CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Residential Lighting

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team October 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

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1. Overview

a. Measure Title	Residential Lighting
b. Description	The proposed changes apply to interior lighting of single-family residences, and the residential units of multifamily buildings. The proposed changes modify the mandatory requirements of the "Base Code" (Title 24 Part 6) and create new prescriptive requirements in the "Reach Code" (Title 24 Part 11). The changes to Base Code clarify the existing description of "high efficacy" lighting, and slightly increase the required lamp efficacies. They also add new requirements for high efficacy lighting and/or controls in various rooms of a house, and place new restrictions on the use of medium-base sockets in certain fixture types. The changes to Reach Code create a new requirement for all lighting in the dwelling to be high efficacy. The residential lighting CASE study prepared by the California investor-owned utilities for the2008 code cycle showed that high efficacy lighting was cost-effective in all rooms, but high-efficacy lighting was not adopted as a mandatory requirement because the lamps available at the time (i.e. CFLs) fell short on amenity, i.e. they were not able to replicate the full range of light distributions required by the different types of luminaires commonly used in residences. However, at the time of writing this CASE study, LED lamps are available which either already do produce the full range of light distributions, or will soon be able to. They are cost-effective and technically feasible in most fixture types, which makes a mandatory requirement for high efficacy lighting viable. In response to input from stakeholders, this CASE study stops short of recommending mandatory high efficacy lighting for all luminaires in the base code, but does recommend mandatory high efficacy lighting in the reach code.
c. Type of Change	**Mandatory Measure (Base Code)-** These changes add or modify mandatory measures **Prescriptive Requirement (Reach Code) -** These changes add or modify a prescriptive requirement. **Modeling (Reach Code)** - These changes provide a basis (energy budget) for residential lighting, which would allow it to be traded against other building systems in reach code. The standards, ACM, Manuals, and compliance forms would all need to be updated in response to these changes.
d. Energy Benefits	The table in this section shows energy savings for the luminaires and controls in *all* spaces, not just in the spaces for which they're proposed. See section 3.2 and 3.3 for more detailed discussion of energy benefits

Measure	Installed Savings (MW)	Average Daily Hours of Use	Statewide Savings (GWh/year)
No Medium Base Cans			
Bedroom	2.9	1.7	1.81
Living Room	5.6	2.3	4.70
Dining Room	2.3	1.9	1.57
Hallway	9.1	1.2	3.98
Bathrooms	1.3	1.4	1.30
Kitchens	1.4	2.5	1.32
No Medium Base Decorative in Hallways	4.2	1.2	1.85
Bathroom Measures	2.8	1.4	2.76
Utility / Closet High Efficacy	3.0	1.4	2.01
Total	**32.6**		**21.31**

	Electricity Savings (kwh/yr)	Demand Savings (W)	Natural Gas Savings (Therms/yr)	30 yr TDV Electricity Savings	TDV Gas Savings
Per Prototype Building (870sf multifamily)	119	TBD	N/A	$298.22	N/A
Per Prototype Building (2700sf single family)	535	TBD	N/A	$925.50	N/A
Savings per square foot (870sf multifamily)	0.14	TBD	N/A	$0.34	N/A
Savings per square foot (2700sf single family)	0.14	TBD	N/A	$0.34	N/A

The savings from this/these measures results in the following statewide first year savings:

	Total Electric Energy Savings (GWh)	Total Gas Energy Savings (MMtherms)	Total TDV Savings (million $)
As recommended by the CASE team	21.31	N/A	$53.6
As proposed by the CEC	4.78	N/A	$12.0

e. Non-Energy Benefits	The non-energy benefits of the proposed measure are not significant.

f. Environmental Impact

The proposed change does not have any potential adverse environmental impacts. Because the proposed energy measure will reduce electricity use, this will reduce electricity generation, and thereby have a small reduction in mercury emissions from coal-burning power plants, and in water consumption from electricity generation. However, because the primary benefit is energy reduction these environmental benefits are not considered here, and all material uses are shown as No Change (NC).

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Statewide total for all measures originally proposed by IOU team	257(I)	255(I)	76553(I)	51036(I)	127589(I)	NC
Statewide total for measures included in CEC language	104(I)	104(I)	31213(I)	20809(I)	52022(I)	NC

Water Consumption:

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Unit Measure	Not applicable
Per Prototype Building	NC

Water Quality Impacts:

None

g. Technology Measures	The proposed change does not encourage a particular technology.
h. Performance Verification of the Proposed Measure	Residential lighting compliance forms will need to be modified to reflect the proposed changes

i. Cost Effectiveness

This section shows that the proposed changes are cost effective using life cycle costing (LCC) methodology. The cost effectiveness analysis uses the Energy Commission's Life Cycle Costing Methodology posted on the 2011 Standards website and state the additional first and maintenance costs, the measure life, energy cost savings, and other parameters required for LCC analysis.

1. **Current Measure Costs** - as is currently available on the market, and
2. **Post Adoption Measure Costs** - assuming full market penetration of the measure as a result of the new Standards, resulting in mass production of the product and possible reduction in unit costs of the product once market is stabilized. Provide estimate of current market share and rationale for cost prediction. Cite references behind estimates.
3. **Maintenance Costs** - the initial cost of both the basecase and proposed measure must include the PV of maintenance costs (savings) that are expected to occur over the assumed life of the measure. The present value (PV) of maintenance costs (savings) must be calculated using the discount rate (d) described in the 2011 LCC Methodology. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows (where d is the discount rate):

   $$\text{PV Maint Cost} = \text{Maint Cost} \times \left\lfloor \frac{1}{1+\text{d}} \right\rfloor^{n}$$

4. **Energy Cost Savings** - the PV of the energy savings are calculated using the method described in the 2011 LCC Methodology report.

A	b	c			d	e			f		g		g	
Measure Name	Measure Life (years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)			Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)	PV of Additional[3] Maintenance Costs (Savings) (Relative to Basecase) (PV$)			PV of[4] Energy Cost Savings (PV$)		LCC Based on Current Costs (c+e)-f ($)		LCC Based on Post-Adoption Costs (d+e)-f ($)	
		Per Unit[1]	Per 870sf MF	Per 2700sf SF	Per Unit	Per Unit[1]	Per 870sf MF	Per 2700sf SF	Per 870sf MF	Per 2700sf SF	Per 870sf MF	Per 2700sf SF	Per 870sf MF	Per 2700sf SF
No Medium Base Recessed														
Bedroom	30	30.00	14.23	44.15	0.00	(21.77)	(10.32)	(32.04)	28.20	87.52	(24.30)	(75.40)	(38.52)	(119.55)
Living	30	30.00	27.89	86.55	0.00	(31.71)	(29.48)	(91.49)	74.80	232.14	(76.39)	(237.07)	(104.28)	(323.62)
Dining	30	30.00	12.17	37.76	0.00	(25.11)	(10.18)	(31.60)	26.96	83.66	(24.97)	(77.50)	(37.14)	(115.26)
Hallway	30	30.00	43.05	133.61	0.00	(15.29)	(21.94)	(68.09)	60.24	186.96	(39.13)	(121.45)	(82.18)	(255.05)
Bathroom	30	30.00	6.55	20.33	0.00	(18.46)	(4.03)	(12.51)	10.70	33.19	(8.18)	(25.37)	(14.73)	(45.70)
Kitchen	30	30.00	7.30	22.65	0.00	(32.49)	(7.91)	(24.54)	21.28	66.05	(21.89)	(67.93)	(29.19)	(90.58)
No Medium Base Hallway Decorative														
	30	34.35	17.15	53.21	0.00	(1.59)	(0.79)	(2.46)	34.92	108.39	(18.57)	(57.64)	(35.72)	(110.85)
Bathroom Measures														
	30	3.35	0.40	1.23	0.00	(5.01)	(0.59)	(1.84)	6.67	20.69	(6.86)	(21.30)	(7.26)	(22.53)
Utility / Closet High Efficacy														
	30	25.57	28.40	88.13	0.00	(0.59)	(0.66)	(2.03)	34.45	106.91	(6.71)	(20.82)	(35.11)	(108.95)

j. Analysis Tools	This measure is proposed as mandatory, so analysis tools are not relevant, since the measure would not be subject to whole building performance trade-offs.
k. Relationship to Other Measures	This measure will not have a significant impact on other measures.

2. Methodology

The primary goal of this code change proposal is to simplify the residential lighting requirements while continuing to improve energy efficient practices. Analysis of existing installed lighting and hours-of-use data has identified areas where efficiency measures could achieve additional savings.

2.1 Data Collection

The data used in this analysis was collected primarily from two main sources. The 2010 New Home Energy Survey (CEC, 2010) provided an inventory of all luminaire and lamp types in an 80-dwelling-unit representative sample of new residential construction in the IOU territories in California. All of the dwelling units in this sample were permitted under Title 24 2005, representing an example of residential construction practices using recent code requirements.

In addition, detailed hours of use data was provided by the 2010 Upstream Lighting Program Final Evaluation Report (CPUC, 2010). Hours of use data available (to date) from the 2010 Upstream Lighting Program Final Evaluation was limited to compact fluorescent sources. Because the inclusion of only compact fluorescent hours of use may overlook the use of certain luminaire types such as bathroom vanity lighting and other decorative lighting that tend to use incandescent and halogen sources, the 1997 California Baseline Lighting Efficiency Technology Report was also used as a basis for residential lighting hours of use, because this report included hours of use data from all lamp types in the residence, including incandescent (CEC, 1997).

These data sets were combined and analyzed in various ways to determine the viability of the various code change proposals.

Cost information for various lighting products and technologies was also gathered and analyzed for this analysis. Cost information used is based on retail prices collected from online retailers and large home improvement stores, with prices verified by industry stakeholders. These prices are appropriate for residential lighting because they are typically the same prices paid by homeowners or contractors, i.e. large contractor discounts are not available in all residential projects (as they typically are for nonresidential projects).

2.2 Energy Savings

To predict the energy savings from the proposed measures, lighting inventory data from the 2010 New Home Energy Survey was combined with average daily hours-of-use data from the 2010 Upstream Lighting Program Final Evaluation Report. Average hours-of-use data was broken down by room type, and by the number of bathrooms in the dwelling unit. Because the Upstream Lighting Program Final Evaluation Report did not record square footage for the surveyed dwelling units the number of bathrooms was used as a proxy for house size in order to compare the data to New Home Energy Survey Data. Each luminaire and lamp type in the survey inventory was assigned an hours-of-use number based on the corresponding room type, and the number of bathrooms in the dwelling unit. Combining these data sets produced annual energy use predictions for each luminaire, and by extension, for each dwelling unit.

2.3 Lifecycle Cost (LCC) Analysis

HMG calculated lifecycle cost analysis using methodology explained in the California Energy Commission report *Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards*, written by Architectural Energy Corporation, using the following equation:

$$\Delta LCC = Cost\ Premium - Present\ Value\ of\ Energy\ Savings$$

$$\Delta LCC = \Delta C - (PV_{TDV\text{-}E} * \Delta TDV_E + PV_{TDV\text{-}G} * \Delta TDV_G)$$

Where:

ΔLCC change in life-cycle cost

ΔC cost premium associated with the measure, relative to the base case

$PV_{TDV\text{-}E}$ present value of a TDV unit of electricity (3% discount rate)

$PV_{TDV\text{-}G}$ present value of a TDV unit of gas (3% discount rate)

ΔTDV_E TDV of electricity

ΔTDV_G TDV of gas

We used a 30-year lifecycle as per the LCC methodology for residential lighting control measures, taking into account rated life of the various lighting technologies. We have not included any interactions effects from the proposed measure (e.g. reductions in air conditioning energy, or increases in heating energy).

2.4 Statewide Savings Estimates

The statewide energy savings associated with the proposed measures will be calculated by multiplying the per unit estimate with the statewide estimate of new construction in 2014. Details on the method and data source of the residential construction forecast are in Appendix section 6.1.

2.5 Stakeholder Meeting Process

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at one of three public Lighting Stakeholder Meetings.

At each meeting, the utilities' CASE team invited feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Lighting Stakeholder Meeting: March 18th, 2010, Pacific Energy Center, San Francisco, CA
- Second Lighting Stakeholder Meeting: September 21st 2010, California Lighting Technology Center, Davis, CA

- Third Lighting Stakeholder Meeting: February 24th, 2011, UC Davis Alumni Center, Davis CA

In addition to the Stakeholder Meetings, five Stakeholder Work Sessions were conducted to allow detailed review of specific technical issues. These meetings were held on the following dates:

- October 29th 2010: Residential lighting stakeholder work session

3. Analysis and Results

The sections below outline the analysis and results from the various data sources, cost effectiveness assessments, and recommended proposals for residential lighting measures.

3.1 Analysis of 2010 New Home Energy Survey Lighting Data

As described in section 2.1, above, the data collected by the 2010 New Home Energy Survey represents the best available data on how recent code requirements are being applied in residential construction, as well as snapshot of typical residential lighting practice. HMG obtained the raw survey data from the survey authors, and analyzed the lighting inventory of the surveyed homes in a wide variety of ways.

3.1.1 Total Lighting Power Density

One of the first pieces of information derived from the raw data was the overall installed lighting wattage (both hardwired and portable) for each unit, as well as the area of each. Figure 1, below, shows each dwelling unit plotted by total wattage and house area. The trend line shown (R^2 = 0.65) represents the typical lighting power density (LPD) in Watts per square foot for residential lighting. The results show that residential lighting (across both multifamily and single family homes) averages 1.2 W/sf, plus 125W. This figure includes both hardwired and portable lighting. The relatively high R^2 value of 0.65 shows that the installed lighting load is closely related to dwelling size.

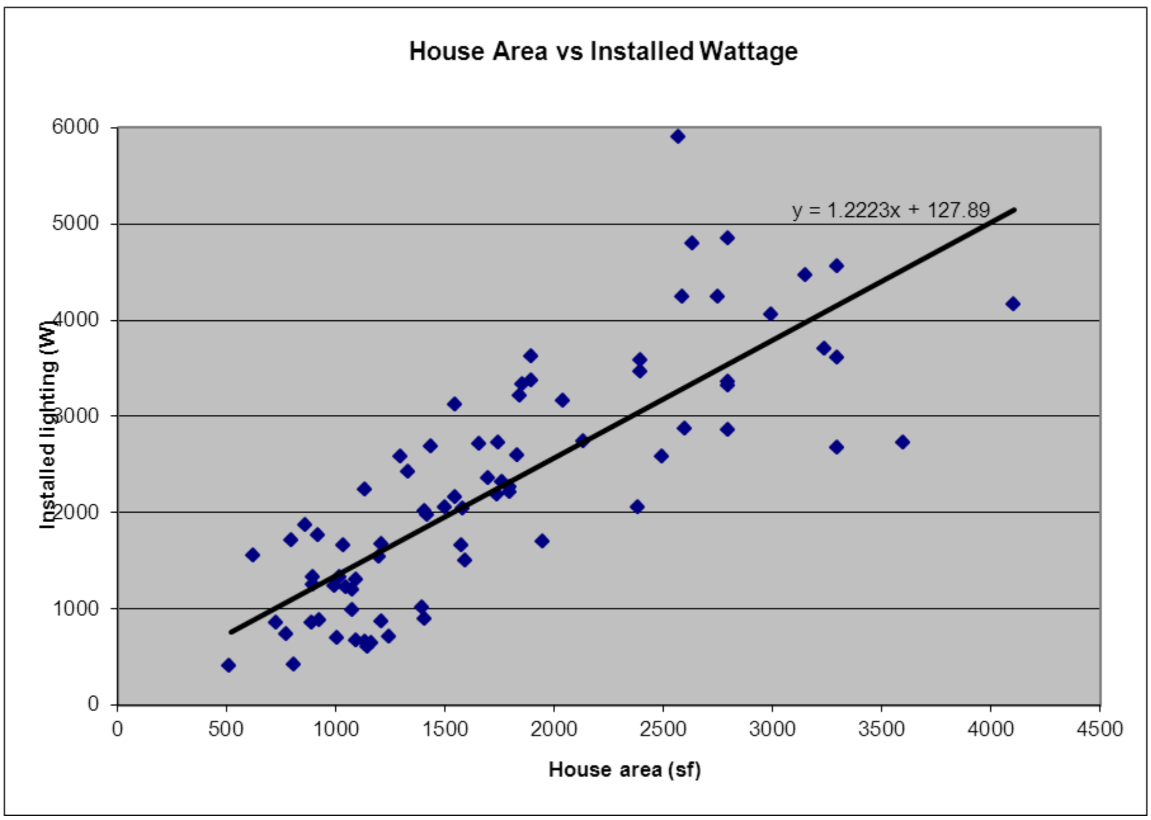

Figure 1: House Area vs Installed Wattage

3.1.2 Lighting Power per Room

The 2010 PIER data was also used to determine typical installed wattage for common residential room types. In Figure 2 below, shows average installed lighting wattage (permanently installed and portable) for typical room types. While portable lighting is beyond the scope of the energy code, this data provides the basis used in this report for the available reductions in lighting load from the proposed measures.

Room Type	Average Total Watts per Room	Average Permanently Installed Watts	Average Other Watts
Kitchens	250	202	48
Master Bathrooms	317	317	--
Secondary Bathrooms	190	190	--
Power Rooms	115	115	--
Closets	78	78	--
Master Bedrooms	200	107	93
Secondary Bedrooms	150	94	56
Utility Rooms	64	64	--
Hallways	207	207	--
Living Rooms	256	201	55
Dining Rooms	235	235	--

Figure 2: Average Lighting Watts (permanently installed and portable) per room type[1]

3.1.3 Lamp Types in Use

In addition, the data provided an overview of the types of lighting that are used in residential spaces. Figure 3, below, shows the percentage of residential lamp sources, by wattage, from the entire survey for both permanently installed and portable lighting. Despite the efforts of code revisions and utility programs, 81% of residential lighting wattage is provided by low efficacy sources. This data suggests there is potential for additional savings.

[1] Vent hood lighting in kitchens is not considered permanently installed lighting and is listed under "Other Watts" along with plug-load lighting sources in other room types.

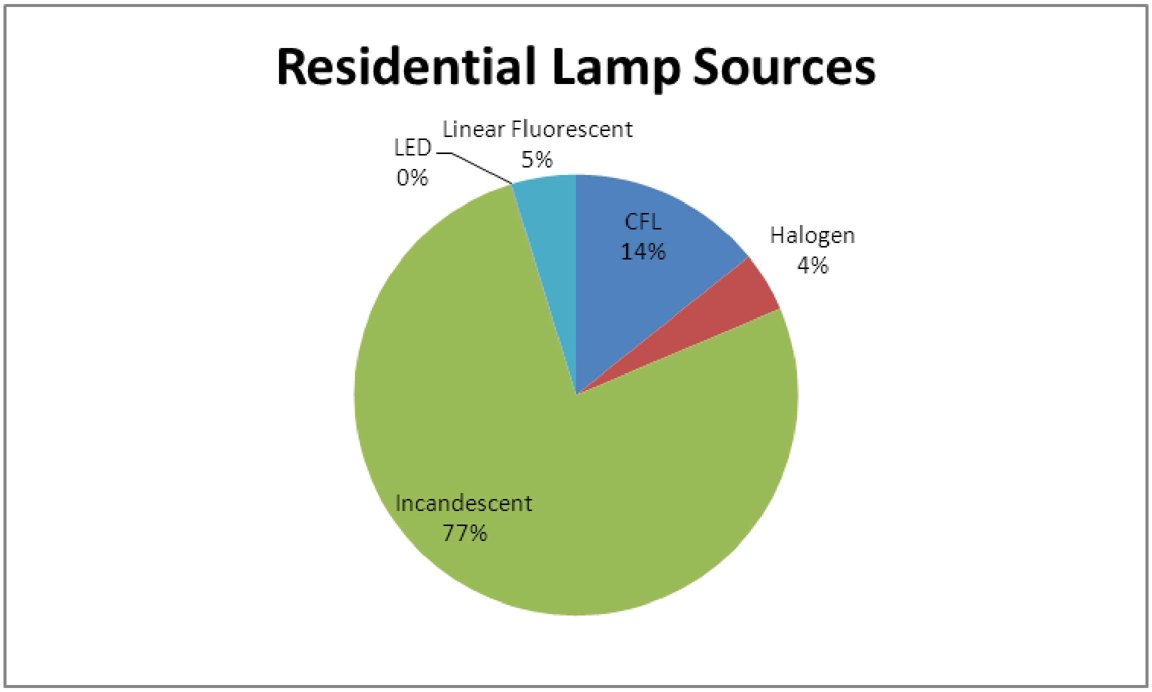

Figure 3: Percentage of Residential lamp sources (by Wattage)

Lamp source data was also broken down for both portable and permanently installed lighting. Figure 4 illustrates the average proportions of permanently installed and portable lighting wattage in typical residential units. As shown, an estimated 87% of residential lighting is permanently installed, and therefore within the scope of the code requirements.

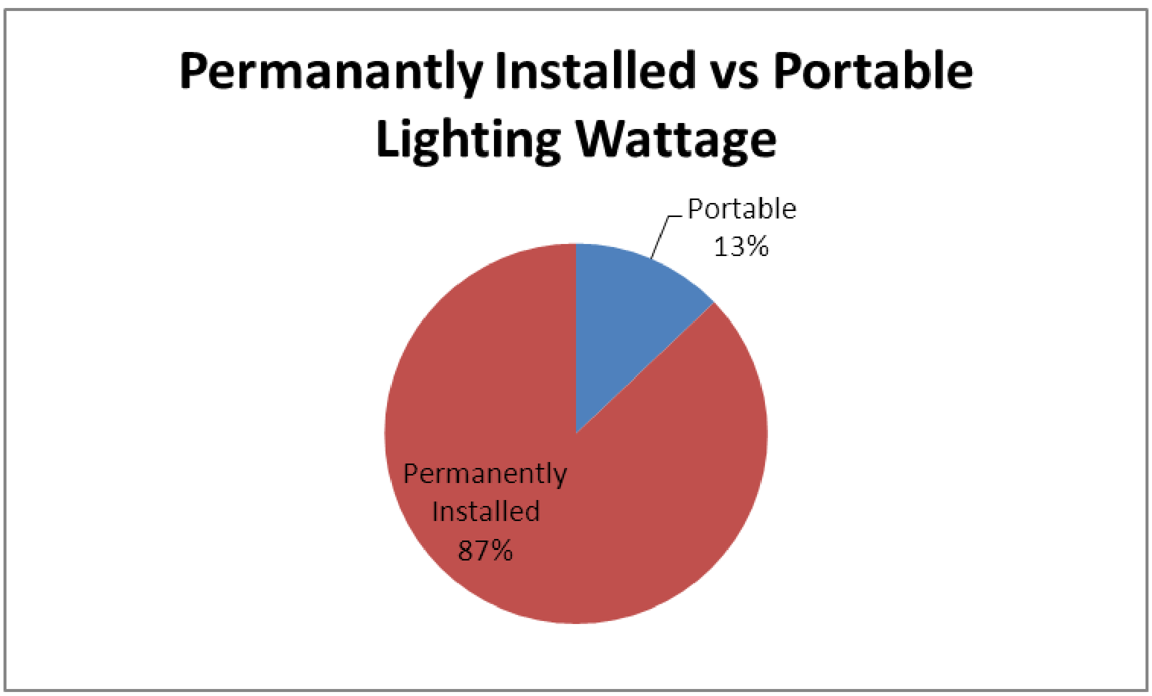

Figure 4: Permanently Installed vs Portable Lighting Wattage

Figure 5 and Figure 6 illustrate the breakdown of lamp sources for portable and permanently installed lighting, respectively. As shown, low efficacy sources make up 82% of portable lighting wattage, and 81% of permanently installed lighting wattage. The fact that low efficacy sources make up such a substantial portion of permanently installed lighting indicates that there is still significant savings to be achieved in residential lighting.

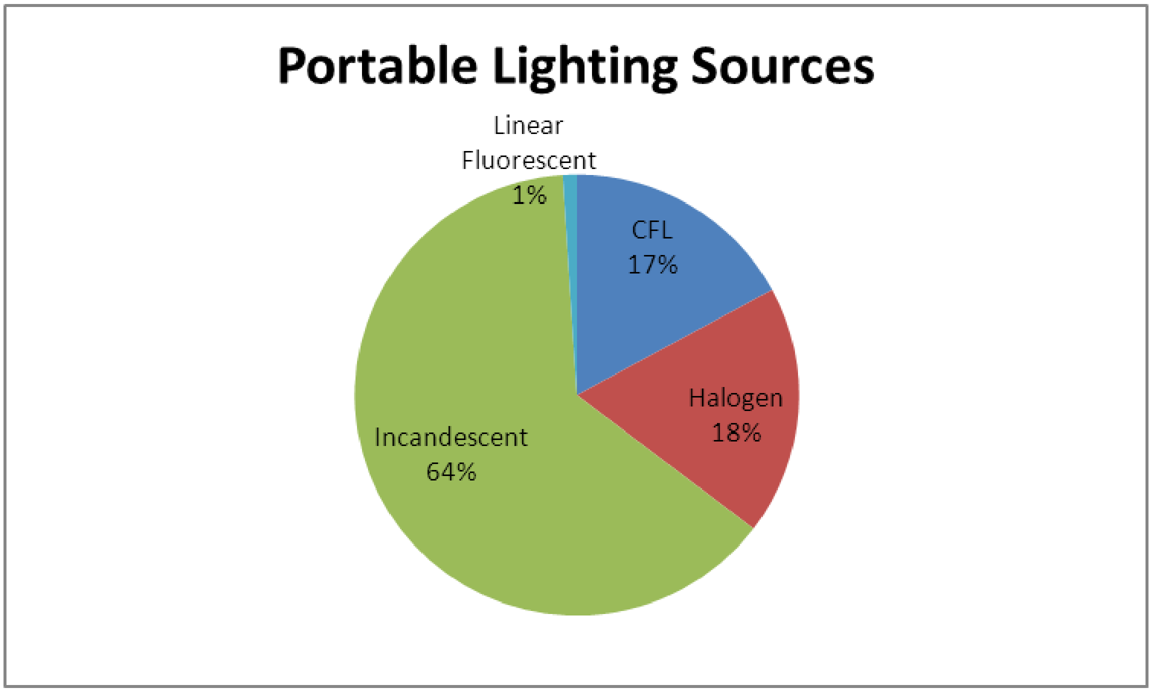

Figure 5: Percentage of Portable Lighting sources (by Wattage)

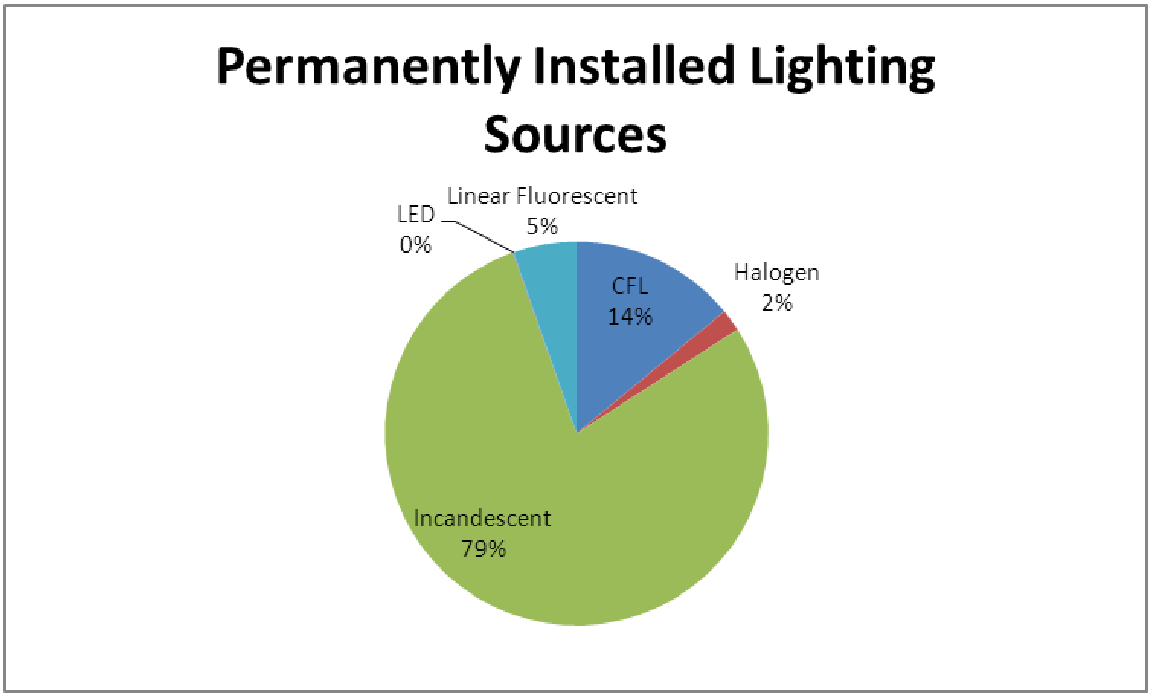

Figure 6: Percentage of Permanently Installed Lighting sources (by Wattage)

3.1.4 Hours of Use

Figure 7, below, shows average daily hours of use for typical residential room types. Hours of use data for this study was taken from the 2010 Upstream Lighting Program Final Evaluation Report (CPUC, 2010). Although the data from the 2010 Upstream Lighting Program Final Report was limited to compact fluorescent sources and compact fluorescent lamp sources make up only 14% of residential lighting wattage (see Figure 3), this data is considered the most current representation of typical residential lighting use.

Room Type	**Average Daily Hours of Use**[2]
Bedroom	1.7
Bathroom	1.4
Hallway	1.2
Garage	1.2
Dining	1.9
Living Room	2.3
Utility Room	1.4
Kitchen	2.5
Other	1.4

Figure 7: Average Daily Hours of Use for Residential Space Types

[2] CPUC, 2010

3.2 Energy Savings

This section sets out the energy savings available from each of the room categories used in Title 24. For convenience, we have summarized the proposed changes to code at the end of each section.

Note that Title 24 does not break out "hallways" as a separate room type, but in this proposal we have identified specific requirements that we believe are appropriate for hallway lighting.

3.2.1 Recessed Downlights

This section outlines the current use of recessed downlights in residential lighting, as well as the proposed code change recommendation.

Current code requires high efficacy lighting in all residential spaces, unless the luminaires are controlled by a dimmer. Based on this existing requirement and the increasing availability of a wide range of LED products, we had originally considered requiring high efficacy lighting for all permanently installed residential lighting. However, feedback from stakeholders suggested that there are not sufficient high efficacy products currently available to replace all low efficacy lighting applications. As a result, we developed a proposed measure for only recessed downlights, a luminaire type with proven high efficacy options using both compact fluorescent and LED sources.

Current Practice

While not all homes use recessed downlights, in those that do, the average installed load is 913W per housing unit. In addition, 79% of residential recessed downlights use medium screw-base sockets. As shown in Figure 8, recessed downlights with medium screw-base sockets are almost entirely incandescent.

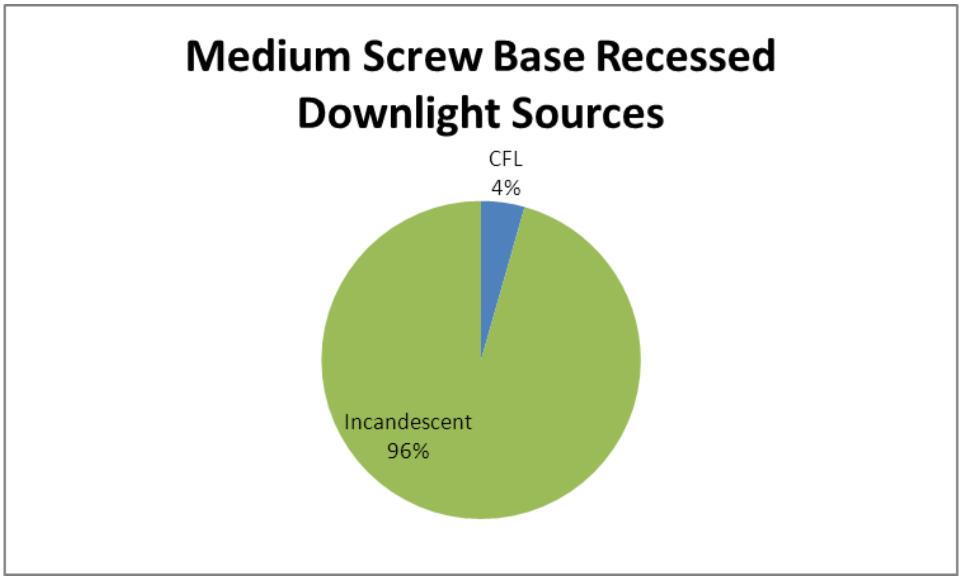

Figure 8: Medium screw-base recessed downlight sources (by wattage)

Based on the data on existing homes, medium screw-base recessed downlights represent a significant opportunity for additional energy savings.

Recommendations

Based on the findings shown above, as well as the input from stakeholders, and the cost effectiveness data in section 3.3, below, we are proposing the following luminaire requirement:

- Recessed downlights shall not contain medium screw base sockets.

This requirement would provide the flexibility to encourage high efficacy recessed downlights, while still allowing for low efficacy options such as pin base MR-16 luminaires. This requirement would also allow for the use of GU-24 base recessed downlights if they are combined with a manual dimmer or vacancy sensor.

3.2.2 Bathroom Lighting

This section outlines the typical current practice for residential bathroom lighting, as well as the proposed code change recommendations.

Current Practice

Using data from the 2010 New Home Energy Survey, typical residential bathroom lighting was assessed. The 80-dwelling-unit sample contained 71 master bathrooms, 100 "secondary" (non-master) full baths, and 25 powder rooms. The average installed lighting wattage across all bathrooms types is 227 Watts. Master bathrooms have an average of 317 Watts, while secondary bathrooms have an average of 190 Watts, and powder rooms have an average of 115 Watts.

In addition to total installed load, the analysis looked at lamp types in use in bathrooms. Incandescent lamp sources make up the overwhelming majority of installed watts in bathrooms at 81% by wattage, with the remainder being mostly compact fluorescent lamp types. Lamp source use was also broken down by bathroom type, as illustrated below in Figure 9, Figure 10, and Figure 11.

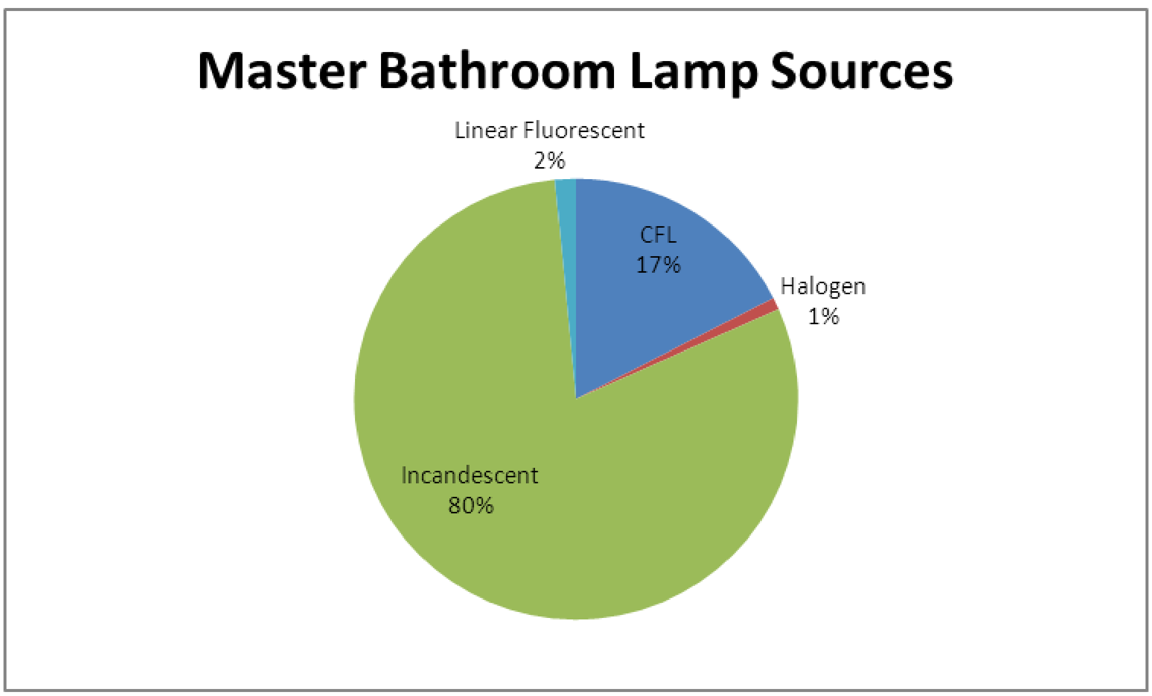

Figure 9: Master bathroom lamp sources (by wattage)

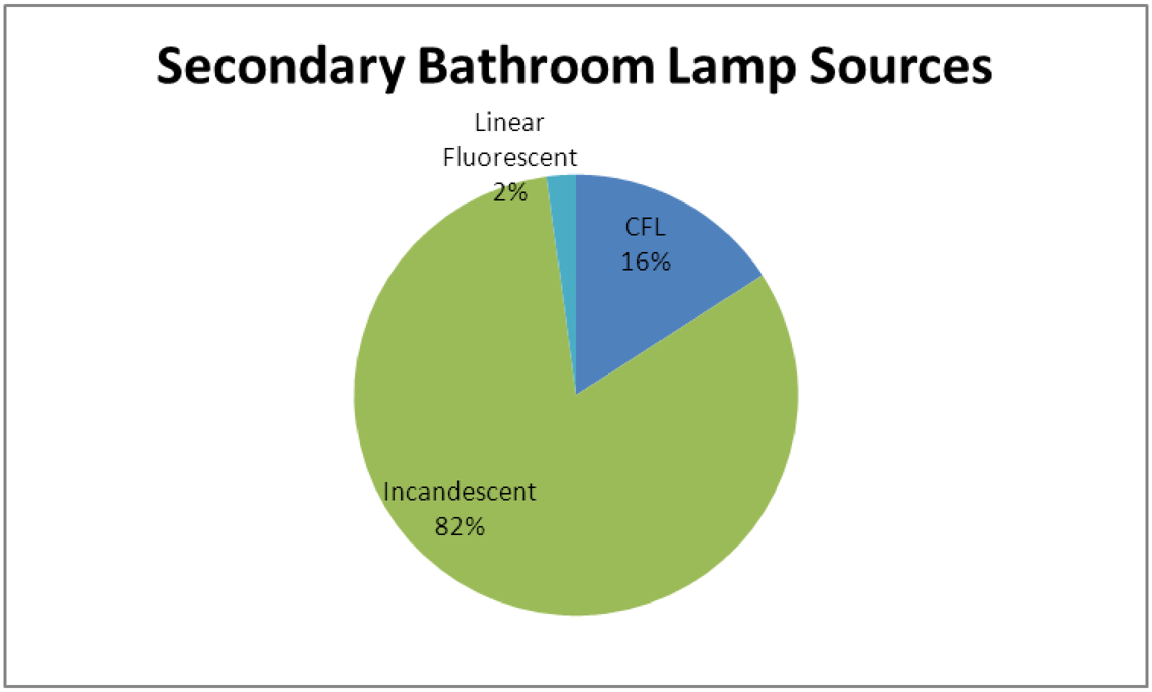

Figure 10: Secondary bathroom lamp sources (by wattage)

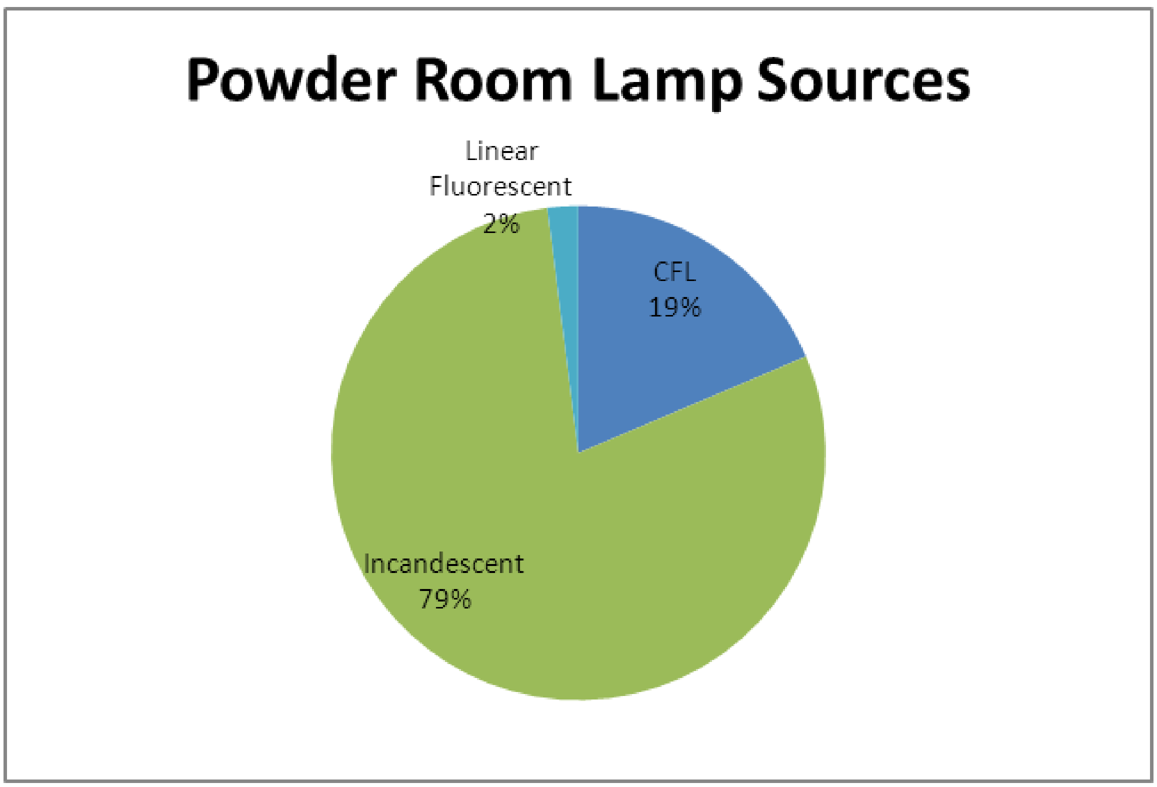

Figure 11: Powder room lamp sources (by wattage)

Recommendations

Based on the finding shown above, as well as on the cost effectiveness data discussed in section 3.3, we are proposing the following changes to the bathroom lighting requirements:

- Require at least one high efficacy luminaire (as defined by Table 150-C) in each bathroom
- Require vacancy sensors for all lighting in bathrooms

As shown in section 3.3.1, high efficacy luminaires are cost effective across all residential room types. In addition, section 3.3.2 showed that vacancy sensors are also cost effective across all room types.

3.2.3 Kitchen Lighting

The sections below outline typical current practice for residential kitchen lighting, as well as the proposed code change recommendations.

Current Practice

Using data from the 2010 New Home Energy Survey, typical residential kitchen lighting was assessed. Kitchens in the 80-dwelling-unit sample had an average installed lighting load of 205 Watts (not including integral equipment lighting such as vent hood lighting). As shown below in Figure 12, the majority of kitchen lighting in the survey sample was fluorescent, with compact fluorescent sources comprising 35% of the total kitchen wattage, and linear fluorescent making up 32% of installed kitchen wattage. Incandescent and halogen sources represent 28% and 4% of installed kitchen lighting, respectively, with LED lighting making up the remaining 1%.

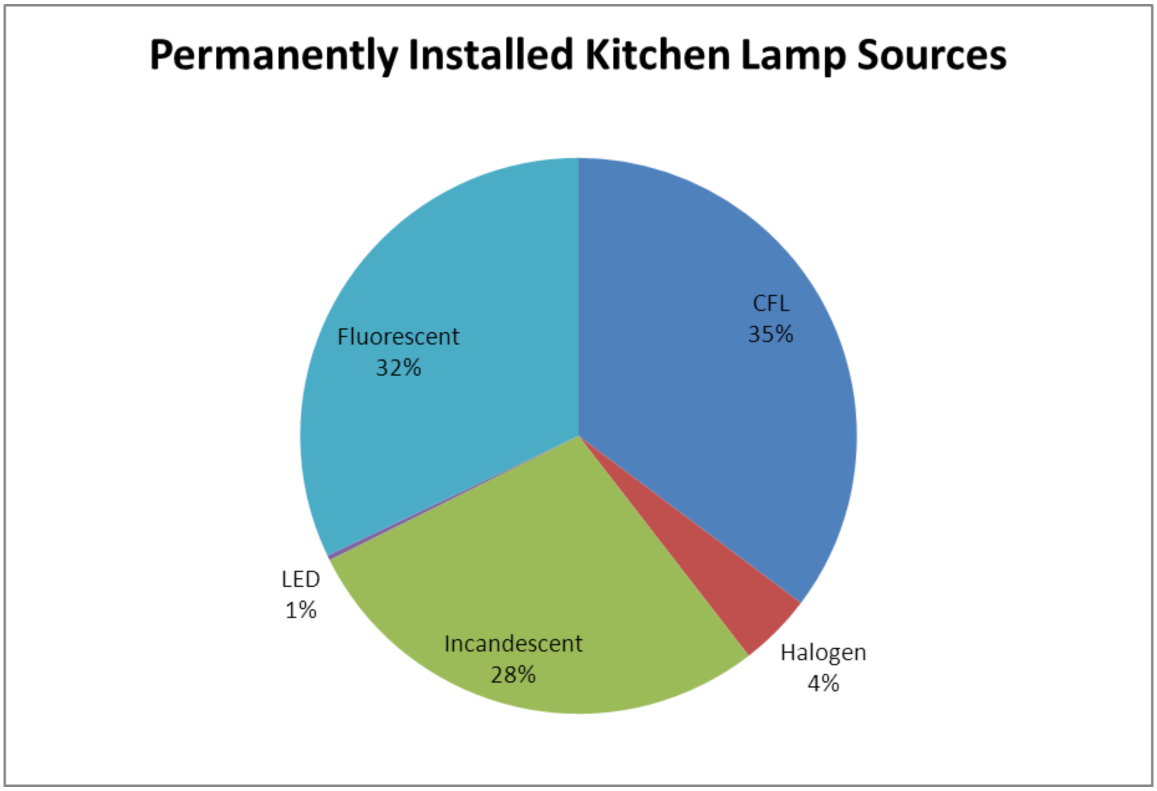

Figure 12: Percentage of permanently installed lamp sources in kitchens (by wattage)

As the data in Figure 12 shows, the average residential kitchen is well within the current code requirement that no more than 50% of kitchen lighting is low efficacy. Based on these initial findings we considered proposing fixed wattage caps for low efficacy lighting wattage in kitchens. The analysis considered two different cap levels, one at 100W for homes under 2500 square feet and 150W for homes over 2500 square feet, and another at 150 W for homes under 2500 square feet and 250W for homes over 2500 square feet. Figure 13 shows the resulting average lighting load when the proposed thresholds are applied to the existing survey sample. A closer look at the existing survey sample also found that a handful of the surveyed homes exceeded the existing code. For the basis of comparison, the original sample was also adjusted to bring the non-compliant homes into compliance with current code. The average code compliant kitchen wattage is also shown in Figure 13.

	Low Efficacy Average (W)	High Efficacy Average (W)	Total Average (W)
Existing Sample	63	139	202
Title 24 Compliant	40	146	186
Threshold A (100/150)	25	154	179
Threshold B (150/250)	31	152	183

Figure 13: Kitchen lighting wattage with proposed thresholds

As the data in Figure 13 shows, the proposed low efficacy lighting caps result in only marginal savings over the current code requirements.

Figure 14, below, compares the cumulative average high efficacy lighting wattage in kitchens with the ranked order of low efficacy lighting wattage. As the graph shows, only a small proportion of existing homes have significant levels of low efficacy lighting wattage. In fact, over two thirds of the surveyed kitchens had no low efficacy lighting at all.

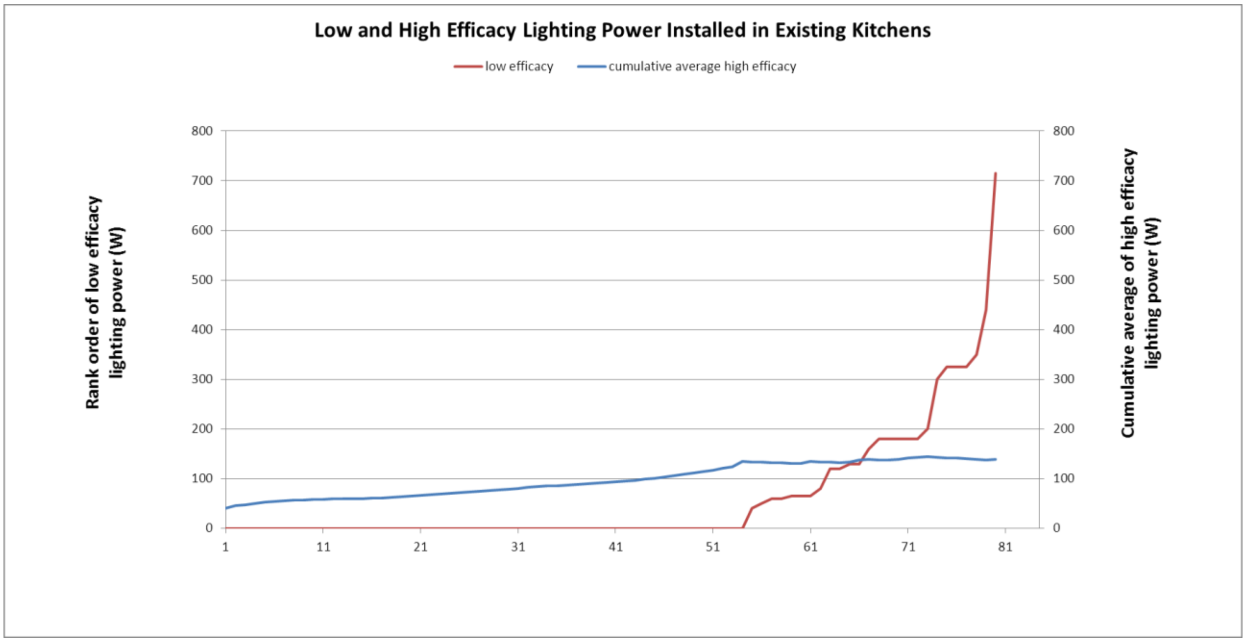

Figure 14: Low and High Efficacy Lighting Power in Kitchens

In addition to the limited savings potential suggested by the data, feedback from some stakeholders suggested that certain color quality and light distribution needs cannot yet be achieved with high efficacy sources.

Recommendations

Based on the findings discussed above, we recommend maintaining the current kitchen lighting provisions, including the 50% low efficacy wattage limit.

Because we are recommending eliminating the additional low efficacy credit in kitchens for using controls and high efficacy luminaires in utility rooms, garages, closets and laundry rooms, we are also proposing an additional low efficacy wattage allowance in kitchens of 50W for homes under 2500 square feet and 100W for homes over 2500 square feet, if all kitchen luminaires are controlled with a vacancy sensor or other control system.

3.2.4 Garage, Laundry Room, Closet and Utility Room Lighting

The sections below outline the current practice for lighting in residential garages, laundry rooms, closets and utility rooms, as well as the proposed code change recommendations.

Current Practice

The current code (2008) requires high efficacy luminaires in garages, laundry rooms, closets and utility rooms. However, an exception allows for low efficacy luminaires if the lighting is controlled by a vacancy sensor. In addition, the existing code provides an additional low efficacy allowance in kitchens if all garage, laundry room, closet and utility room lighting is high efficacy and controlled by vacancy sensors.

As discussed above in section 3.2.3, the new kitchen lighting proposal would eliminate the additional low efficacy allowance, but there is still opportunity to simplify these requirements. As shown below in Figure 15, data from the 2010 New Home Energy Survey shows that only 28% of utility room lighting wattage is low efficacy, with the balance being made up of either linear fluorescent or compact fluorescent. The 2010 New Home Energy Survey did not distinguish between utility rooms and laundry rooms, so the data shown in Figure 15 is assumed to include laundry rooms.

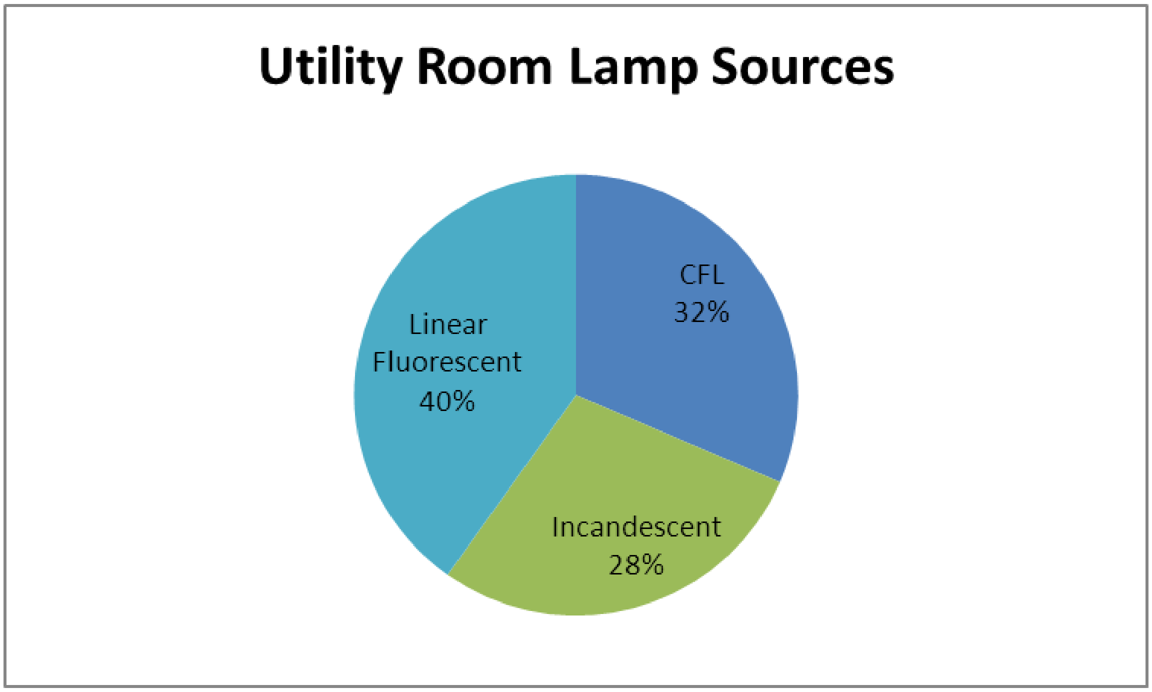

Figure 15: Percentage of permanently installed lamp sources in Utility Rooms (by wattage)

Conversely, Figure 16 shows that the vast majority of closet lighting (75% of installed Watts) is incandescent. The 2010 New Home Energy Survey did not document the square footages of the individual spaces, so it is not possible to know how many of the closets in the sample fall below the 70 square foot threshold to exempt them from the current code requirements, but this data suggests that there is an opportunity for further energy savings in closets.

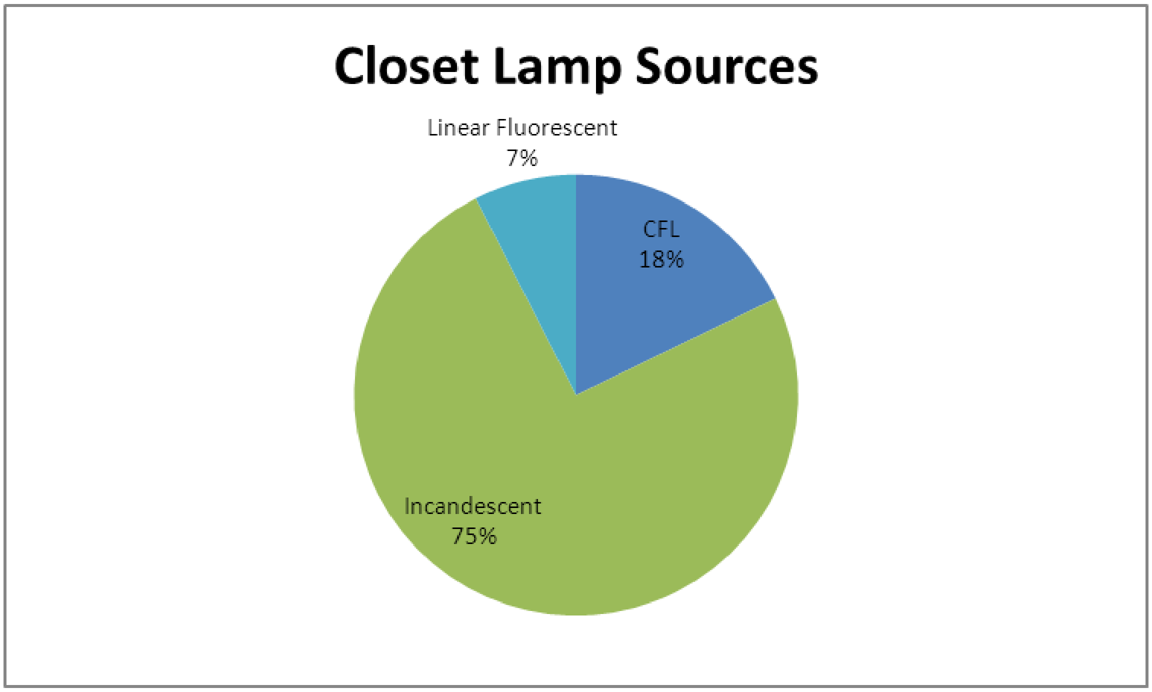

Figure 16: Percentage of permanently installed lamp sources in Closets (by wattage)

The 2010 New Home Energy Survey did not have data for lighting in garages.

Recommendations

Based on the cost effectiveness data discussed in section 3.1.4, we have proposed eliminating the existing exceptions in code section 150(k)10, and instead requiring high efficacy luminaires and vacancy sensors for all lighting in garages, laundry rooms, closets and utility rooms (the exception to the control requirement for closets under 70 square feet would be maintained). As shown in section 3.3.2, above, vacancy sensors were found to be cost effective for all of these space types.

The hours of use for garages (1.2), utility rooms (1.4) and closets (1.4[3]) suggests that the lighting in these rooms may be left on at times when the rooms are not in use. Therefore the requirement for a mandatory vacancy sensor is likely to be effective in saving energy.

3.2.5 Hallway Lighting

The sections below outline the typical current practice for residential hallway lighting, as well as the proposed code change recommendations.

Current Practice

Current code does not have specific requirements that apply to hallway lighting. The current requirements for hallway lighting are found in section 150(k)11, "Lighting other than in Kitchens, Bathrooms, Garages, Laundry Rooms, Closets and Utility Rooms." This section requires high efficacy luminaires unless they are controlled by a dimmer.

[3] The "Other" category was used for closets, see Figure 7. This number is consistent with the hours of use for closets reported in the California Baseline Lighting Efficiency Technology Report (CEC, 1997).

Despite the requirement for high efficacy lighting in hallways (unless dimmers are used), the 2010 New Home Energy Survey found that the vast majority installed lighting wattage in hallways is low efficacy sources. As shown in Figure 17, below, only 9% of hallway lighting is compact fluorescent, with the remaining 91% made up of low efficacy halogen or incandescent. The same data shows that the average dwelling units has 207 Watts of permanently installed hallway lighting.

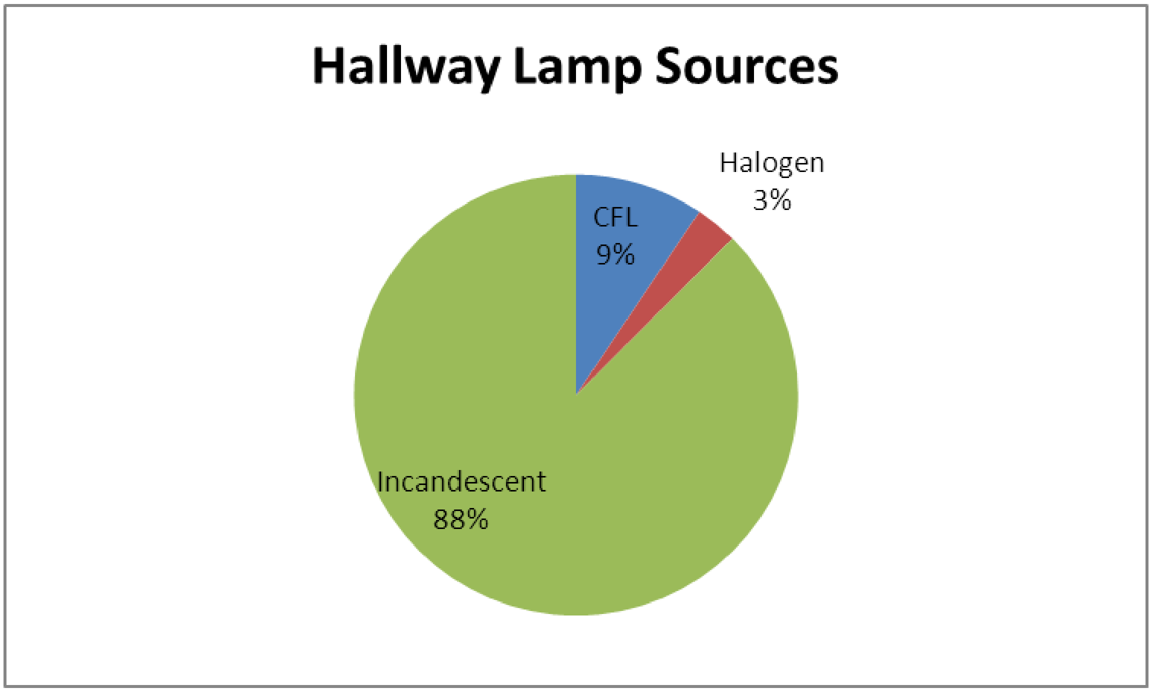

Figure 17: Percentage of permanently installed lamp sources in Hallways (by Wattage)

This data suggests that there are opportunities for further savings in residential hallway lighting.

Recommendations

Current code language allows low efficacy lighting in hallways if it is controlled with dimmers. However, based on the high percentage of low efficacy luminaires used in hallways and the short amount of time for which people actually occupy hallways, we have proposed also allowing vacancy sensors as an appropriate means of controlling low efficacy lighting. We believe that this is appropriate because hallways are not “living spaces”, i.e. people do not occupy the space unless they are moving around.

Section 3.3.2, above, showed that vacancy sensors are cost effective in all room types, including hallways, and they are generally assumed to result in more energy savings than manual dimmers.

In addition, in an effort to encourage high efficacy luminaires in hallways, this proposal recommends adding a requirement that any decorative chandeliers, pendants or sconces in hallways not have medium screw-base sockets. This would limit decorative lighting to either pin-based halogen sources or, more commonly, high efficacy luminaires such as GU-24 based fixtures. This proposal could also help drive the market for more high efficacy decorative luminaire options.

3.3 Cost Effectiveness and Statewide Savings

The cost effectiveness of the proposed residential lighting requirements is examined below. Analysis of cost effectiveness is based on average hours of lighting use for each type of space.

3.3.1 Cost Effectiveness of Luminaires

Although high efficacy luminaires have been proven cost effective in previous code cycles, cost effectiveness for various high efficacy luminaire types was analyzed for this proposal based on new product cost and energy cost data. The analysis includes basic approaches like pin-base compact fluorescent luminaires, but it also includes more specialized or advanced technologies like decorative LED pendants, LED under-cabinet lighting and LED alternatives to halogen PAR and reflector lamps. Cost effectiveness of dimmers and vacancy sensors was also examined.

Each luminaire and control type was analyzed by room type based on the hours of use data shown above in Figure 7. Cost effectiveness analysis is a per-luminaire assessment, based on a 30-year life cycle for residential measures, and use conservative average TDV values to estimate savings. As described in section 2.1, cost data is based on retail pricing, and confirmed by lighting industry stakeholders. The retail pricing is assumed to be a conservative cost estimate because contractors and builders typically have access to equipment directly from distributors at lower costs. Figure 18 shows first cost for the various measures including luminaire housing and lamp. Where no lamp cost is listed, the LED light engine is integral to the luminaire. Figure 19 shows the cost, wattage assumptions, and rated life used for various lamp source types in the cost effectiveness assessments.

Low Efficacy Baseline	Luminaire First Cost	Lamp First Cost	Total First Cost	High Efficacy Measure	Luminaire First Cost	Lamp First Cost	Total First Cost
Incandescent downlight	$ 16.00	$ 0.65	$ 16.65	GU-24 (LED) with dimmer	$ 16.00	$ 35.00	$ 51.00
Incandescent downlight	$ 16.00	$ 0.65	$ 16.65	Pin-base CFL downlight	$ 45.00	$ 3.00	$ 48.00
Halogen Undercabinet	$ 100.00	$ 9.00	$ 109.00	LED Undercabinet	$ 145.00	$ -	$ 145.00
Halogen Decorative	$ 66.00	$ 5.00	$ 71.00	LED Decorative	$ 83.00	$ -	$ 83.00
Incandescent downlight	$ 16.00	$ 0.65	$ 16.65	LED downlight	$ 17.00	$ 78.00	$ 95.00

Figure 18: Luminaire First Cost

Lamp	Cost	Wattage	Life (hours)
Incandescent A-Lamp	$0.65	57	1,000
Halogen Par Lamp	$5.00	45	3,000
Pin-based Compact Fluorescent	$3.00	26	8,000
GU-24 base LED	$35.00	15	30,000
LED Downlight Replacement	$78.00	12	35,000
LED Undercabinet Replacement	$145.00	7.4	50,000
LED Decorative Pendant Replacement	$83.00	4.7	50,000

Figure 19: Cost and wattage assumptions for lamp types

Each of the following tables shows the cost effectiveness assessment for a specific high-efficacy luminaire type. Cost and savings estimates are based on a comparison to the equivalent low-efficacy fixture. Various factors such as hours of use, energy costs and maintenance costs used to determine cost effectiveness are summarized in the table. Both lifecycle cost (LCC) savings and overall benefit/cost ratios are also shown (highlighted in yellow) to illustrate cost effectiveness. Positive LCC values and benefit/cost ratios of more than 1.0 are considered cost effective. Cost effectiveness for each space is also summarized in the far right column (highlighted in green, below), indicating either "passes" or "fails."

Figure 20 shows the cost effectiveness analysis for a GU-24 base recessed downlight with a dimmer. While GU-24 base recessed downlights cannot be considered as high efficacy luminaires, this is expected to be the main compliance path for the proposed recessed downlight requirement.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Baseline Maintenance Costs (PV$)	Proposed Measure Maintenance Costs (PV$)	additional maintenance costs	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	17	$ 59.47	$ 21.77	$ -	$ (21.77)	$ 81.24	**$ 51.24**	**2.71**	**YES**
Bathroom	1.4	511	14	$ 48.98	$ 18.46	$ -	$ (18.46)	$ 67.44	**$ 37.44**	**2.25**	**YES**
Hall	1.2	438	12	$ 41.98	$ 15.29	$ -	$ (15.29)	$ 57.27	**$ 27.27**	**1.91**	**YES**
Dining	1.9	694	19	$ 66.47	$ 25.11	$ -	$ (25.11)	$ 91.58	**$ 61.58**	**3.05**	**YES**
Living	2.3	840	23	$ 80.46	$ 31.71	$ -	$ (31.71)	$ 112.17	**$ 82.17**	**3.74**	**YES**
Utility	1.4	511	14	$ 48.98	$ 18.46	$ -	$ (18.46)	$ 67.44	**$ 37.44**	**2.25**	**YES**
Kitchen	2.5	913	25	$ 87.46	$ 32.49	$ -	$ (32.49)	$ 119.95	**$ 89.95**	**4.00**	**YES**

Figure 20: Cost Effectiveness Analysis for GU-24 downlight with dimmer

The tables below show cost effectiveness analysis for a range of typical luminaire types.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Low Effciacy Maintenance Costs (PV$)	High Effciacy Maintenance Costs (PV$)	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	19	$ 68.28	$ 7.55	$ 3.43	$ 72.40	**$ 40.40**	**2.26**	**YES**
Bathroom	1.4	511	16	$ 56.23	$ 6.28	$ 1.87	$ 60.64	**$ 28.64**	**1.89**	**YES**
Hall	1.2	438	14	$ 48.20	$ 5.36	$ 1.71	$ 51.85	**$ 19.85**	**1.62**	**YES**
Dining	1.9	694	21	$ 76.31	$ 8.45	$ 3.58	$ 81.18	**$ 49.18**	**2.54**	**YES**
Living	2.3	840	26	$ 92.38	$ 10.46	$ 5.17	$ 97.67	**$ 65.67**	**3.05**	**YES**
Utility	1.4	511	16	$ 56.23	$ 6.28	$ 1.87	$ 60.64	**$ 28.64**	**1.89**	**YES**
Kitchen	2.5	913	28	$ 100.41	$ 11.32	$ 5.41	$ 106.33	**$ 74.33**	**3.32**	**YES**

Figure 21: Cost Effectiveness Analysis for pin-based compact fluorescent downlights

Figure 21 shows that pin-based compact fluorescent luminaires are cost effective in all room types.

In addition to this typical scenario, HMG also assessed the cost effectiveness of more specialized lighting applications using even higher efficacy LED sources. Figure 22, below, shows the cost effectiveness analysis for LED under-cabinet lighting, and Figure 23 shows the cost effectiveness analysis for LED decorative pendants. Both tables show that these LED applications are cost effective in all space types.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Low Efficacy Maintenance Costs (PV$)	High Efficacy Maintenance Costs (PV$)	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	33	$ 115.86	$ 15.39	$ -	**$ 86.25**	**2.92**	**YES**
Bathroom	1.4	511	27	$ 95.41	$ 10.74	$ -	**$ 61.15**	**2.36**	**YES**
Hall	1.2	438	23	$ 81.78	$ 9.88	$ -	**$ 46.67**	**2.04**	**YES**
Dining	1.9	694	36	$ 129.49	$ 16.36	$ -	**$ 100.85**	**3.24**	**YES**
Living	2.3	840	44	$ 156.75	$ 21.40	$ -	**$ 133.15**	**3.96**	**YES**
Utility	1.4	511	27	$ 95.41	$ 10.74	$ -	**$ 61.15**	**2.36**	**YES**
Kitchen	2.5	913	48	$ 170.38	$ 22.30	$ -	**$ 147.68**	**4.28**	**YES**

Figure 22: Cost Effectiveness Analysis for LED under-cabinet lighting

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Low Effciacy Maintenance Costs (PV$)	High Effciacy Maintenance Costs (PV$)	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	22	$ 77.75	$ 9.25	$ -	**$ 70.00**	**5.12**	**YES**
Bathroom	1.4	511	18	$ 64.03	$ 8.55	$ -	**$ 55.58**	**4.27**	**YES**
Hall	1.2	438	15	$ 54.88	$ 6.04	$ -	**$ 43.92**	**3.58**	**YES**
Dining	1.9	694	24	$ 86.90	$ 11.89	$ -	**$ 81.79**	**5.81**	**YES**
Living	2.3	840	30	$ 105.20	$ 15.15	$ -	**$ 103.35**	**7.08**	**YES**
Utility	1.4	511	18	$ 64.03	$ 8.55	$ -	**$ 55.58**	**4.27**	**YES**
Kitchen	2.5	913	32	$ 114.34	$ 15.62	$ -	**$ 112.96**	**7.64**	**YES**

Figure 23: Cost Effectiveness for LED decorative pendants

Based on the findings from Figure 22 and Figure 23, above, HMG also performed a cost effectiveness analysis for LED recessed downlights. Similar to the analysis for compact fluorescent luminaires, shown above in Figure 21, the LED luminaires were compared to typical incandescent recessed luminaires. As shown below in Figure 24, LED recessed downlights were also found to be cost effective for all residential space types. However, life cycle cost savings and benefit cost ratios for LED downlights are lower than those for other high efficacy products.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Low Effciacy Maintenance Costs (PV$)	High Effciacy Maintenance Costs (PV$)	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	28	$ 99.12	$ 2.40	$ -	$ 101.52	**$ 22.52**	**1.29**	**YES**
Bathroom	1.4	511	23	$ 81.63	$ 1.97	$ -	$ 83.60	**$ 4.60**	**1.06**	**YES**
Hall	1.2	438	20	$ 69.97	$ 1.59	$ -	$ 71.56	**$ (7.44)**	**0.91**	**NO**
Dining	1.9	694	31	$ 110.78	$ 2.52	$ -	$ 113.30	**$ 34.30**	**1.43**	**YES**
Living	2.3	840	38	$ 134.10	$ 3.28	$ -	$ 137.38	**$ 58.38**	**1.74**	**YES**
Utility	1.4	511	23	$ 81.63	$ 1.97	$ -	$ 83.60	**$ 4.60**	**1.06**	**YES**
Kitchen	2.5	913	41	$ 145.76	$ 3.65	$ -	$ 149.42	**$ 70.42**	**1.89**	**YES**

Figure 24: Cost Effectiveness Analysis for LED recessed downlights

Overall, the analysis confirms that high efficacy luminaire types are cost effective, and that even higher efficacy LED luminaires are cost effective in all cases. It is expected that the increased availability of a wide range of LED products at more competitive prices will make LED luminaires even more cost effective in the near future.

3.3.2 Cost Effectiveness of Controls

In addition to the cost effectiveness assessments for luminaires, discussed above, HMG also performed cost effectiveness analysis for residential vacancy sensors and dimming controls. The cost effectiveness assessments below are similar to the luminaire analysis above, except that rather than comparing low efficacy and high efficacy sources, the analysis below compares controlled and uncontrolled scenarios. The analysis for both control types is based on controlling a single 57 Watt incandescent luminaire, i.e. the cost-effectiveness of controls is assessed relative to a low-efficacy luminaire, and the cost-effectiveness of converting that luminaire to high efficacy (see section 3.3.1) is assessed based on the reduced energy use of the fixture, adjusted for controls.

This cost analysis is conservative because it is based on only one luminaire being controlled, whereas vacancy sensors or dimmers typically control multiple luminaires in a space.

The analysis for vacancy sensors assumes they will achieve an energy savings of 30% over standard manual switching. This assumption is based on a commercial meta-study (study of studies) performed by the Lighting Research Center that estimated savings of 25% in private offices, 30% in shared spaces with scheduled use (e.g. school classrooms), and 40% in shared spaces with non-scheduled use (e.g. open offices, corridors, restrooms, etc.) (LRC, 2003). A later study for Southern California Edison found that the 40% estimate was optimistic for open offices (depending heavily on how the lighting is circuited) (SCE, 2009). Based on these studies, 30% savings was determined to represent an average savings across space types. Savings in residential are expected to be at least as high as these commercial examples, since dwelling units typically have fewer occupants, and are usually not occupied during the day (note that this value is not the same as the conservative Power Adjustment Factor value in Table 146-C in the 2008 Title 24). Figure 25 summarizes the cost and estimated savings assumptions for dimmers and vacancy sensors.

Control	**Added Cost**	**Estimated Savings**
Dimmer	$10.00	10%
Vacancy Sensor	$24.57	30%

Figure 25: Cost and savings estimates for control devices

As shown below in Figure 26, vacancy sensors were found to be cost effective in all residential space types.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Non-Control Maintenance Costs (PV$)	Controlled Maintenance Costs (PV$)	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	11	$ 37.67	$ 2.40	$ 1.68	**$ 13.82**	**1.56**	**YES**
Bathroom	1.4	511	9	$ 31.02	$ 1.97	$ 1.38	**$ 7.04**	**1.29**	**YES**
Hall	1.2	438	7	$ 26.59	$ 1.59	$ 1.11	**$ 2.49**	**1.10**	**YES**
Dining	1.9	694	12	$ 42.10	$ 2.52	$ 1.77	**$ 18.28**	**1.74**	**YES**
Living	2.3	840	14	$ 50.96	$ 3.28	$ 2.29	**$ 27.37**	**2.11**	**YES**
Utility	1.4	511	9	$ 31.02	$ 1.97	$ 1.38	**$ 7.04**	**1.29**	**YES**
Kitchen	2.5	913	16	$ 55.39	$ 3.65	$ 2.56	**$ 31.92**	**2.30**	**YES**

Figure 26: Cost Effectiveness Analysis for vacancy sensors

Similarly, cost effectiveness for dimmers assumes a savings of 10% over standard manual switching. This assumption is based on the manual dimming power adjustment factor (PAF) of 0.1 used for commercial lighting in table 146-C (the PAF of 0.1 allows for 10% reduction in the calculated wattage for all controlled luminaires when determining wattage allowances for commercial spaces). This is considered a conservative assumption because PAFs generally provide less credit than the amount of savings expected from the control measure. As Figure 27 shows, manual dimming was found to be cost effective for all residential space types, except hallways, where the benefit/cost ratio is slightly less than one.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Non-Control Maintenance Costs (PV$)	Controlled Maintenance Costs (PV$)	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	4	$ 13.22	$ 2.40	$ 2.16	**$ 3.46**	**1.35**	**YES**
Bathroom	1.4	511	3	$ 10.88	$ 1.97	$ 1.77	**$ 1.08**	**1.11**	**YES**
Hall	1.2	438	3	$ 9.33	$ 1.59	$ 1.43	**$ (0.51)**	**0.95**	**NO**
Dining	1.9	694	4	$ 14.77	$ 2.52	$ 2.27	**$ 5.02**	**1.50**	**YES**
Living	2.3	840	5	$ 17.88	$ 3.28	$ 2.95	**$ 8.21**	**1.82**	**YES**
Utility	1.4	511	3	$ 10.88	$ 1.97	$ 1.77	**$ 1.08**	**1.11**	**YES**
Kitchen	2.5	913	5	$ 19.44	$ 3.65	$ 3.29	**$ 9.80**	**1.98**	**YES**

Figure 27: Cost Effectiveness Analysis for manual dimming

In addition to the two control scenarios discussed above, an additional analysis was performed to determine the cost effectiveness of high efficacy lamp sources controlled with occupancy sensors. The analysis compares the typical residential lighting code baseline of a 57W incandescent controlled with a dimmer to a 26W pin-based compact fluorescent controlled with a vacancy sensor. Assumptions for control savings are the same as those used in the scenarios above. Figure 28, below, shows that high efficacy luminaires controlled by vacancy sensors are cost effective for all space types.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Code Baseline Maintenance Costs (PV$)	Controlled High Efficacy Maintenance Costs (PV$)	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	21	$ 72.91	$ 2.40	$ 3.43	$ 71.87	**$ 25.30**	**1.54**	**YES**
Bathroom	1.4	511	17	$ 60.04	$ 1.97	$ 1.87	$ 60.14	**$ 13.57**	**1.29**	**YES**
Hall	1.2	438	14	$ 51.46	$ 1.59	$ 1.71	$ 51.34	**$ 4.77**	**1.10**	**YES**
Dining	1.9	694	23	$ 81.48	$ 2.52	$ 3.58	$ 80.43	**$ 33.86**	**1.73**	**YES**
Living	2.3	840	28	$ 98.64	$ 3.28	$ 5.17	$ 96.75	**$ 50.18**	**2.08**	**YES**
Utility	1.4	511	17	$ 60.04	$ 1.97	$ 1.87	$ 60.14	**$ 13.57**	**1.29**	**YES**
Kitchen	2.5	913	30	$ 107.22	$ 3.65	$ 5.41	$ 105.46	**$ 58.89**	**2.26**	**YES**

Figure 28: Cost Effectiveness Analysis for high efficacy luminaire with vacancy sensor

Overall, as shown in the examples above, the analysis confirms that vacancy sensors for both low and high efficacy luminaires across all residential space types, and manual dimmers are cost effective for all space types except hallways.

The primary finding is that vacancy sensors save significantly more energy than dimmers and are more cost-effective. Dimmers should be used sparingly especially as an alternative to high efficacy lighting. For those spaces where the base case is mostly low efficiency lighting, high efficacy lighting saves twice as much energy as a vacancy sensors and 5 times as much energy as dimmers. High efficiency lighting is cost-effective for all sockets. Thus as amenity issues are addressed for high efficacy sources, this should be the primary efficiency measure with added savings from some spaces enhanced with vacancy sensors.

3.3.3 Cost Effectiveness of Non Line of Sight Vacancy Sensors

In order to address concerns about the use of vacancy sensors in spaces such as garages where people work with power tools and are more likely to be hidden from the direct "line of sight" of an infra-red vacancy sensor by obstructions such as vehicles, lumber, recreational equipment etc., an additional analysis was conducted to determine the cost effectiveness of non-line–of-sight vacancy sensors, such as ultrasonic or dual-technology (ultrasonic plus infra-red) sensors. The analysis assumed an ultrasonic vacancy sensor, at an equipment cost of $54.00, controlling 64W of lighting (i.e. two 32W T8 tubes or two 32W CFLs). The occupancy sensor is assumed to save 30% of the lighting energy. As shown in Figure 29, below, this scenario is not cost effective in garages.

Socket Location	Hours per day	Hours per year	Energy Savings (kWh/yr)	Energy Cost Savings (PV$)	Code Baseline Maintenance Costs (PV$)	Controlled High Efficacy Maintenance Costs (PV$)	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Garage	1.2	438	8	$ 29.85	$ -	$ -	$ 29.85	**$ (24.15)**	**0.55**	**NO**

Figure 29: Cost Effectiveness Analysis for ultrasonic vacancy sensor

Although ultrasonic vacancy sensors in garages are not cost effective individually, when this measure is considered in conjunction with the other proposed measures, the combined residential lighting measures are cost effective. Figure 30, below, shows the combined Life-Cycle Cost (LCC) Savings for the proposed measures in a typical house.

Measure	Avg No of Rooms per House	LCC Savings per Room	Total LCC Savings per House
Bathroom Measures	2.45	$ 28.64	$ 70.17
Utility Room	0.66	$ 13.57	$ 8.96
Garage	1.00	$ (24.15)	$ (24.15)
Total			**$ 54.97**

Figure 30: Combined Life-Cycle Cost Savings for Residential Measures

Total LCC Savings is based on the average number of each room type per house, based on the 2010 New Home Energy Survey. The table assumes a worst case scenario of 1.00 garages per average dwelling unit because the 2010 New Home Energy Survey did not contain data on garages. In this table, the positive total LCC value indicates that the combined measures are cost effective. The recessed downlight measures are not included in Figure 30 because the use of recessed downlights varies from room to room, whereas bathroom and utility room measures will be uniformly applicable in all cases.

3.3.4 Statewide Savings

Figure 31, below, shows the estimated statewide savings of all proposed measures. Estimated installed load savings based on the existing data set were scaled up to represent estimated housing starts in 2013. In addition, average hours of use profiles for each space are used to estimate overall statewide savings (shown in GWh/year). For the measures eliminating medium screw-base sockets, savings estimates assume that 20% are replaced with other non-medium screw-base low efficacy luminaires.

Measure	Installed Savings (MW)	Average Daily Hours of Use	Statewide Savings (GWh/year)
No Medium Base Cans			
Bedroom	2.9	1.7	1.81
Living Room	5.6	2.3	4.70
Dining Room	2.3	1.9	1.57
Hallway	9.1	1.2	3.98
Bathrooms	1.3	1.4	1.30
Kitchens	1.4	2.5	1.32
No Medium Base Decorative in Hallways	4.2	1.2	1.85
Bathroom Measures	2.8	1.4	2.76
Utility / Closet High Efficacy	3.0	1.4	2.01
Total	**32.6**		**21.31**

Figure 31: Statewide Savings for all proposed measures

Based on the 2010 New Home Energy Survey, the typical dwelling unit contains the room type quantities outlined below in Figure 32. Closet and Hallway numbers represent the typical number of these space types that contain permanently installed lighting. The quantities shown in Figure 32 represent the typical dwelling unit basis for the statewide savings shown in Figure 31, above.

Space	Avg No per Dwelling Unit
Kitchen	1.00
Master Bathroom	0.89
Secondary Bathroom	1.25
Powder room	0.31
Closets	0.94
Master Bedrooms	0.93
Secondary Bedrooms	1.91
Utility Rooms	0.66
Hallways	0.69
Living Rooms	1.26
Dining Rooms	0.80

Figure 32: Average Room Type Quantities per Dwelling Unit

3.4 Materials Impacts

The proposed measures will result in an increased use of materials to provide the components for the high efficacy lamps and occupancy sensors required by code. This section describes those impacts.

Figure 33 shows the number of luminaires that would affected by each proposed requirement, e.g., the number of incandescent lamps in recessed cans (according to the PIER data) that would be required to become high efficacy luminaires. The calculation assumes that 40% of the affected luminaires would be fitted with CFLs, while the remaining 60% would be fitted with LEDs or another type of high efficacy lamp. The materials impact is calculated from the CFLs only, i.e. the LEDs are assumed to have no impact on materials.

Measure		Count of affected luminaires per multifamily prototype building (870sf)	Count of affected luminaires per single-family prototype building (2700sf)	Total statewide number of affected luminaires	Of which LEDs	Of which occ Sensors
No medium screw based cans	Bedroom	0.47	1.47	85209	34084	0
	Living room	0.93	2.89	167054	66822	0
	Dining room	0.41	1.26	72876	29150	0
	Hallway	1.44	4.45	257869	103148	0
	Bathroom	0.22	0.68	39241	15696	0
	Kitchen	0.24	0.76	43726	17490	0
	Hallway Decorative	0.50	1.55	89694	35877	0
Bathroom Measures		0.12	0.37	21302	8521	0
Utility / Closet High Efficacy		1.11	3.45	199568	0	199568
				TOTAL	310788	199568

Figure 33. Basis for Calculation of Materials Impacts

Figure 34 shows the projected statewide weight of additional materials required for the proposed measures, based on the materials impacts *per component* shown in Section 6.2 Data for Materials Impacts. The statewide total is shown for all the measures originally proposed by the IOUs, and also for the subset of measures that are included in the CEC's language (i.e., excluding the ban on medium screw-based recessed cans).

<table>
<tr><th colspan="2" rowspan="2">Component</th><th colspan="6">Materials impact (lbs/year)</th></tr>
<tr><th>Mercury</th><th>Lead</th><th>Copper</th><th>Steel</th><th>Plastic</th><th>Others (Identify)</th></tr>
<tr><td rowspan="7">No medium screw based cans</td><td>Bedroom</td><td>17</td><td>17</td><td>5113</td><td>3408</td><td>8521</td><td>0</td></tr>
<tr><td>Living room</td><td>34</td><td>33</td><td>10023</td><td>6682</td><td>16705</td><td>0</td></tr>
<tr><td>Dining room</td><td>15</td><td>15</td><td>4373</td><td>2915</td><td>7288</td><td>0</td></tr>
<tr><td>Hallway</td><td>52</td><td>52</td><td>15472</td><td>10315</td><td>25787</td><td>0</td></tr>
<tr><td>Bathroom</td><td>8</td><td>8</td><td>2354</td><td>1570</td><td>3924</td><td>0</td></tr>
<tr><td>Kitchen</td><td>9</td><td>9</td><td>2624</td><td>1749</td><td>4373</td><td>0</td></tr>
<tr><td>Hallway Decorative</td><td>18</td><td>18</td><td>5382</td><td>3588</td><td>8969</td><td>0</td></tr>
<tr><td colspan="2">Bathroom Measures</td><td>4</td><td>4</td><td>1278</td><td>852</td><td>2130</td><td>0</td></tr>
<tr><td colspan="2">Utility / Closet High Efficacy</td><td>100</td><td>100</td><td>29935</td><td>19957</td><td>49892</td><td>0</td></tr>
<tr><td colspan="2">Statewide total for all measures originally proposed by IOU team</td><td>257</td><td>255</td><td>76553</td><td>51036</td><td>127589</td><td>0</td></tr>
<tr><td colspan="2">Statewide total for measures included in CEC language</td><td>104</td><td>104</td><td>31213</td><td>20809</td><td>52022</td><td>0</td></tr>
</table>

Figure 34. Statewide Materials Impact

4. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

4.1 Summary of Code Change Proposals

Residential lighting requirements are located in code section 150(k). All proposed changes are contained in that section. Recommendations discussed above are summarized in the sections below.

4.1.1 Recessed Downlights

We have proposed required that all recessed downlights shall not have medium screw-base sockets.

4.1.2 Efficacy and Controls Requirements in Bathrooms

We have proposed creating a distinct section for bathroom lighting (currently combined with garages, laundry rooms, closets and utility rooms in section 150(k)10) with the following changes:

- Require at least one high efficacy luminaire (as defined by Table 150-C) in each bathroom
- Require vacancy sensors for all lighting in bathrooms

See section 3.2 for detailed discussion.

4.1.3 Relocation of Low Efficacy Allowance for Kitchens

Because we have proposed eliminating the existing low efficacy kitchen wattage allowance for using controls in garages, laundry rooms, closets and utility rooms, we are proposing adding the same allowance for using controls in kitchens.

4.1.4 Eliminate Exceptions and Require Controls in Garages, Laundry Rooms, Closets and Utility Rooms

We have proposed eliminating the existing exceptions in code section 150(k)10, and instead requiring high efficacy luminaires and vacancy sensors for all lighting in garages, laundry rooms, closets and utility rooms (the exception to the control requirement for closets under 70 square feet would be maintained). See section 3.2.4 for detailed discussion.

4.1.5 Decorative Requirements for Hallways

We have proposed creating a distinct section for hallway lighting (separate from the current requirements in current section 150(k)11) which would require high efficacy lighting, or allow for low efficacy luminaires if dimmers or vacancy sensors are installed. This proposal also recommends adding a requirement that any decorative chandeliers, pendants or sconces in hallways not have medium screw-base sockets.

See section 3.2.5 for detailed discussion.

4.1.6 Require All High Efficacy Lighting for Reach Code

HMG has also performed research and analysis to support proposals for residential lighting requirements in the Reach Code. Cost effectiveness analysis presented in section 0 show that high efficacy lighting is cost effective in all residential space types. Therefore, we have proposed that the reach code require that all permanently installed lighting be high efficacy. Generic proposed language is presented below in section 4.3.

4.2 Code Language Recommended by the Investor-Owned Utilities Codes and Standards Team

This is the language that was originally proposed to the CEC by the IOU Codes and Standards team as a result of the stakeholder meetings and analysis described in this report, and as a result of initial discussions with the CEC. This language was presented in the Draft CASE report.

4.2.1 Section 150(k)

New text to be included as part of luminaire requirements in section 150(k):

Recessed Downlights: Recessed downlights shall not contain medium screw-base sockets

Additional proposed changes to section 150(k):

8. Lighting in Kitchens. A minimum of 50 percent of the total rated wattage of permanently installed lighting in kitchens shall be high efficacy.

EXCEPTION to Section 150(k)8A: Up to 50 watts for dwelling units less than or equal to 2,500 ft^2 or 100 watts for dwelling units larger than 2,500 ft^2 may be exempt from the 50 percent high efficacy requirement when~~ the following conditions are met~~:

A. All ~~low efficacy~~ luminaires in the kitchen are controlled by a ~~manual-on occupant~~ **vacancy** sensor, dimmer, energy management control system (EMCS), or a multi-scene programmable control system~~; and~~

~~B. All permanently installed luminaires in garages, laundry rooms, closets greater than 70 square feet, and utility rooms are high efficacy and are controlled by a manual-on occupant sensor.~~

…

10. Lighting in Bathrooms. Lighting installed in bathrooms shall meet all of the following requirements:

A. A minimum of one high efficacy luminaire shall be installed in each bathroom; and

B. All installed bathroom lighting shall be controlled by a vacancy sensor.

~~10.~~11. Lighting in ~~Bathrooms,~~ Garages, Laundry Rooms, Closets, and Utility Rooms. Permanently installed luminaires in bathrooms, attached and detached garages, laundry rooms, closets and utility rooms shall be high efficacy luminaires **and shall be controlled by a vacancy sensor. Vacancy sensors in garages shall not rely only on passive infra-red to detect occupants.**

~~EXCEPTION 1 to Section 150(k)10: Permanently installed low efficacy luminaires shall be allowed provided that they are controlled by a manual-on occupant sensor certified to comply with the applicable requirements of Section 119.~~

EXCEPTION ~~2~~ to Section 150(k)10: ~~Permanently installed low efficacy l~~**L**uminaires in closets less than 70 square feet are not required to be **high efficacy** ~~controlled by a manual-on occupant sensor~~.

12. Lighting in Hallways. Lighting installed in hallways shall meet all of the following requirements:

A. **Be high efficacy or controlled by a vacancy sensor or dimmer; and**
B. **Chandeliers, pendants, and sconces installed in hallways shall not contain medium screw-base sockets.**

~~11.~~13. Lighting other than in Kitchens, Bathrooms, Garages, Laundry Rooms, Closets, ~~and~~ Utility Rooms**, and Hallways**. Permanently installed luminaires located in rooms or areas other than in kitchens, bathrooms, garages, laundry rooms, closets, ~~and~~ utility rooms**, and hallways** shall be high efficacy luminaires**, or shall be controlled by either a vacancy sensor or dimmer.**

~~EXCEPTION 1 to Section 150(k)11: Permanently installed low efficacy luminaires shall be allowed provided they are controlled by either a dimmer switch that complies with the applicable requirements of Section 119, or by a manual-on occupant sensor that complies with the applicable requirements of Section 119.~~

EXCEPTION ~~2~~ to Section 150(k)1~~1~~3: Lighting in detached storage buildings less than 1000 square feet located on a residential site is not required to comply with Section 150(k)1~~1~~3.

4.3 Code Language Proposed by the California Energy Commission

Below is the text of the code language proposed by the California Energy Commission for section 150(k). This language was sent by the CEC to the California investor-owned utilities Codes and Standards Team on August 17, 2011.

~~7~~**2**. **Switching Devices and Controls.**

A. ~~All permanently installed h~~**H**igh efficacy luminaires shall be switched separately from low efficacy luminaires.

~~B. All exhaust fans shall be switched separately from lighting system(s).~~

~~EXCEPTION to Section 150(k)7B: An exhaust fan with an integral lighting system where the lighting system can be manually turned on and off while allowing the fan to continue to operate for an extended period of time.~~

B. Exhaust fans shall be switched separately from lighting systems, or if an exhaust fan has an integral lighting system, the lighting system shall be separately switched in accordance with the applicable provision of Section 150(k) while allowing the fan to continue to operate for an extended period of time.

C. ~~All permanently installed l~~**L**uminaires shall be switched with readily accessible controls that permit the luminaires to be manually switched ~~on~~**ON** and ~~off~~**OFF**.

D. ~~All l~~**L**ighting controls and equipment shall be installed in accordance with the manufacturer's instructions.

E. **No controls shall bypass a dimmer or vacancy sensor function** ~~A lighting circuit controlled by more than one switch~~ where **that**~~a~~ dimmer or ~~manual-on occupant~~**vacancy** sensor has been installed to comply with Section 150(k) ~~shall meet the following~~

~~conditions:~~

~~i. No controls shall bypass the dimmer or manual-on occupant sensor function.~~

~~ii. The dimmer or manual-on occupant sensor shall comply with the applicable requirements of Section 119.~~

F. ~~Manual-on occupant sensors, motion sensors, and dimmers~~**Lighting controls** ~~installed to comply with Section 150(k)~~ shall comply with the applicable requirements of Section 119.

G. An Energy Management Control System may be used to comply with dimmer requirements in Section 150(k) if at a minimum it provides the functionality of a dimmer in accordance with Section 119, meets the acceptance test requirements in Section 134 for dimming lighting control systems, and complies with all of the applicable requirements in Section 150(k)2.

H. An Energy Management Control System may be used to comply with vacancy sensor requirements in Section 150(k) if at a minimum it provides the functionality of a vacancy sensor in accordance with Section 119, meets the acceptance test requirements in Section 134 for vacancy sensor lighting control systems, and complies with all of the applicable requirements in Section 150(k)2.

I. A multi-scene programmable controller may be used to comply with dimmer requirements in Section 150(k) if at a minimum it provides the functionality of a dimmer in accordance with Section 119, and complies with all of the applicable requirements in Section 150(k)2.

3. Lighting in Kitchens. A minimum of 50 percent of the total rated wattage of permanently installed lighting in kitchens shall be high efficacy.

EXCEPTION to Section 150(k)3: Up to 50 watts for dwelling units less than or equal to 2,500 ft² or 100 watts for dwelling units larger than 2,500 ft² may be exempt from the 50 percent high efficacy requirement when ~~the following conditions are met:~~

~~A. A~~all ~~low efficacy luminaires~~ **lighting** in the kitchen **is controlled in accordance with the applicable provisions in Section 150(k)2, and is** ~~are~~ **also** controlled by ~~a manual-on occupant~~ **vacancy** sensor**s**~~,~~ **or** dimmer**s**~~,~~**.** ~~energy management control system (EMCS), or a multi-scene programmable control system; and~~

~~B. All permanently installed luminaires in garages, laundry rooms, closets greater than 70 square feet, and utility rooms are high efficacy and are controlled by a manual-on occupant sensor.~~

NOTE: For the purpose of ~~this requirement~~ **compliance with Section 150(k)**, kitchen lighting includes all permanently installed lighting in the kitchen except for lighting that is internal to cabinets for the purpose of illuminating only the inside of the cabinets. Lighting in areas adjacent to the kitchen, including but not limited to dining and nook areas, are considered kitchen lighting if they are not separately switched from kitchen lighting.…

5. Lighting in Bathrooms. Lighting installed in bathrooms shall meet the following requirements:

A. A minimum of one high efficacy luminaire shall be installed in each bathroom; and

B. All other lighting installed in each bathroom shall be high efficacy or controlled by vacancy sensors.

6. Lighting in~~ Bathrooms,~~ Garages, Laundry Rooms, ~~Closets, ~~and Utility Rooms. ~~Permanently~~ **Lighting** installed ~~luminaires ~~in ~~bathrooms, ~~attached and detached garages, laundry rooms, ~~closets~~ and utility rooms shall be high efficacy luminaires **and shall be controlled by vacancy sensors. Vacancy sensors in garages shall use ultrasonic, dual technology, or other methods for occupant detection which do not rely solely on line of sight.**

~~EXCEPTION 1 to Section 150(k)10: Permanently installed low efficacy luminaires shall be allowed provided that they are controlled by a manual-on occupant sensor certified to comply with the applicable requirements of Section 119.~~

~~EXCEPTION 2 to Section 150(k)10: Permanently installed low efficacy luminaires in closets less than 70 square feet are not required to be controlled by a manual-on occupant sensor.~~

7. Lighting other than in Kitchens, Bathrooms, Garages, Laundry Rooms, ~~Closets, ~~and Utility Rooms. ~~Permanently ~~**Lighting** installed ~~luminaires located ~~in rooms or areas other than in kitchens, bathrooms, garages, laundry rooms, ~~closets, ~~and utility rooms shall be high efficacy~~ luminaires~~**, or shall be controlled by either dimmers or vacancy sensors.**

EXCEPTION 1 to Section 150(k)7: Luminaires in closets less than 70 square feet.

~~EXCEPTION 1 to Section 150(k)11: Permanently installed low efficacy luminaires shall be allowed provided they are controlled by either a dimmer switch that complies with the applicable requirements of Section 119, or by a manual-on occupant sensor that complies with the applicable requirements of Section 119.~~

EXCEPTION 2 to Section 150(k)~~11~~**7**: Lighting in detached storage buildings less than 1000 square feet located on a residential site~~ is not required to comply with Section 150(k)11~~.

4.4 Differences between the Recommended and Proposed Language

This section highlights the key differences between the language recommended by the IOU team (Section 4.2) and the language proposed by the CEC (Section 4.3).

4.4.1 Removal of the requirement that recessed luminaires should not have medium screw bases.

The removal of this measure eliminates almost all of the potential savings from residential lighting (14.68 out of 21.31 GWh/yr, see Figure 31).

Despite the stated intention of the CEC to remove this requirement, we believe that it should still be included in Code, and so we have maintained it in our final report. The rationale for the requirement was that the measure is cost-effective, and does not impinge on the ability of lighting designers to provide full-spectrum or warm color temperature lighting; it merely requires the vast majority of general lighting in production homes to be high efficacy. The text of the requirement was developed in discussion between the IOU team, the American Lighting Association (ALA), and the California Lighting Technology Center. We requested from the CEC a summary of the reasons why the requirement was dropped from the proposed language, but did not receive an explanation.

After the initial requirement had been agreed in discussion with the ALA, CEC received a written communication from the ALA opposing the requirement. We have reproduced (below) the memo from ALA and the responses provided by the IOU team to the ALA's concerns, which was sent to both the ALA and CEC on May 17 2011. We do not believe that the ALA concerns are valid; the concerns listed were factually incorrect, unsubstantiated, or irrelevant to the proposed measure.

Concerns Raised by ALA over the Proposed Requirement that Recessed Downlights should not have Medium Screw Bases

- There is already a "low-efficacy" classification, without exception, on E-26 sockets in Title 24 so the quantity of defined low-efficacy luminaires in residences is already being regulated.
  - **IOU team response**: Actually the *quantity* of low efficacy luminaires in residences is not "regulated"; any number of low efficacy luminaires can be installed as long as they have dimmers. New residential portable luminaires are similarly regulated via Title 20, of course.
- For downlight luminaires, an E-26 ban could also potentially limit homeowners from using new high-efficacy products in the future as such products are typically developed first by manufacturers with E-26 bases so as to take advantage of the large number of E-26 sockets already present in residential buildings nationwide.
  - **IOU team response**: There is already a well-developed market for leading-edge LED and CFL lamps with both GU-24 and proprietary lamp holders. These are widely available in home improvement stores. There appears to be no market lag for these products at present, and requiring them in new construction will help to support this market in future.
- There is no indication that E-26 sockets will become obsolete in the foreseeable future. Indeed, the current practice of developing new and leading-edge high-efficacy light source products first for E-26 sockets is expected to continue. The U.S. DOE "L Prize Competition" is an example of that practice.
  - **IOU team response**: Agreed. We are not trying to eliminate the market for the ES lamp holder. The market for ES lamps will remain strong indefinitely due to the retrofit market and because they will be allowed in all fixture types except recessed downlights under Title 24 2013.
- The E-26 socket has a 100-year history of safety, reliability and capability to hold and operate light sources properly even under conditions of vibration, shock, high and low ambient temperatures and other adverse conditions including fire and earthquake. No other light source socket has this record. The E-26 socket is one of the most tested of all electrical components in the history of lighting.
  - **IOU team response**. All lamp holders have to meet the same UL safety requirements. Has ALA lodged a complaint with UL regarding the sufficiency of the safety requirements for GU-24 and other lamp holders?
- Since consumers are very familiar with E-26 sockets, they tend to favor energy-efficient products with E-26 bases since they know installation of those products will not be difficult.
  - **IOU team response**: The installation of GU-24 lamps is just as easy as ES lamps, since the sockets have the same form factor and are the same size. No additional actions are required to replace a GU-24 lamp compared to an ES lamp. Manufacturers make a variety of proprietary LED lamp holders, and these luminaires all come with instructions for lamp replacement.

- Concerns about E-26 sockets "ending up with incandescent lamps in them" are misplaced as consumers learn more about the importance of energy-efficient lighting and standard incandescent bulbs are phased out according to existing legislative requirements.
  - **IOU team response**: ES sockets <u>will</u> "end up with incandescent lamps in them" indefinitely into the future, because there is no current or proposed Federal or State legislation to ban incandescent lamps. If there was a realistic prospect of incandescent lamps being banned, there would be no need to propose this change to Title 24. We agree that "standard" incandescent lamps will be phased out according to Federal standards, but the more-efficient incandescent lamps required by that standard do not even meet the current Title 24 definition of "high efficacy" and will be three to four times less efficient than the most efficient lamps available at the time the Federal standard goes into effect.
- There are some lighting applications in residences where a "low-efficacy" downlight equipped with a screw-base halogen reflector lamp remains the best choice for the proper application of light and where the "application efficacy" of the system is not properly measured by the light source efficacy. That choice should remain available to home owners.
  - **IOU team response**: Through the stakeholder process we have considered a wide range of residential lighting applications, and opinion among designers is split regarding whether LED lamps give sufficient color quality for all applications. Designers who want to continue to use incandescent lamps can do so, by using any type of luminaire except a recessed downlight. If the Energy Commission receives comments from designers that they would like to use halogen lamps in recessed fixtures, then we recommend that the language should require that those fixtures be adjustable (not fixed angle) fixtures.]

CEC language adds text in the Exception to 150(k)3 (Kitchen lighting)

The added text says "is controlled in accordance with the applicable provisions in Section 150(k)2," and removes EMCS and multi-scene programmable control systems as control options in the exception. This change is simply to clarify the language, and does not affect the code requirement.

CEC language revised vacancy sensor language in requirements for Garages

This amendment requires that sensors must not rely solely on line of sight for occupant detection. The amendment was made to ensure that people in garages can be detected by vacancy sensors even if the person is working underneath a car or behind some other kind of obstruction. This amendment was made to enhance safety and does not affect energy savings. The amended requirement requires a slightly more expensive type of vacancy sensor, but this is still cost-effective, as set out in Section 3.3.2.

CEC language removes "Closets" from room types under 150(k) 6 (Garages, Laundry Rooms, Utility Rooms)

This amendment makes closets fall under 150(k)7 (Lighting other than in Kitchens, Bathrooms, Garages, Utility Rooms, Laundry Rooms), so that they require high efficacy lighting, or dimmers or vacancy sensors, with an exception for closets under 70 square feet. This amendment was made because closets *over* 70 square feet should be considered "dressing rooms" and therefore low-efficacy lighting with dimmers should be allowed. This change does not significantly affect energy savings.

4.5 Recommended Reach Code Language

As discussed above in section 3.3, high efficacy luminaires are cost effective in all residential space types. As compact fluorescent and even LED luminaires become more affordable and higher in quality, their use will become more common in residential lighting. Figure 35 shows the potential savings of typical high efficacy replacement products when compared to the standard low efficacy option.

Low Efficacy Baseline	High Efficacy Replacement	W Savings	% Savings
57W Incandescent	14W Compact Fluorescent	43W	75%
57W Incandescent	12W LED	45W	79%

Figure 35: Savings from High Efficacy Lighting

Using a conservative estimate of 60% savings from high efficacy lighting to account for the broad range of luminaire products, Figure 36 illustrates the potential savings from all high efficacy lighting for a typical dwelling unit based on the 2010 New Home Energy Survey.

Space	Watts per room	Avg hours per day	Avg hours per year	Avg No per Dwelling Unit	Avg Watts per Dwelling Unit	Energy kWh/yr avg home	Existing Fraction low efficacy	Low efficacy kWh/yr per home	Potential savings from high efficacy kWh/yr
Kitchen	250	3.4	1,241	1.00	250	310	32%	99	60
Master Bathroom	317	2.0	730	0.89	281	205	80%	164	99
Secondary Bathroom	190	2.0	730	1.25	238	173	82%	142	85
Powder room	115	2.0	730	0.31	36	26	79%	21	12
Closets	78	1.4	511	0.94	73	37	75%	28	17
Master Bedrooms	107	1.4	511	0.93	99	51	93%	47	28
Secondary Bedrooms	94	1.4	511	1.91	180	92	87%	80	48
Utility Rooms	64	2.6	949	0.66	42	40	28%	11	7
Hallways	207	1.2	438	0.69	142	62	88%	55	33
Living Rooms	201	2.6	949	1.26	254	241	95%	229	137
Dining Rooms	235	3.4	1,241	0.80	188	233	94%	219	132
Totals					**1,783**	**1,472**		**1,096**	**657**

Figure 36: Potential Savings from High Efficacy Lighting for a Typical Dwelling Unit

Proposed language regarding residential lighting for Tier 1 of Title 24, Part 11 (CALGreen) is as follows:

All permanently installed indoor and outdoor lighting for residences shall be high efficacy as defined by Title 24, Part 6 Section 150(k).

Every luminaire shall be controlled by a lighting control device. The lighting control device shall be a vacancy sensor, dimmer, energy management control system (EMCS), or multi-scene programmable control system having dimming functionality.

EXCEPTION: Low efficacy lighting offset by an equal or greater nominal wattage photovoltaic system permanently installed on the site.

Exact structure and placement of the proposed language within CALGreen will be determined as the structure and form of that code develop.

5. Bibliography and Other Research

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6. Appendices

6.1 Residential Construction Forecast Details

6.1.1 Summary

The Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from the California Department of Finance and California Construction Industry Research Board (CIRB) building permits. The Department of Finance uses census years as independent data and interpolates the intermediate years using CIRB permits.

CASE stakeholders expressed concern that the Residential forecast was inaccurate compared with other available data (in 2010 CEC forecast estimate is 97,610 new units for single family and the CIRB estimate is 25,526 new units). In response to this discrepancy, HMG revised the CEC construction forecast estimates. The CIRB data projects an upward trend in construction activity for 2010-2011 and again from 2011-2012. HMG used the improvement from 2011-2012 and extrapolated the trend out to 2014. The improvement from 2011-2012 is projected to be 37%. Instead of using the percent improvement year on year to generate the 2014 estimate, HMG used the conservative value of the total units projected to be built in 2011-2012 and added this total to each subsequent year. This is the more conservative estimate and is appropriate for the statewide savings estimates. Based on this trend, the new construction activity is on pace to regain all ground lost by the recession by 2021. The multi-family construction forecasts are consistent between CEC and CIRB and no changes were made to the multi-family data.

Residential New Construction Estimate (2014)			
	Single Family	Multi-family Low Rise	Multi-family High Rise
CZ 1	378	94	-
CZ 2	1,175	684	140
CZ 3	1,224	863	1,408
CZ 4	2,688	616	1,583
CZ 5	522	269	158
CZ 6	1,188	1,252	1,593
CZ 7	2,158	1,912	1,029
CZ 8	1,966	1,629	2,249
CZ 9	2,269	1,986	2,633
CZ 10	8,848	2,645	1,029

CZ 11	3,228	820	81
CZ 12	9,777	2,165	1,701
CZ 13	6,917	1,755	239
CZ 14	1,639	726	-
CZ 15	1,925	748	-
CZ 16	1,500	583	-
Total	47,400	18,748	13,845

Residential construction forecast for 2014, in total dwelling units

6.1.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ). These 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and decay rate. Total construction is the sum of all existing dwelling units in a given category (Single family, Multi-family low rise and Multi-family high rise). Decay rate is the number of units that were assumed to be retrofitted, renovated or demolished. The difference in total construction between consecutive years (including each year's decay rate) approximates the new construction estimate for a given year.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has segmented all multi-family buildings into low rise and high rise space (where high rise is defined as buildings 4 stories and higher). This calculation is based on data collected by HMG through program implementation over the past 10 years. Though this sample is relatively small (711), it is the best available source of data to calculate the relative population of high rise and low rise units in a given FCZ.

Most years show close alignment between CIRB and CEC total construction estimates, however the CEC demand forecast models are a long-term projection of utility demand. The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022, and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure), however to estimate next year's construction, CIRB is a more reliable data set.

6.1.3 Citation

"Res Construction Forecast by BCZ v4"; Developed by Heschong Mahone Group with data sourced September, 2010 from Sharp, Gary at the California Energy Commission (CEC)

6.2 Data for Materials Impacts

This section sets out the raw data used to calculate the materials impacts of the proposed measure (see Overview: Section F), and the underlying data and assumptions.

Component	Weight per component (lbs)					
	Mercury	**Lead**	**Copper**	**Steel**	**Plastic**	**Others (Identify)**
3-lamp magnetic ballast for linear fluorescent, steel case	0.0080	0.0080	0.50	7.5	0	0
3-lamp electronic ballast for linear fluorescent, steel case	0.0025	0.0025	0.15	2.35	0	0
3-lamp electronic ballast linear fluorescent, plastic case	0.0005	0.0005	0.15	0.1	0.25	0
occupancy sensor	0.0005	0.0025	0.15	0.1	0.25	0
#12 power wiring, 100'	0	0	2	0	0	0
Cat 5 control wire, 100'	0	0	0.94	0	0	0
Linear fluorescent or compact fluorescent lamp	0.00001	0	0	0	0	0
35W PAR30 CMH lamp	0.0055	0	0	0	0	0
70W PAR30 CMH lamp	0.022	0	0	0	0	0
150W T6 CMH lamp	0.031	0	0	0	0	0

Figure 37. Materials Content of Typical Lighting Components, by Weight

Note that in Figure 37 the materials weights for an occupancy sensor are the same as those for an electronic ballast with a plastic case. We made this assumption because these two components are very close to the same size, and both contain electronics that control electrical power, within an insulated plastic case.

Mercury and Lead

The figures for mercury and lead were calculated in one of two ways. For electrical components (ballasts and occupancy sensors) they were calculated by using the maximum allowed percentages, by weight, under the European RoHS[4] requirements, which were incorporated into California state law effective January 1, 2010. The California Lighting Efficiency and Toxics Reduction Act applies RoHS to general purpose lights, i.e. "lamps, bulbs, tubes, or other electric devices that provide functional illumination for indoor residential, indoor commercial, and outdoor use." RoHS allows a maximum of 0.1% by total product weight for both mercury and lead. In practice the actual percentage of mercury and lead in these components may be very much *less* than these values, so the values in the table are conservative overestimates. Values for the total weight of these components (from which the lead and mercury values are calculated) were obtained from the online retailer www.ballastshop.com, and corroborated by the Lighting Research Center's Specifier Report on electronic ballasts[5].

[4] http://ec.europa.eu/environment/waste/weee/index_en.htm

[5] http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SREB2.pdf

For lamps, the mercury content of the lamp is almost always given by the lamp manufacturer in product cut sheets. The figures in the table are all based on high-volume products from the online catalog for Philips lighting. The amount of lead in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

Copper, Steel and Plastics

For ballasts, the amount of copper and steel was estimated by comparing the weight of the electronic plastic-cased ballast with the electronic steel-cased ballast, and assuming that the difference in weight was due to the steel case (i.e., that the electronics inside the two ballasts were the same). For the plastic ballast, a little more than half the weight of the component was assumed to come from the case, with the remaining weight being made up by copper and steel. For the magnetic ballast, the weights for copper and steel were scaled up from the electronic ballast, in proportion to the increase in total component weight (from 2.5lbs up to 8lbs).

For wiring, the weight of copper was calculated using the cross-sectional area of the conductor wires, and multiplying this by the nominal length (100') and by the density of copper (8.94 g/cm^3). The area of the conductor wires was obtained from online sources[6].

For lamps, the amount of copper, steel and plastic in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

[6] http://en.wikipedia.org/wiki/American_wire_gauge, and http://en.wikipedia.org/wiki/Cat_5