CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Residential Lighting

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, March 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.

Measure Information Template – Residential Lighting

2011 California Building Energy Efficiency Standards

[California Utilities Statewide Codes and Standards Team, March 2011]

CONTENTS

FIGURES

1. Overview

<table>
<tr><td>a. Measure Title</td><td>Residential Lighting</td></tr>
<tr><td>b. Description</td><td>
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.
</td></tr>
<tr><td>c. Type of Change</td><td>
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.
</td></tr>
<tr><td>d. Energy Benefits</td><td>
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 3.3 for more detailed discussion of energy benefits
<table>
<tr><th></th><th>Electricity Savings (kwh/yr)</th><th>Demand Savings (W)</th><th>Natural Gas Savings (Therms/yr)</th><th>30 yr TDV Electricity Savings</th><th>TDV Gas Savings</th></tr>
<tr><td>Per unit measure (luminaire) by space type</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CFL luminaire</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Bedroom</td><td>16</td><td>3.4</td><td>N/A</td><td>$56.23</td><td>N/A</td></tr>
<tr><td>Bathroom, Den</td><td>23</td><td>3.4</td><td>N/A</td><td>$80.33</td><td>N/A</td></tr>
<tr><td>Hall</td><td>25</td><td>3.4</td><td>N/A</td><td>$88.36</td><td>N/A</td></tr>
</table>
</td></tr>
</table>

Garage	26	3.4	N/A	$92.38	N/A
Living, Utility	29	3.4	N/A	$104.43	N/A
Yard	35	3.4	N/A	$124.51	N/A
Kitchen/Dining	38	3.4	N/A	$136.56	N/A
LED luminaire					
Bedroom	23	5.0	N/A	$81.63	N/A
Bathroom, Den	33	5.0	N/A	$116.61	N/A
Hall	36	5.0	N/A	$128.27	N/A
Garage	38	5.0	N/A	$134.10	N/A
Living, Utility	43	5.0	N/A	$151.59	N/A
Yard	51	5.0	N/A	$180.75	N/A
Kitchen/Dining	56	5.0	N/A	$198.24	N/A
Vacancy sensor					
Bedroom	17	3.6	N/A	$60.04	N/A
Bathroom, Den	24	3.6	N/A	$85.77	N/A
Hall	27	3.6	N/A	$94.35	N/A
Garage	28	3.6	N/A	$98.64	N/A
Living, Utility	31	3.6	N/A	$111.51	N/A
Yard	37	3.6	N/A	$132.95	N/A
Kitchen/Dining	41	3.6	N/A	$145.81	N/A
Per Prototype Building (870sf multifamily)	84	TBD	N/A	$298.22	N/A
Per Prototype Building (2700sf single family)	261	TBD	N/A	$925.50	N/A
Savings per square foot (870sf multifamily)	0.10	TBD	N/A	$0.34	N/A
Savings per square foot (2700sf single family)	0.10	TBD	N/A	$0.34	N/A

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 (Indentify)
Per Unit Measure	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Per Prototype Building	NC	NC	NC	NC	NC	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):

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

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. 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 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.

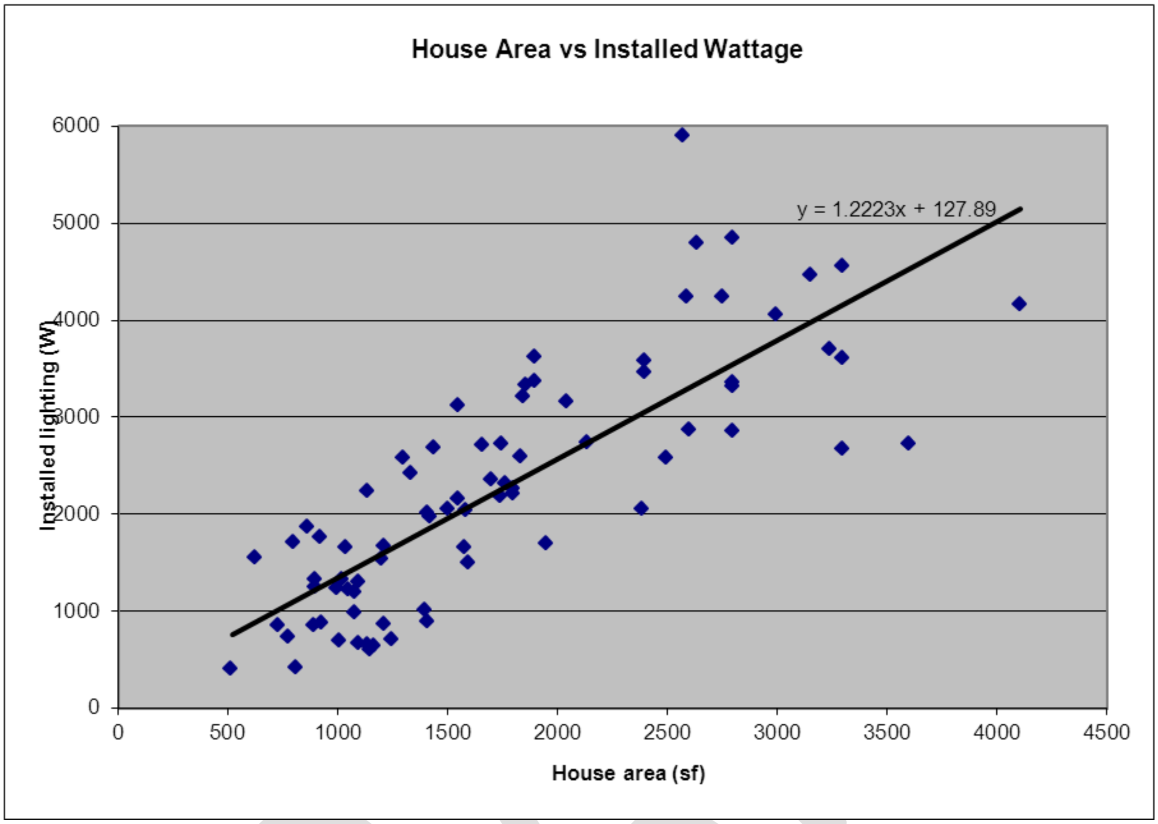

Figure 1: House Area vs Installed Wattage

3.1.2 Lighting Power per Room

The data was also used to determine typical installed wattage for common residential room types.

Room Type	Average Total Watts	Average Permanently Installed Watts	Average Portable Watts
Kitchens	250	250	--
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, 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	Average Permanently Installed Watts	Average Portable Watts
Kitchens	250	250	--
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) by room type

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.

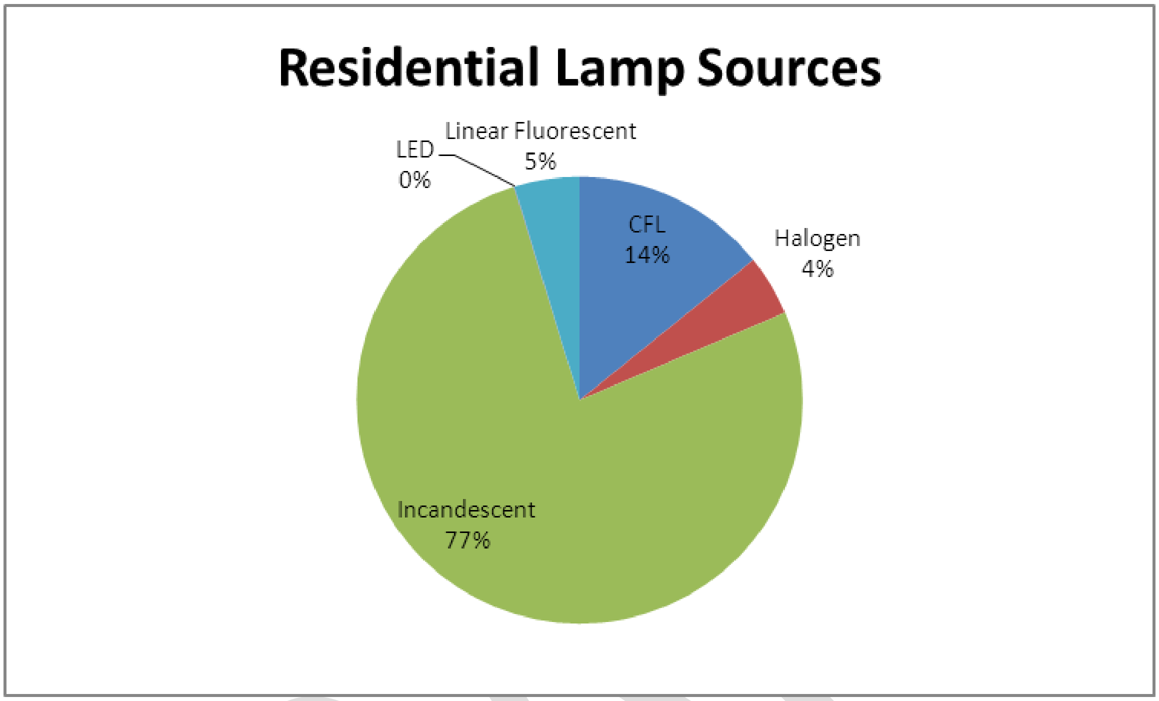

Figure 3: Percentage of Residential lamp sources (by Wattage)

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.

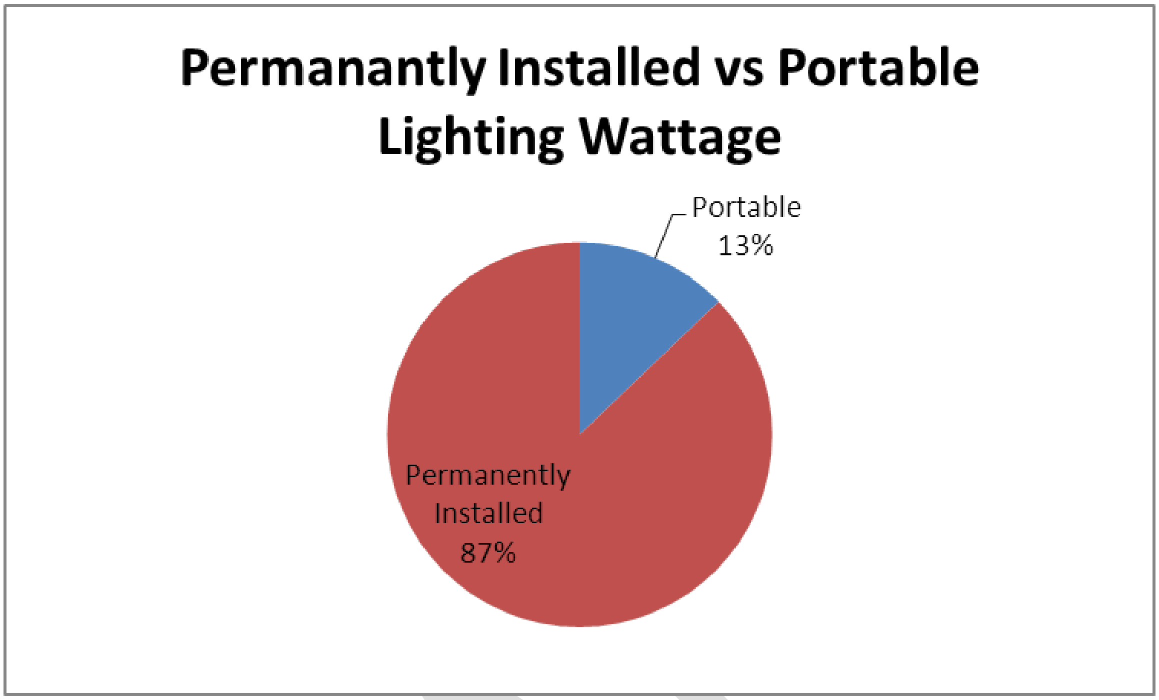

Figure 4: Permanently Installed vs Portable Lighting Wattage

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.

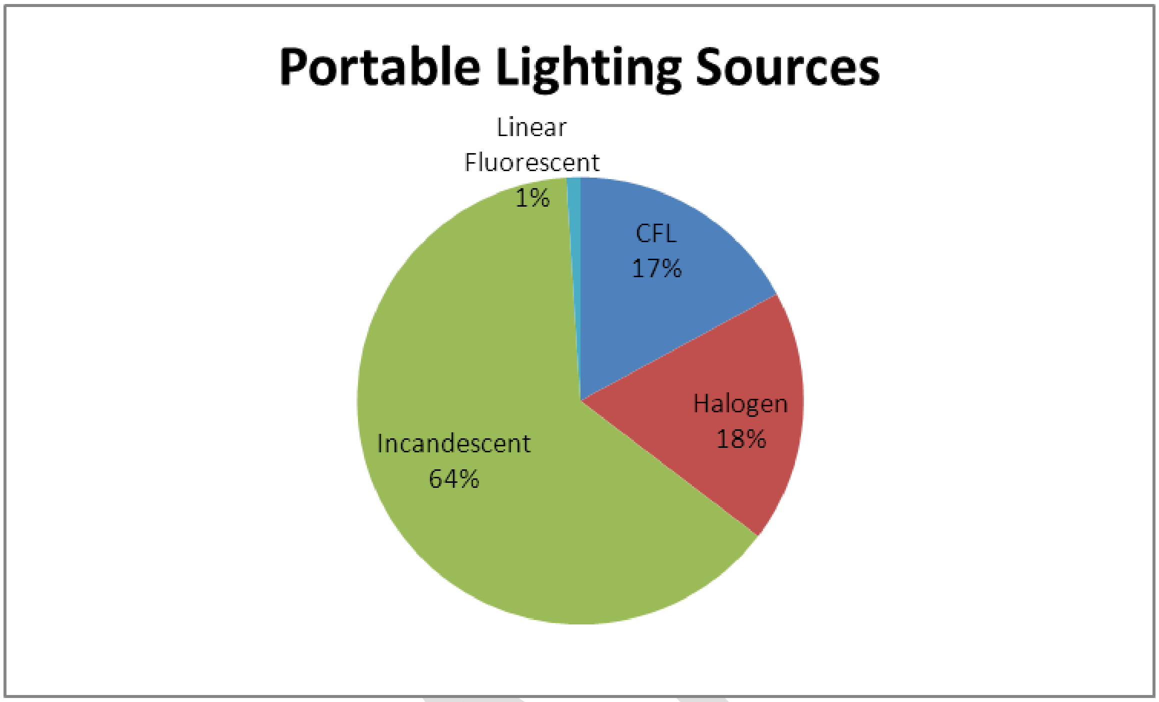

Figure 5: Percentage of Portable Lighting sources (by Wattage)

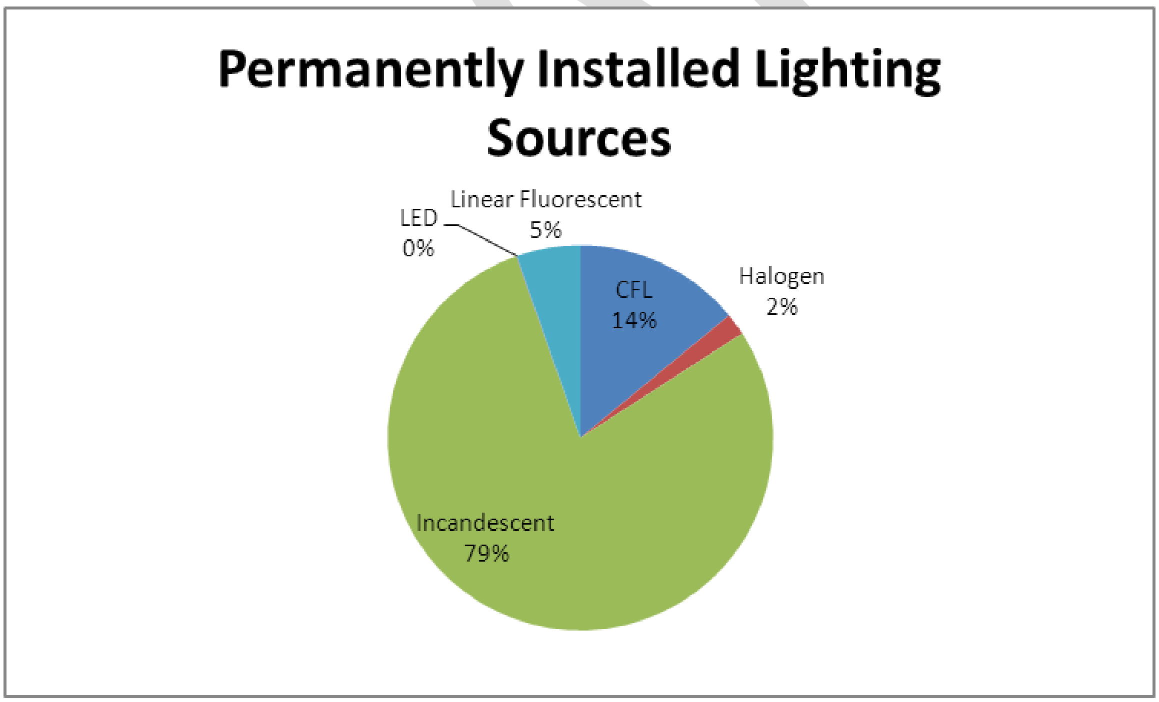

Figure 6: Percentage of Permanently Installed Lighting sources (by Wattage)

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 California Baseline Lighting Efficiency Technology Report (CEC, 1997). Because more recent hours of use data from the 2010 Upstream Lighting Program Final Evaluation Report (CPUC, 2010) 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 not considered representative of typical residential lighting

Room Type	Average Daily Hours of Use[1]
Bedroom	1.4
Bathroom	2.0
Den	2.0
Hallway	2.2
Garage	2.3
Living Room	2.6
Utility Room	2.6
Yard	3.1
Kitchen / Dining Room	3.4

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

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.

[1] CEC, 1997

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.

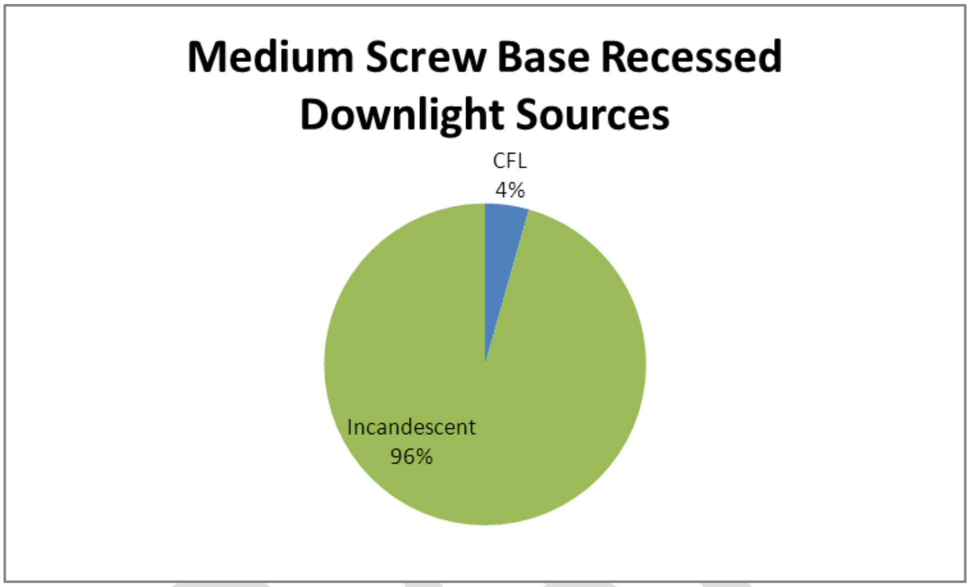

Figure 8: Medium screw-base recessed downlight sources (by wattage)

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" (nonmaster) 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.

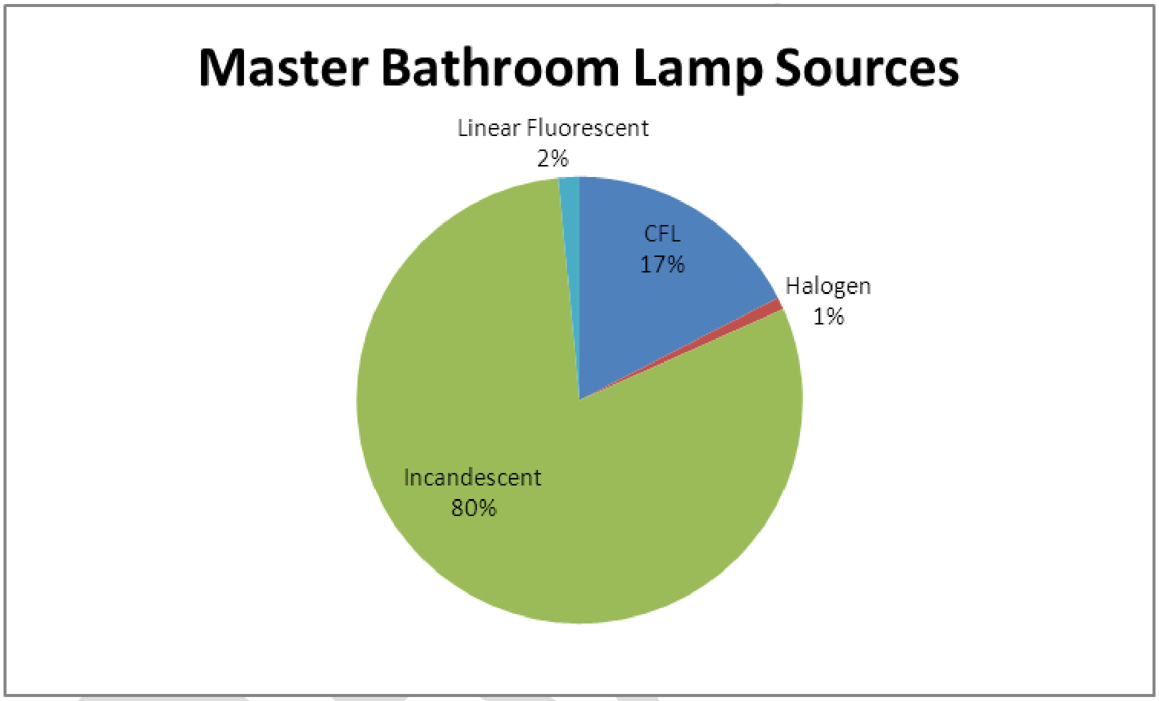

Figure 9: Master bathroom lamp sources (by wattage)

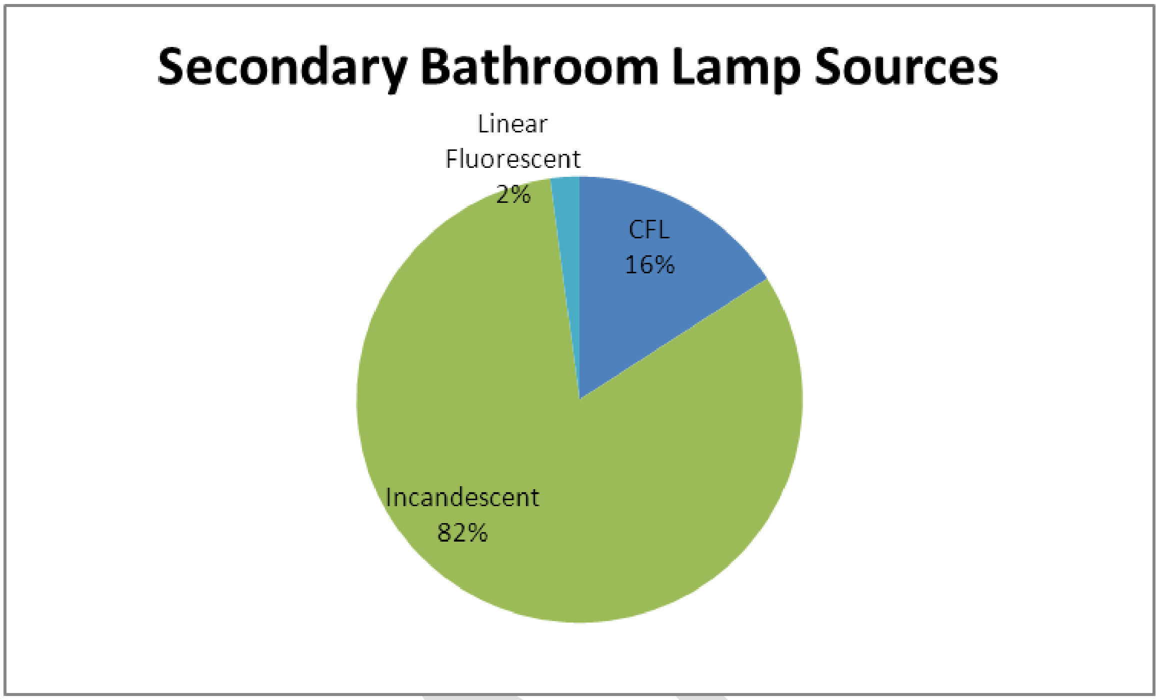

Figure 10: Secondary bathroom lamp sources (by wattage)

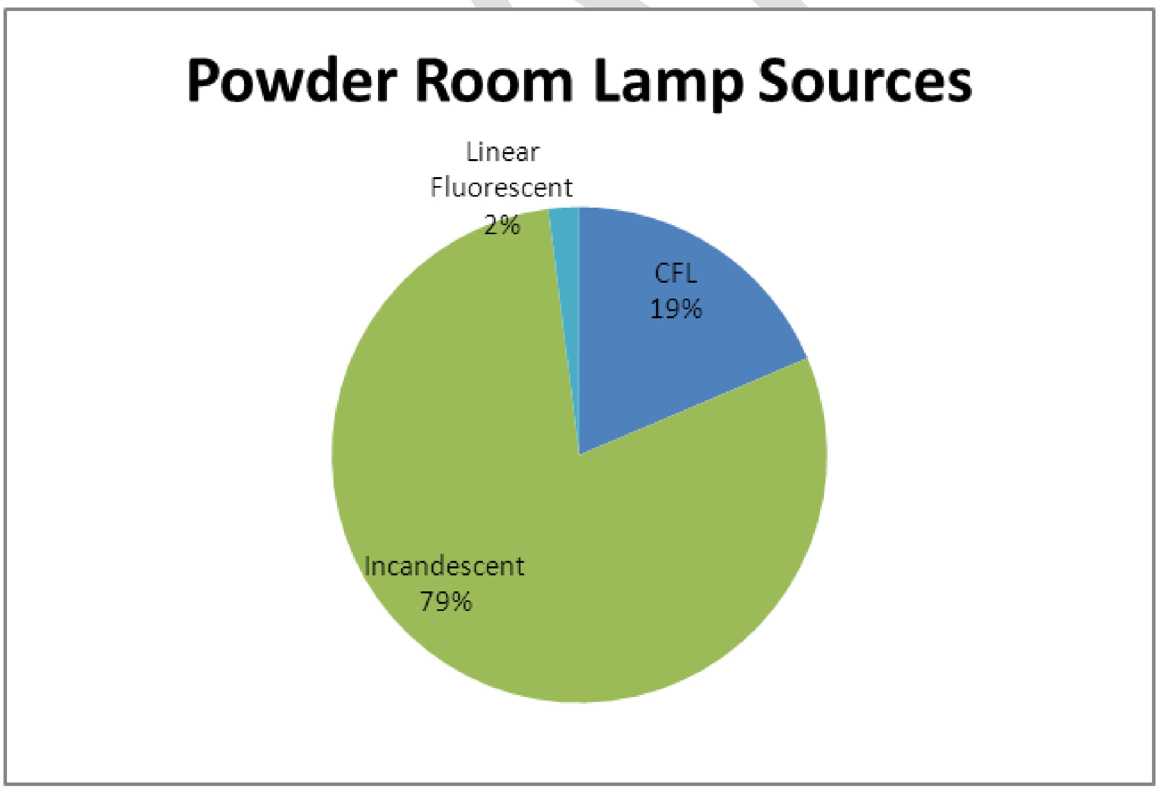

Figure 11: Powder room lamp sources (by wattage)

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%.

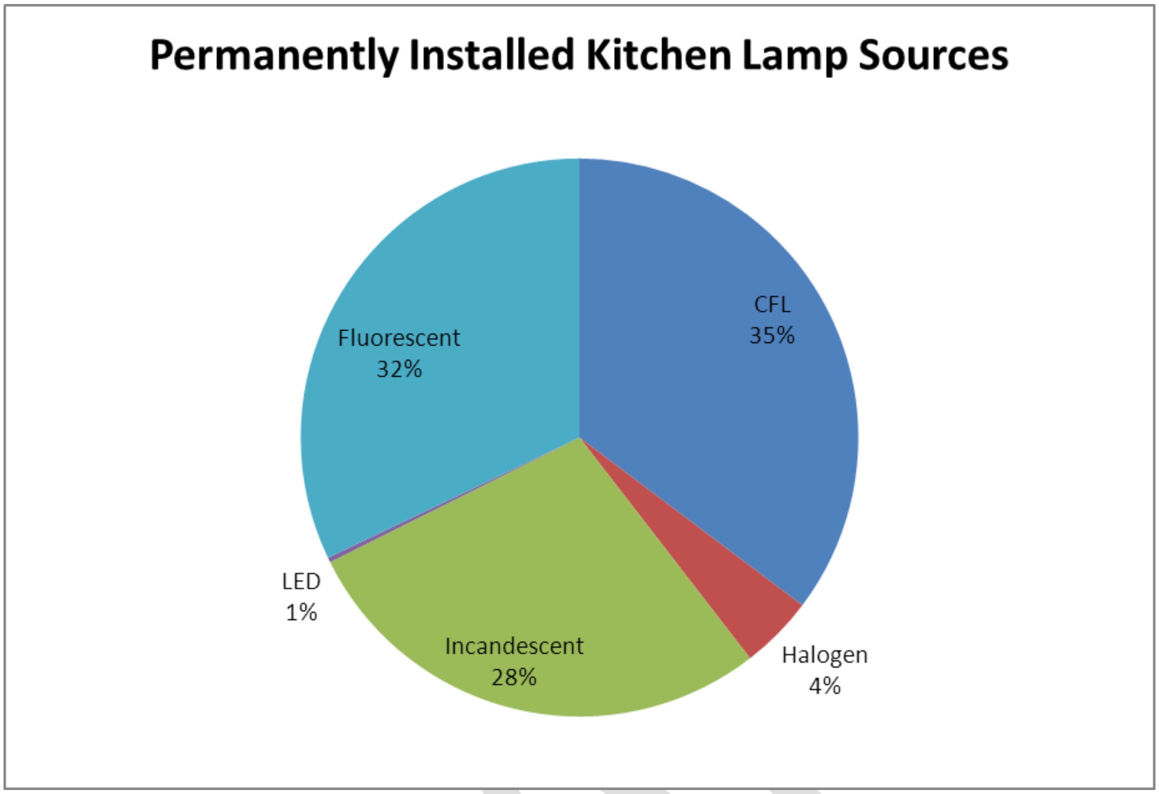

Figure 12: Percentage of permanently installed lamp sources in kitchens (by wattage)

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.

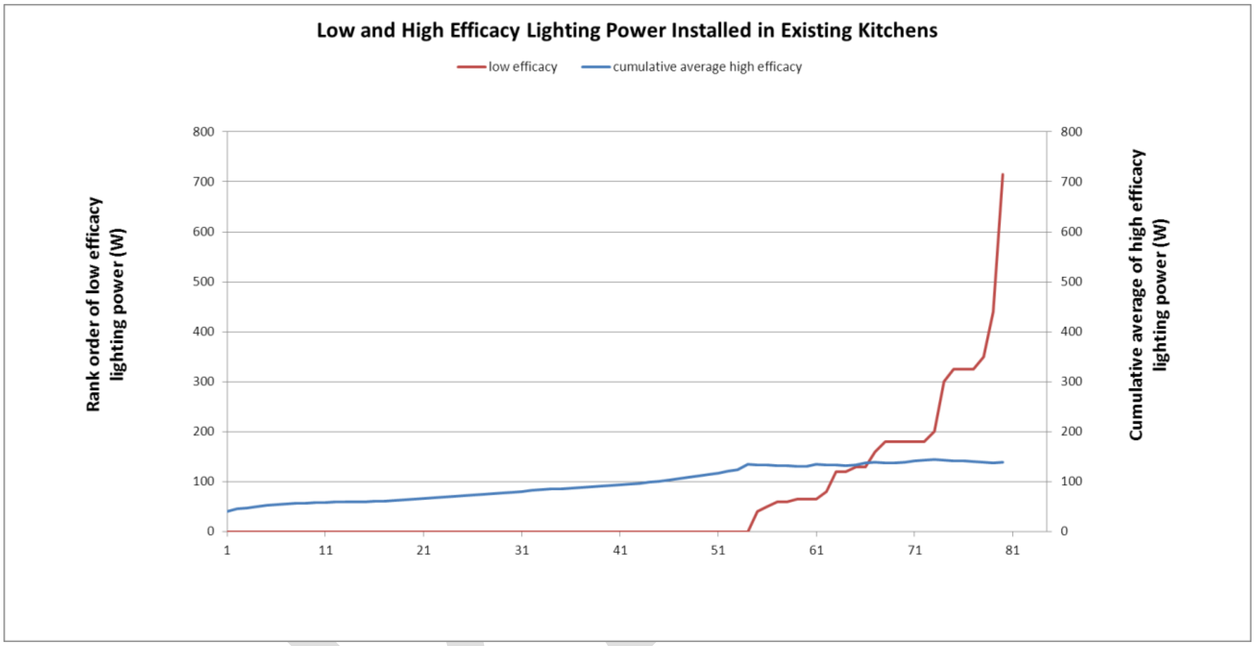

Figure 14: Low and High Efficacy Lighting Power in Kitchens

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.

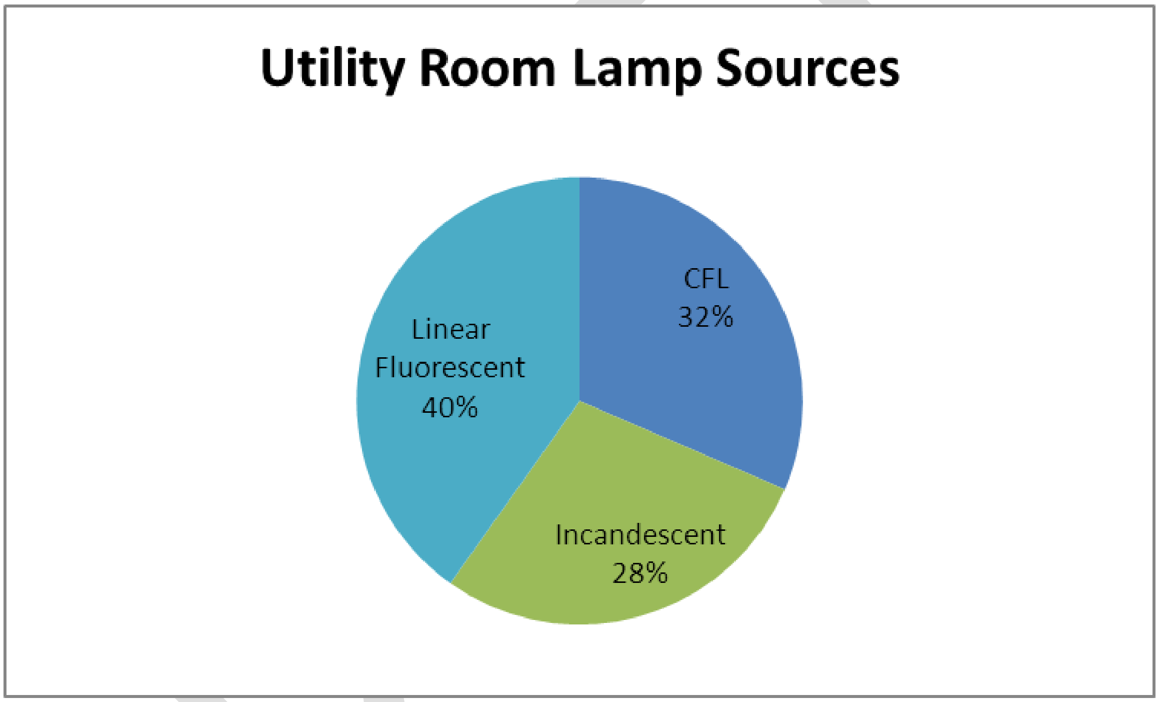

Figure 15: Percentage of permanently installed lamp sources in Utility Rooms (by wattage)

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.

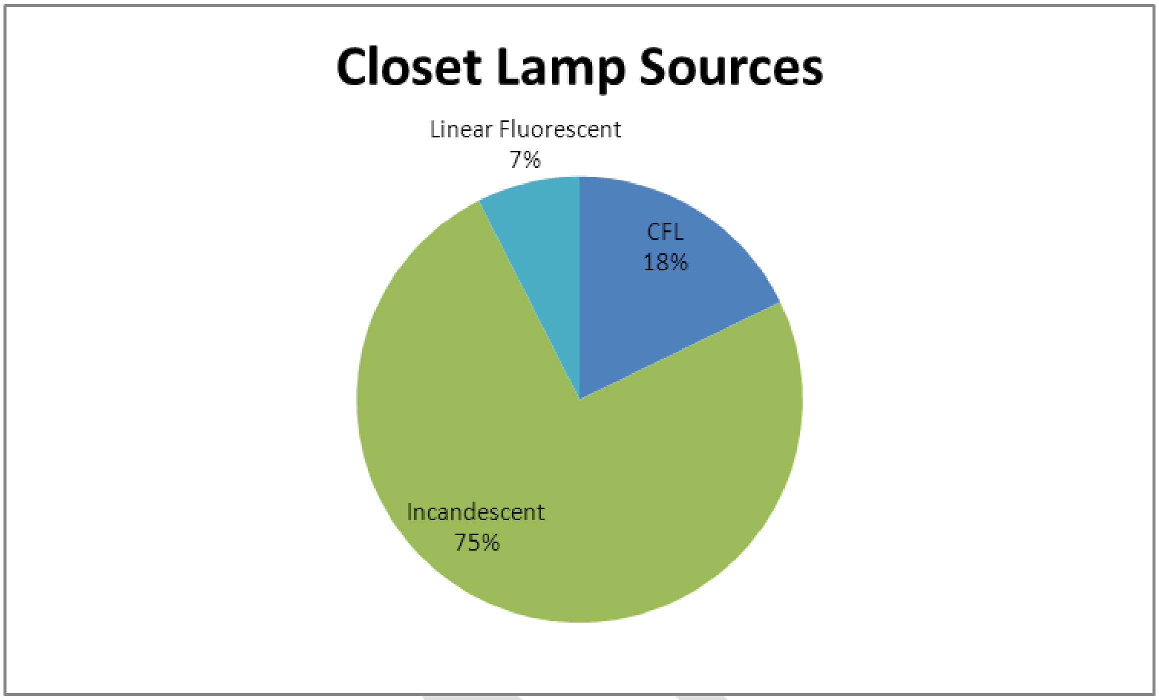

Figure 16: Percentage of permanently installed lamp sources in Closets (by wattage)

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 high hours of use for garages (2.3), utility rooms (2.6) and closets (1.4) despite the fact that these are not "living spaces" suggests that the lighting in these rooms is frequently 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.

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.

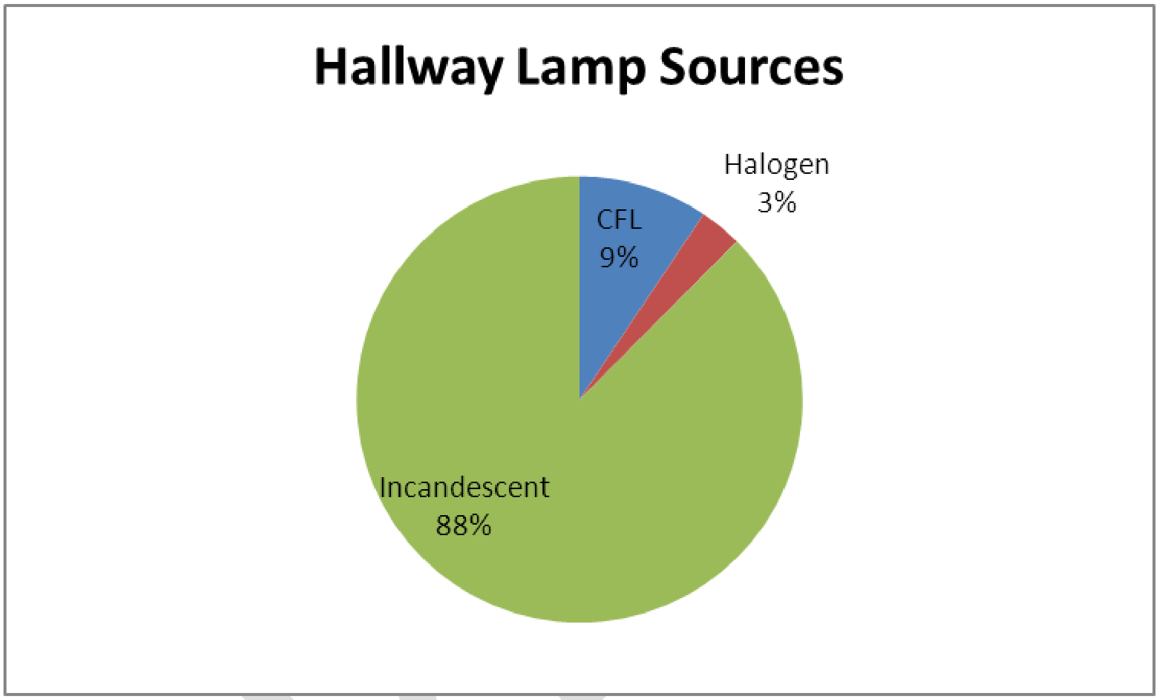

Figure 17: Percentage of permanently installed lamp sources in Hallways (by Wattage)

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 the cost and wattage assumptions used for various lamp source types in the cost effectiveness assessments.

Lamp	Cost	Wattage	Life (hours)
Incandescent A-Lamp	$0.65	57	3,000
Halogen Par Lamp	$5.00	45	2,500
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 18: 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 19 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$)	Total O&M Savings	LCC Savings	Benefit / Cost Ratio	Cost Effective
Bedroom	1.7	621	17	$ 59.47	$ 2.83	$ -	$ 62.30	**$ 27.95**	**1.81**	**YES**
Bathroom	1.4	511	14	$ 48.98	$ 2.40	$ -	$ 51.38	**$ 17.03**	**1.50**	**YES**
Hall	1.2	438	12	$ 41.98	$ 1.99	$ -	$ 43.97	**$ 9.62**	**1.28**	**YES**
Dining	1.9	694	19	$ 66.47	$ 3.26	$ -	$ 69.73	**$ 35.38**	**2.03**	**YES**
Living	2.3	840	23	$ 80.46	$ 4.12	$ -	$ 84.58	**$ 50.23**	**2.46**	**YES**
Utility	1.4	511	14	$ 48.98	$ 2.40	$ -	$ 51.38	**$ 17.03**	**1.50**	**YES**
Kitchen	2.5	913	25	$ 87.46	$ 4.22	$ -	$ 91.68	**$ 57.33**	**2.67**	**YES**

Figure 19: 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	$ 2.40	$ 3.43	$ 67.25	**$ 35.25**	**2.10**	**YES**
Bathroom	1.4	511	16	$ 56.23	$ 1.97	$ 1.87	$ 56.33	**$ 24.33**	**1.76**	**YES**
Hall	1.2	438	14	$ 48.20	$ 1.59	$ 1.71	$ 48.08	**$ 16.08**	**1.50**	**YES**
Dining	1.9	694	21	$ 76.31	$ 2.52	$ 3.58	$ 75.26	**$ 43.26**	**2.35**	**YES**
Living	2.3	840	26	$ 92.38	$ 3.28	$ 5.17	$ 90.49	**$ 58.49**	**2.83**	**YES**
Utility	1.4	511	16	$ 56.23	$ 1.97	$ 1.87	$ 56.33	**$ 24.33**	**1.76**	**YES**
Kitchen	2.5	913	28	$ 100.41	$ 3.65	$ 5.41	$ 98.66	**$ 66.66**	**3.08**	**YES**

Figure 20: Cost Effectiveness Analysis for pin-based compact fluorescent downlights

Figure 20 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 21, below, shows the cost effectiveness analysis for LED under-cabinet lighting, and Figure 22 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 21: 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 22: Cost Effectiveness for LED decorative pendants

Based on the findings from Figure 21 and Figure 22, above, HMG also performed a cost effectiveness analysis for LED recessed downlights. Similar to the analysis for compact fluorescent luminaires, shown above in Figure 20, the LED luminaires were compared to typical incandescent recessed luminaires. As shown below in Figure 23, 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 23: 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. Figure 24 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 24: Cost and savings estimates for control devices

As shown below in Figure 25, 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 25: 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 26 shows, manual dimming was found to be cost effective for 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	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 26: 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 27, 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 27: 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 and manual dimmers are cost effective across all residential space types.

3.3.3 Statewide Savings

Figure 28, 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).

Measure	**Installed Savings (MW)**	**Average Daily Hours of Use**	**Statewide Savings (GWh/year)**
No Medium Base Cans			
Bedroom	4.9	1.7	3.03
Living Room	9.4	2.3	7.87
Dining Room	3.8	1.9	2.64
Hallway	15.2	1.2	6.67
Bathrooms	2.2	1.4	1.11
Kitchens	2.4	2.5	2.21
No Medium Base Decorative in Hallways	7.1	1.2	3.10
Bathroom Measures	4.6	1.4	3.07
Utility / Closet High Efficacy	5.1	1.4	3.37
Total	**54.7**		**33.07**

Figure 28: Statewide Savings for all proposed measures

In addition to savings estimates for the proposed measures, we also estimated the potential statewide savings of requiring that ceiling fans not have medium screw base sockets, as shown in Figure 29.

		No Medium Screw Base in Downlights		No Medium Screw Base in Ceiling Fans	
	Average Daily Hours of Use	Installed Savings (MW)	Statewide Savings (GWh)	Installed Savings (MW)	Statewide Savings (GWh)
Bedrooms	1.7	4.9	3.03	8.2	5.09
Living Rooms	2.3	9.4	7.87	5.3	4.42
Dining Rooms	1.9	3.8	2.64	0.8	0.54
Hallways	1.2	15.2	6.67	--	--
Bathrooms	1.4	2.2	1.11	--	--
Kitchens	2.5	2.4	2.21	--	--
Total		**37.9**	**23.5**	**14.2**	**10.0**

Figure 29: Statewide savings for eliminating medium screw base sockets in downlights and ceiling fans

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

4.1 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 Recommended Code Language

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 Proposed Reach Code Language

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

CEC (California Energy Commission). 1997. *California Baseline: Lighting Efficiency Technology Report*. Report prepared by Heschong Mahone Group.

CEC (California Energy Commission), funded by a PIER Building Energy Research Grant, and co-funded by the Statewide Utility Codes and Standards Program. 2010. *California New Home Energy Survey*. Report prepared by Bruce Wilcox (not yet published).

CPUC (California Public Utilities Commission), Energy Division. 2010. *Final Evaluation Report: Upstream Lighting Program*. Report prepared by KEMA, Inc., available at http://calmac.org/publications/FinalUpstreamLightingEvaluationReport_Vol1_CALMAC_3.pdf

LRC (Lighting Research Center). 2003. *Reducing Barriers to the Use of High Efficiency Lighting Systems. Final Report: Year 2*. Retrieved from http://www.lrc.rpi.edu/researchAreas/reducingBarriers/pdf/year2FinalReport.pdf

SCE (Southern California Edison). 2009. *Proximity of Workplace Lighting Controls CASE: Literature Review*. Unpublished. Submitted to SCE by the Heschong Mahone Group. Robert Thompson SCE project manager.