step in the proposed code change process is a Test and List code change.

Under this change, the current Title 24 Codes would be expanded to include a mandate for manufacturers to test each control device (model or sensor/power pack combination) -- according to Commission approved testing protocols -- specified in the Section 119 and list the standby load on product specification sheets, the control device, and on external packaging materials.

Any Phase Two code change would involve a minimum efficiency requirement for standby load requirements for each major device technology category. This proposed change would involve not only an expansion of the current Title 24, Section 119 requirements, but also a potential change in the current list of control devices. New technologies, such as digital controls for dimmable ballasts, will likely require that a new subsection be added to the existing lighting controls standards. An alternative approach for the Phase Two code change language would be to establish an overall lighting system efficiency requirements rather than individual device efficiency mandated levels. This may be warranted given the interactions among the individual devices in a lighting system but the project team has not evaluated this potential approach.

[2] Table 1, Appendix B page 2, Initial Study/Proposed Negative Declaration for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings September 2003 P400-03-018. Values provided by the CEC System Assessment and Facilities Siting Division http://www.energy.ca.gov/reports/2003-09-12_400-03-018.PDF

Proposed Measure	Type of change	Impact on standards	Documents to be modified
"Test and List": Require labeling/reporting of standby energy load for devices on specification sheets/packaging	Mandatory measure	Expands the scope of the existing standards. Minimum efficacies are currently not required.	Standards, Manuals and Compliance Forms
Establish minimum efficiency requirements lighting controls	Mandatory measure	Expands the scope of the existing standards. Minimum efficiencies are currently not required.	Standards, Manuals and Compliance Form

The performance approach calculations contained in the Alternative Compliance Method (ACM) Manual do not include energy consumption from lighting controls. This proposal would not change this approach and thus this measure will not impact the ACM manual.

Technology Measures

The two proposed code changes described in this study require measurement and efficiency improvement of current technologies. The team researched the data and information about the availability, cost, useful life, and performance of the technology described below from the following sources:

- Manufacturers' websites and product specification sheets
- Communication directly with manufacturers and manufacturers' associations
- Communication with California electrical contractors.
- Discussions with lighting control researchers (university and U.S. government laboratory).

Lighting controls are manufactured or branded by many lighting and electrical device companies, including but not limited to:

- Acuity Lighting Group
- Advance Transformer Company
- Articulated Technologies, LLC
- Cooper Lighting
- Cooper Wiring Devices
- Day-Brite Lighting
- GE Total Lighting Control
- Genlyte Group LLC
- Holophane An Acuity Brands Company
- Home Land Security
- Hubbell Incorporated
- Leviton Manufacturing Co., Inc.
- Lightolier
- Lithonia Lighting

- Lutron Electronics Company, Inc.
- Sensor Switch
- Universal Lighting Technologies
- Pass & Seymour/Legrand
- RAB Lighting
- Watt Stopper, Inc.

Basic control devices, such as wall switch occupancy sensors, are distributed through electrical contracting supplier stores, big box retailers like Home Depot and Lowes, and hardware stores. These basic devices are readily available throughout California. Although not exclusively, more complex lighting system design controls, such as multiple ("ganged") sensors and power packs, are typically sold through electric supply wholesalers to lighting designers and contractors. Manufacturers also design for specific functionality in different market segments such as example, hospitals, schools, and offices and design changes necessary to improve standby efficiency may vary by segment.

Table 5 shows ranges of costs and potential cost impacts resulting from each proposed code change based on those products tested in this analysis. The costs shown are the retail prices for those devices tested in this study. Again, there is a wide range of sensor types from a relatively simple switch to more complex dual-technology sensors. Of the changes that manufacturers could make to increase device-level standby efficiency, materials, design, and manufacturing would be the primary drivers for increased costs. The costs increases reflected in this analysis for the Phase One test and list are minimal device level changes associated with product testing and labeling changes. Estimated Phase Two minimum efficiency cost increases are shown at a device level with costs increasing in testing, materials, manufacturing, and installation. We recognize that these estimates would vary considerably by technology and device and evaluated the potential cost increases by exploring a range of cost impacts.

The team recognizes that there are a number of control devices that are outside this cost range. Further analysis is required for higher-end controls.

Table 5: Range of Costs from Measured Devices and Estimated Cost Increases from Code Changes

Device	Type of Code Change	Average Measured Device Cost	Minimum Measured Device Cost	Maximum Measured Device Cost	Average Cost Increase due to Code Change	Minimum Cost Increase due to Code Change	Maximum Cost Increase due to Code Change
Lighting Controls	Test & List	$18.66	$6.98	$53.00	$0.19	$0.09	$0.37
Lighting Controls	Minimum Efficiency	$18.66	$6.98	$53.00	$1.84	$0.37	$3.31

Manufacturers who have conducted product performance research or collaborated with advanced research programs sponsored by government and utilities may have a competitive advantage over other manufacturers because they are familiar with advanced system designs and efficient component options and availability. However, initial discussions with some of these manufacturers did not reveal that any of them were especially aware of or concerned with standby power loads for their devices. Only one manufacturer identified in this research, RAB lighting, presently lists power consumption on their product specification sheets. This manufacturer may have a slight competitive advantage over others who are not testing for or reporting this information.

Useful Life, Persistence and Maintenance

The useful life of the sensor devices addressed in this proposal is approximately 8-10 years. This estimate is from the Database for Energy Efficiency Resources (DEER) indicates the life of occupancy sensors to be 8 years. This is consistent with 3 years of additional operation over the average manufacturer warranty period of 5 years for controls evaluated. It is anticipated that controls would be replaced upon control equipment failure. No additional maintenance would be required during the useful life of the equipment.

Performance Verification

If labeling requirements are adopted, no performance verification would be required. Testing that the lighting controls are operating properly upon installation will be the primary performance verification method required. During Phase One: "Test and List" of the proposed standard, the possibility of encouraging US EPA/US DOE to initiate a voluntary labeling program could be explored. For example, an ENERGY STAR program could help develop a common test method, promote professional awareness of the forthcoming efficient products, and create a national market demand that would increase volume of sales of these devices and thus help drive costs down for California purchasers.

The project team used the International Electrotechnical Commission (IEC) 62301: *Household Electrical Appliances - Measurement of Standby Power* protocol to measure all devices in this study. The specific measurement procedure is described in subsection (4) of this IEC protocol. An Energy Commission approved testing protocol would need to be adopted in association with the recommended code changes.

Cost Effectiveness

Since both proposed code changes are mandatory, a cost-effective approach must be identified. Based on manufacturer interviews, our team developed a scenario analysis of the cost-effectiveness of each proposed code change. The cost-effectiveness methodology uses the Energy Commission's TDV values for a weighted average among climate zones. The team used the weighted average value in lieu of the hourly TDV values because these proposed measures would save energy equally during all periods and would not result in greater peak period reductions.

The proposed Test and List code change will not result in any significant savings but raising the awareness among the lighting design and contracting community – especially for zero energy new homes – would offset the minimal additional costs required by manufacturers to comply with this change.

Table 6 and Table 7 show an overview of the cost effectiveness for each code change proposal. Nine scenarios were analyzed for both estimated savings and cost, representing a reasonable bound for forecasted life cycle cost. In all cases, the negative values indicate cost effective scenarios and in each case more than 50% of the scenarios analyzed are cost-effective.

Table 6: Cost-Effectiveness Scenarios for Proposed Test and List Code Change

Lighting Controls: Phase One Test and List Proposal
Using TDV Weighted Average Values
Range of Cost-effectiveness (negative values = cost effective)

	Cost Premium over Baseline		
PV Savings	Min	Average	Max
Min	($9,541)	$70,360	$230,160
Average	($367,306)	($287,405)	($127,605)
Max	($814,512)	($734,612)	($574,811)

Table 7: Cost-Effectiveness Scenarios for Proposed Minimum Efficiency Code Change

Lighting Controls: Phase Two Minimum Efficiency Proposal
Using TDV Weighted Average Values
Range of Cost-effectiveness (negative values = cost effective)

	Cost Premium over Baseline		
PV Savings	Min	Average	Max
Min	($812,294)	$1,100,543	$3,013,380
Average	($2,153,913)	($241,076)	$1,671,761
Max	($3,495,531)	($925,765)	$330,143

Analysis Tools

Our team performed measurements of standby load for each device directly using the IEC 62301 testing protocol. The resulting standby load values were evaluated in conjunction with limited manufacturer estimates and input by experts in power pack and sensor designs.[3] The analysis to quantify energy savings and peak electricity demand reductions will be conducted using a spreadsheet tool which will be developed to compare technologies and anticipated savings.

Relationship to Other Measures

Both proposed code changes will relate to the mandatory installation of lighting controls associated with commercial lighting systems in Title 24 Sections 130 through 132, however it will not significantly impact these measures at this point. The additional information required under the proposed Test and List code change will not impact the installation of lighting control devices. The minimum efficiency code changes to be developed after Phase One would likely enhance the overall efficiency of the lighting systems required under Sections 130 through 132.

Methodology

This CASE study topic was developed as a result of prior discussion of the cumulative impacts of standby loads in California. Since plug-in appliance standby loads are being evaluated under the Title 20 CASE process, this topic began as an initial screening of the potential impacts of over 20 hardwired devices that spend the majority the time in standby mode. Each device was assessed based on estimated statewide energy load impacts from standby energy demand. Variable factors include standby wattage, market penetration, and persistence of standby mode. A preliminary stakeholder analysis was also conducted to inform the final decision to evaluate hardwired lighting controls in non-residential and high-rise residential applications.

The methodology for the evaluation of standby loads resulting from hardwired lighting controls involved the following steps:

- Manufacturer and contractor interviews
- Preliminary lighting control device testing
- Review of industry publications and research
- Calculation of statewide energy and demand impact estimates
- Review of California building code language
- Development of proposal

[3] Our conversation with researcher and manufacturers indicated that better designs for power packs exist and can improve power pack efficiency significantly. However, since opinions differ in the incremental cost range for these better designs, we have estimated a range of increased costs from 2% to 10% per device.

Results

Energy and Cost Savings

This section contains detailed energy and cost savings results that are summarized in the energy benefits section of the report. As a basis for the energy and cost savings estimates in this study, Table 8 shows a listing of devices measured during this analysis.

Table 8: Measured Lighting Controls Standby Power Consumption and Retail Price

	Product Type	Location	Connection	Standy-By Power Consumption (W)	Retail Price (no installation)
1	Motion Sensor	Outdoor	120VAC, 60Hz	1.05	$53.00
2	Motion Sensor	Outdoor	120 VAC	1.25	$14.50
3	Motion Sensor	Outdoor	120 VAC	0.94	$36.00
4	Motion Sensor	Outdoor	125	0.28	$23.00
5	Occ Sensor	Indoor	120VAC, 60 Hz	0.63	$35.00
6	Occ Sensor	Indoor	125VAC/CA Hz	0.34	$22.99
7	Occ Sensor	Indoor	120 VAC	0.36	$22.73
8	Occ Sensor	Indoor	120VAC	0.34	$18.62
9	Occ Sensor	Indoor	120VAC	0.34	$15.87
10	Occ Sensor	Indoor	125VAC/60 Hz	0.34	$19.99
11	Occ Sensor	Indoor	125	0.41	$20.00
12	Occ Sensor	Indoor	125	0.42	$25.00
13	Photo Sensor	Outdoor	120VAC	1.38	$12.98
14	Photo Sensor	Outdoor	120 VAC	1.40	$12.98
15	Photo Sensor	Outdoor	120 VAC	1.48	$9.98
16	Photo Sensor	Outdoor	120 VAC/ 15 A	1.18	$9.98
17	Photo Sensor	Outdoor	120 VAC/ 15 A	1.38	$9.98
18	Photo Sensor	Outdoor	120 VAC/ 15 A	1.07	$6.98
19	Photo Sensor	Outdoor	120 VAC/ 15 A	1.13	$7.98
20	Photo Sensor	Outdoor	120 VAC/ 15 A	1.12	$9.99

For the purposes of this analysis, we used the actual retail price as listed above for the basis of our cost-effectiveness analysis and included an estimate of additional installation costs per device. As an additional data point, DEER reports costs for lighting controls on a region-wide basis as follows[4]:

- Wall –Mounted (Hardwired) Occupancy Sensors: Equipment - $42.28; Installation - $35
- Photocell: Equipment - $12.058; Installation - $47.

Given the wide variety of lighting control devices on the market, a more detailed analysis of the costs and cost impact of improving standby efficiencies of different technologies would be required to determine any ultimate Phase Two minimum efficiency requirements.

Cost-effectiveness

Since the individual energy savings potential is low on a per device basis, the cost-effectiveness of both proposed code changes hinges upon achieving maximum possible device savings with very low costs spread over a large volume of devices. Due to prior codes and standards development, lighting controls are now ubiquitous in new

[4] The DEER cost estimates were obtained from a search of the online DEER database, Version 2.01 October 26, 2005 (http://eega.cpuc.ca.gov/deer/)

California construction and thus the statewide impact of potential efficiency changes warrants evaluation. Our team conducted a scenario analysis to determine the range in which costs and achieved savings must fall for these proposed measures to be cost-effective.

Table 9 illustrates the general population assumptions our team used for both non-residential and high-rise residential buildings where lighting controls are mandated under current Title 24 standards.[5] The power density estimates are based upon ASHRAE's building area method for allowed lighting power density. The controls density assumes one installed control (occupancy sensor, photo sensor, or outdoor motion sensor) per 500 watts. The number of controls for new California high rise buildings is calculated assuming one control device per floor and an average of ten floors per high rise building. An additional five (5) percent of the total new building control population was included as an estimate for annual retrofits.

Table 9: Lighting Controls Population Estimates

End Use		Annual Growth (million sq ft)	Power Density (w/sq ft)	Controls Density (watts / device)	# of New CA Commercial Controls
AMUSEMENT	4%	5.71	1.4	500	16,329
ASSEMBLY	1%	1.97	1.7	500	6,491
EDUCATION	1%	1.26	1.5	500	3,788
GOVT	2%	2.51	1.4	500	7,016
HOTEL	4%	6.82	1.7	500	23,191
MEDICAL	4%	6.45	1.6	500	20,645
OFFICE	17%	27.06	1.3	500	70,366
RETAIL	15%	24.13	1.9	500	91,687
SCHOOL	10%	15.16	1.5	500	45,469
SERVICE	14%	21.71	1.5	500	65,973
STORAGE	24%	37.07	1.2	500	88,969
OTHER	4%	6.15	1.5	500	18,702
Total New CA Commercial Controls					***458,625***
Total New CA Commercial Controls					***458,625***
Total New CA High Rise Residential Controls					***357,000***
Retrofit Installations (5% of new)					***40,781***
Annual New Lighting Controls					***856,406***

In Phase One (Test and List) the costs to manufacturers for testing are assumed to be several hundred dollars per model, or even less if manufacturers use the same components for multiple models. The costs for redesigning packaging and specification sheets likewise is expected to be minimal, because the information regarding standby power should be communicated in a few sentences and one or more lines or rows in existing tables. These initial costs would be spread across the production and distribution of a high volume of units.

In any Phase Two's proposed minimum efficiency code changes, some but probably not all, manufacturers would need to redesign some or all of the models of products that they offer. However, we do not anticipate that the redesign would be costly. Instead, it may only require more appropriate sizing and sourcing of the power pack for each unit, rather than using a universal-sized power pack.

[5] New non-residential growth estimates based on Dodge Area of Nonresidential New Construction Project Starts average of PY2000-PY2003; New residential high-rise estimates based on data from U.S. Census Bureau, 2004 American Community Survey.

Our research on the topic of sensor power packs indicates that this is an area that can yield significant savings. The current practice for power packs calls for a simple switching design that can provide power for up to three sensors. Because of the simple design, these power packs consume the same amount of power whether they are powering one, two, or three sensors. The majority of power packs in use are of this type. A more sophisticated power pack design can sense the sensor loads connected to it, and provide only the needed amount of power, and thus uses less power in cases where only one or two sensors are connected to the same power pack. Research by the Lighting Research Center several years ago indicated that adoption of the more sophisticated power pack design was not possible because of cost and availability. However, our more recent conversation with manufacturers indicate that cost for this design has come down significantly, and that widespread adoption of this technology could lead to a cost equalization between the two designs. Further discussion with manufacturers to explore this issue is warranted.

Table 10: Lighting Controls Phase One Test & List Proposal Cost-Effectiveness Analysis

Phase One: Lighting Controls "Test & List" Proposal

Change in Initial Cost			
Average Product Cost	$18.66		
Average Installation Cost	$150.00		
Average Total Cost	$168.66		
% increase per product w/Measure	Min	Average	Max
Manufacturing Process Upgrades	0%	0%	0%
Materials Upgrades	0%	0%	0%
Testing costs and packaging costs	1%	1%	2%
Increased Installation Costs	0%	0%	0%
	Min	*Average*	*Max*
Total Product Cost w/Measure	$18.75	$18.85	$19.03
Total Installation Cost w/Measure	$150.00	$150.00	$150.00
Total Initial Cost Increase	$168.75	$168.85	$169.03
Change in Initial Cost per product	$0.09	$0.19	$0.37
Annual Devices	856,406		
Cost Premium over Baseline (inc. costs)	$ 79,900	$ 159,801	$ 319,602

PV Electric Cost Savings	watts		
Average Product Standby Load	0.93		
	Min	Average	Max
% decrease in load w/Measure	1%	5%	10%
Product Standby Load w/ Measure	0.9207	0.8835	0.837
Standby Load Savings per Product (w)	0.0093	0.0465	0.093
Hours in Standby Mode	6760		
First year Savings (kWh)	53,841	269,203	538,405
First year Savings (kW)	8	40	80
PV TDV-E ($/kWh)	1.66 NPV of 1 kWh		
PV Electric Cost Savings	$ 89,441	$ 447,206	$ 894,412

Lighting Controls: Phase One Test and List Proposal

Using TDV Weighted Average Values

Range of Cost-effectiveness (negative values = cost effective)

	Cost Premium over Baseline		
PV Savings	Min	Average	Max
Min	($9,541)	$70,360	$230,160
Average	($367,306)	($287,405)	($127,605)
Max	($814,512)	($734,612)	($574,811)

Table 11: Lighting Controls Phase Two Minimum Efficiency Proposal Cost-Effectiveness Analysis

Phase Two: Lighting Controls Minimum Efficiency Proposal

Change in Initial Cost			
Average Product Cost	$18.66		
Average Installation Cost	$100.00		
Average Total Cost	$118.66		
% increase per product w/Measure	Min	Average	Max
Manufacturing Process Upgrades	1%	3%	4%
Materials Upgrades	1%	2%	3%
Increased Installation Costs	0%	1%	2%
	Min	*Average*	*Max*
Total Product Cost w/Measure	$19.03	$19.50	$19.97
Total Installation Cost w/Measure	$100.00	$101.00	$102.00
Total Initial Cost Increase	$119.03	$120.50	$121.97
Change in Initial Cost per product	$0.37	$1.84	$3.31
Annual Devices	856,406		
Cost Premium over Baseline (inc. costs)	$ 319,602	$ 1,575,510	$ 2,831,418

PV Electric Cost Savings	watts		
Average Product Standby Load	0.93		
	Min	Average	Max
% decrease in load w/ Code Change	20%	35%	50%
Product Standby Load w/ Code Change	0.744	0.6045	0.465
Standby Load Savings per Product (w)	0.186	0.3255	0.465
Hours in Standby Mode	6760		
First year Savings (kWh)	1,076,810	1,884,418	2,692,026
PV TDV-E ($/kWh)	1.66	NPV of 1 kWh	
PV Electric Cost Savings	$ 1,788,825	$ 3,130,443	$ 4,472,062

Lighting Controls: Phase Two Minimum Efficiency Proposal

Using TDV Weighted Average Values

Range of Cost-effectiveness (negative values = cost effective)

	Cost Premium over Baseline		
PV Savings	Min	Average	Max
Min	($812,294)	$1,100,543	$3,013,380
Average	($2,153,913)	($241,076)	$1,671,761
Max	($3,495,531)	($925,765)	$330,143

Statewide Energy Savings

As described above, the anticipated energy savings for both proposals are highlighted in Table 12 below.

Table 12: Estimated Statewide Energy Savings with Estimated New Commercial and High Rise Residential Growth

Device	Type of Code Change	MWh Savings after 1 Year (average)	kW Savings after 1 Year (average)	Year 1 Million sq. ft. (Non-Residential)	Year 1 New CA High Rise Residential Buildings
Lighting Controls	Test & List	300	40	156	35,700
Lighting Controls	Minimum Efficiency	1,900	280	156	35,700

Recommendations

Our team recommends a two-phase process for implementing code changes associated with the standby loads from hardwired lighting controls. Phase One would be a mandated "test and list" requirement for all lighting controls to be established in the 2008 Title 24 standards. The Phase Two would evaluate establishing minimum efficiency (or alternatively a maximum load per unit or per system) requirements. Any Phase Two requirements should be developed based on the device specifications and function. The evaluation of this minimum efficiency or load requirement would begin after the Phase One two-year data collection period.

No manufacturing changes are required under the "test and list" proposal. However, product testing and additional information on the package and specification sheets would be required. The potential benefits of this Phase One recommended code change are: an increased awareness of product power consumption, and more product options for specifiers and buyers. For our estimates, we assume that a small upward shift in the average efficiency and a downward shift in demand of these devices would be observed as a result of this Phase One test and list mandate, due to increased industry awareness and competition. We also expect that the mandated data disclosure may spur component manufacturers to offer more variety in size and capacity of their components, so that sensor manufacturers could optimize their products' power demand profiles.

Phase Two of this recommended approach entails evaluating the development of mandated efficiency levels for specific device types or technologies. For example, device types could include indoor photo sensors and outdoor motion sensors. Since no data is currently available on which to base specific recommendations, any Phase Two code changes would follow a two-year Phase One reporting period (anticipated 2008-2010) and would likely be implemented in either the next Title 24 update (anticipated for 2011) or a future Title 20 proceeding. With new data available from manufacturers, well-informed recommendations for minimum efficiency code changes should be possible.

In the case of this analysis, our data indicate that lighting controls will require alternative minimum standby requirements by function. Section 119 of the current Title 24 standards maintains specific language for eight different sensor categories. A mandatory minimum efficiency requirement would require similar specificity. The Phase One period of product standby load testing and listing will ensure that the highest impact and most cost-effective requirements are mandated. Proposed language changes are highlighted below.

Proposed Standards Language

SECTION 119 – MANDATORY REQUIREMENTS FOR LIGHTING CONTROL DEVICES

Any automatic time switch control device, occupant-sensor, motion sensor, photo sensor, or automatic daylighting control device shall be installed only if the manufacturer has certified to the Commission that the device complies with all of the applicable requirements of Subsections (a) through (f) and Subsections (h) through (k), and if the device is installed in compliance with Subsection (g).

(a) **All Devices: Instructions for Installation and Calibration**. The manufacturer shall provide step-by-step instructions for installation and start-up calibration of the device.

(b) **All Devices: Status Signal**. The device shall have an indicator that visibly or audibly informs the device operator that it is operating properly, or that it has failed or malfunctioned.

> **EXCEPTION to Section 119 (b):** Photosensor or other devices where a status signal is not feasible due to inadequate power.

(c) **Automatic Time Switch Control Devices**. Automatic time switch control devices shall:

1. Be capable of programming different schedules for weekdays and weekends; and

2. Have program backup capabilities that prevent the loss of the device's program and time setting for at least 10 hours if power is interrupted.

(d) **Occupant Sensors and Motion Sensors**. Occupant sensors and motion sensors shall be capable of automatically turning off all the lights in an area no more than 30 minutes after the area has been vacated. In addition, ultrasonic and microwave devices shall have a built-in mechanism that allows calibration of the sensitivity of the device to room movement in order to reduce the false sensing of occupants, and shall comply with either Item 1 or 2 below, as applicable:

1. If the device emits ultrasonic radiation as a signal for sensing occupants within an area, the device shall:

   A. Have had a Radiation Safety Abbreviated Report submitted to the Center for Devices and Radiological Health, Federal Food and Drug Administration, under 21 Code of Federal Regulations, Section 1002.12 (1996), and a copy of the report shall have been submitted to the California Energy Commission; and

   B. Emit no audible sound; and

   C. Not emit ultrasound in excess of the decibel (dB) values shown in TABLE 119-A, measured no more than five feet from the source, on axis.

2. If the device emits microwave radiation as a signal for sensing occupants within the area, the device shall:

   A. Comply with all applicable provisions in 47 Code of Federal Regulations, Parts 2 and 15 (1996), and have an approved Federal Communications Commission Identifier that appears on all units of the device and that has been submitted to the California Energy Commission; and

   B. Not emit radiation in excess of one milliwatt per square centimeter measured at no more than five centimeters from the emission surface of the device; and

   C. Have permanently affixed to it installation instructions recommending that it be installed at least 12 inches from any area normally used by room occupants.

(e) **Automatic Daylighting Control Devices**. Automatic daylighting control devices used to control lights in daylit zones shall:

1. Be capable of reducing the light output of the general lighting of the controlled area by at least one half in response to the availability of daylight while maintaining relatively uniform illumination throughout the area; and

2. If the device is a dimmer, provide electrical outputs to lamps for reduced flicker operation through the dimming range and without causing premature lamp failure; and

3. If the devices reduce lighting in control steps, incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes and have sufficient separation (deadband) of on and off points for each control step to prevent cycling; and

4. If the devices have a time delay, have the capability for the time delay to be over-ridden or set to less than 5 seconds time delay for the purpose of set up and calibration, and automatically restore its time delay settings to normal operation programmed time delays after no more than 60 minutes; and

5. Have a setpoint control that easily distinguishes settings to within 10% of full scale adjustment; and

6. Have a light sensor that has a linear response with 5% accuracy over the range of illuminances measured by the light sensor; and

7. If the device is a stepped switching control device, show the status of lights in the controlled zone by an indicator on the control device; and

8. If the device is a dimming control device, display the light level measured by the light sensor, if the controlled electric lighting cannot be viewed from where setpoint adjustments are made.

EXCEPTION to Section 119 (e) 7 & 8: If the control device is part of a networked system with a central display of each control zone status, the status indicator or light level display on each individual control device shall not be required if control setpoint adjustments can be made at the central display.

(f) **Interior Photosensors**. Interior photosensor shall not have a mechanical slide cover or other device that permits easy unauthorized disabling of the control, and shall not be incorporated into a wall-mounted occupant-sensor.

(g) **Installation in Accordance with Manufacturer's Instructions**. If an automatic time switch control device, occupant-sensor, automatic daylighting control device, or interior photosensor is installed, it shall comply with both Items 1 and 2 below.

1. The device shall be installed in accordance with the manufacturer's instructions; and

2. Automatic daylighting control devices shall:

A. Be installed so that automatic daylighting control devices control only luminaires within the daylit area; and

B. Have photosensor that are either ceiling mounted or located so that they are accessible only to authorized personnel, and that are located so that they maintain adequate illumination in the area in accordance with the designer's or manufacturer's instructions.

(h) **Multi-level Astronomical Time-switch Controls.** Multi-level astronomical time-switch controls used to control lighting in daylit zones shall:

1. Contain at least 2 separately programmable steps (relays) per zone that reduces illuminance in a relatively uniform manner as specified in Section 131 (b); and

2. Have a separate offset control for each step of 1 to 240 minutes; and

3. Have sunrise and sunset prediction accuracy within +/- 15 minutes and timekeeping accuracy within 5 minutes per year; and

4. Store time zone, longitude and latitude in non-volatile memory; and

5. Display date/time, sunrise and sunset, and switching times for each step; and

6. Have an automatic daylight savings time adjustment; and

7. Have automatic time switch capabilities specified in Section 119 (c).

(i) **Automatic Multi-Level Daylighting Controls.** An automatic multi-level daylighting control used to control lighting in daylit zones shall:

1. Meet all the requirements of Section 119 (e) for automatic daylighting control devices; and

2. Meet all the multi-level and uniformity requirements of Section 131 (b); and

3. Have a light sensor that is physically separated from where setpoint adjustments are made; and

4. Have controls for calibration adjustments to the lighting control device that are readily accessible to authorized personnel.

(j) **Outdoor Astronomical Time-switch Controls.** Outdoor astronomical time-switch controls used to control outdoor lighting as specified in Section 132 (c) shall:

1. Contain at least 2 separately programmable channels per function area; and

2. Have the ability to independently offset the on and off times for each channel by 0 to 99 minutes before or after sunrise or sunset; and 3. Have sunrise and sunset prediction accuracy within +/- 15 minutes and timekeeping accuracy within 5 minutes per year; and

3. Store time zone, longitude and latitude in non-volatile memory; and

4. Display date/time, sunrise and sunset; and

5. Have an automatic daylight savings time adjustment; and

6. Have automatic time switch capabilities specified in Section 119 (c).

TABLE 119-A ULTRASOUND MAXIMUM DECIBEL VALUES

MIDFREQUENCY OF SOUND PRESSURE THIRD-OCTAVE BAND (in kHz)	MAXIMUM dB LEVEL WITHINTHIRD-OCTAVE BAND (in dB reference 20 micropascals)
Less than 20	80
20 or more to less than 25	105
25 or more to less than 31.5	110
31.5 or more	115

(k) **All Devices: Test and List**. The manufacturer shall:

1. Test the standby power requirements for each device per IEC 62301 testing protocol or other test approved by the Commission, and

2. Provide a listing of the standby power requirements on the both the control and the external packaging.

3. Clearly indicate area of product application: interior or exterior

Alternate Calculation Manual

Since both phases of the proposed code changes are mandatory requirements, no changes to the ACM are anticipated.

Bibliography and Other Research

Architectural Energy Corporation. *Life Cycle Cost Methodology, 2008 California Building Energy Efficiency Standards*, California Energy Commission. February 15, 2006.

ASHRAE/IESNA Standard 90.1-1999 - "Energy Standard for Buildings Except Low-Rise Residential Buildings"

Bierman, Andrew, R. Pysar, M. Figueiro, *Development and Demonstration of an Improved, Energy-Efficient, Photosensor Lighting Control*, Final Project Report, Lighting Research Center, Rensselaer Polytechnic Institute, April 4, 2003.

California Department of Housing and Community Development, Division of Housing Policy Development, documents available at http://www.hcd.ca.gov/hpd/

California Energy Commission, PIER Lighting Research Program, *Retrofit Fluorescent Dimming with Integrated Lighting Control – Economic and Market Considerations*, CEC Contract # 500-01-041, Architectural Energy Corporation, Lawrence Berkeley National Laboratory, September 11, 2003.

California Energy Commission, 2008 California Building Energy Efficiency Standards. *Residential Housing Starts and Prototypes*, available at http://www.energy.ca.gov/title24/2008standards/documents/

Connecticut Light and Power, *Self-Commissioning Photosensor,* Sensor Switch (contributions), Renssalaer Polytechnic Institute, Lighting Research Center.

DiLouie, C. *Lighting Controls: Current Major Trends and Future Direction,* Lighting Controls Association, 2003.

Eilert, Patrick, *Lighting Controls Code and Standards Enhancement (CASE) Study,* Pacific Gas & Electric Company, November 8, 2000.

IESNA 2000. IESNA Lighting Handbook Ninth Edition, Illuminating Engineering Society of North America, New York.

International Electrotechnical Commission, Household Electrical Appliances - Measurement of Standby Power, IEC 62301.

Francis Rubinstein , *After DALI: A Look at What's Next*, Lawrence Berkeley National Laboratory, Architectural Lighting, January/February 2005.

United States Census Bureau, American Community Survey 2004.

Manufacturer Interviews

Wattstopper on April 18, 2006

Lutron Electronics Co., Inc. on April 18, 2006

Leviton on May 15, 2006

Acknowledgments

The Pacific Gas and Electric Company sponsored this report as part of its CASE (Codes and Standards Enhancement) project. Steve Blanc of PG&E was the project manager for this commercial CASE project. Pat Eilert is the program manager for the CASE program. Ecos Consulting is the prime contractor and Conway & Silver Energy Associates is the subcontractor.

Carmen Baskette, My K. Ton, Brad Ouderkirk, Lucas Mason, Rick Counihan, Chris Calwell, and Suzanne Foster Porter of Ecos Consulting and Kate Conway of Conway & Silver Energy Associates performed most of the analysis and reporting presented here.