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Proposal Information Template for: Decorative Light Strings

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Prepared for:

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Please note: all savings estimates and information in this document are preliminary and are based on data available to the authors at the time of the report. If the CEC moves forward with this topic, we anticipate updating our estimates and recommendations based upon additional input from stakeholders.

Proposal Information Template – Decorative Light Strings

2011 Appliance Efficiency Standards

Prepared for: Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison, Southern California Gas Company

CONTENTS

Purpose	3
Background	3
Overview	6
Methodology and Modeling used in the Development of the proposal	8
Data, Analysis, and Results	10
Proposed Standards and Recommendations	12
Bibliography and Other Research	12
References and Appendices	14

Purpose

This document is a report template to be used by researchers who are evaluating proposed changes to the California Energy Commission’s (Commission) appliance efficiency regulations (Title 20, Cal. Code Regulations, §§ 1601 – 1608) This report specifically covers Decorative Light Strings.

Background

Decorative light strings are defined as any plug-in fixture consisting of light sources connected in series or parallel attached to a common electric wire. :

- Christmas lights, which commonly adorn landscapes, residences, and public spaces during the holiday season
- light strings used in residential, non-seasonal applications to decorate decks, patios, patio furniture, and interiors
- light strings, including rope lights, used to decorate service establishments such as retailers, restaurants, bars, hotels, and kiosks
- light strings, including rope lights, used in public spaces to decorate trees, courtyards, and streetscapes
- The ENERGY STAR® program uses the following definition for their specification of decorative string lights. A string of lamps that operate on AC power in North America (120 V RMS AC, 60 Hz) or via a power adapter or controller that connects directly to AC power, and is used for decorative residential lighting purposes. The lamps may be replaceable or sealed into the lamp holder/wiring harness, and may be assembled in a net or icicle configuration.

We recommend that Title 20 adopt this definition, with the addition of “and commercial” after “residential,” and “, rope” after “net.”:

- A string of lamps that operate on AC power in North America (120 V RMS AC, 60 Hz) or via a power adapter or controller that connects directly to AC power, and is used for decorative residential and commercial lighting purposes. The lamps may be replaceable or sealed into the lamp holder/wiring harness, and may be assembled in a net, rope, or icicle configuration.

The proposed definition includes product categories listed by the Underwriters Laboratories (UL): UL 588 decorative light strings, UL 588 decorative outfits, and UL 2388 flexible lighting products. Some products are rated for indoor/outdoor use, while others are only for indoor use.

UL 588 decorative light strings, defined as:

- Any product “intended for seasonal, temporary use, not to exceed 90 days per year, consisting of a string of lights which may be draped over or around trees or other objects for decorative effect” (Underwriters Laboratories Inc. 2000; Underwriters Laboratories Inc. 2007).
- Products that consist of a decorative light string with a lampshade or diffuser over the lamp.
- Series-connected lighting strings using LED lamps that employ non-removable covers or diffusers are also considered decorative-lighting strings

UL 2388 Flexible Lighting Products, defined as:

- products composed of non-replaceable lamps enclosed in a flexible polymeric tube and are not intended for permanent installation (Underwriters Laboratories Inc. 2007).

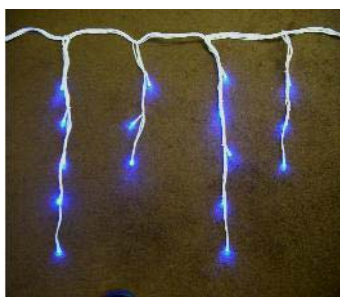
String Configuration

Decorative light strings are available in white and assorted color lamp varieties. In general, light string lamps either remain on at all times or flash on and off. Some decorative light strings come with a controller to flash lamps at different intervals. Decorative light strings are generally displayed as a basic string, in an icicle configuration, or as a rope light, see below:

Figure 1. Common String Displays



Basic Light String



Icicle Light

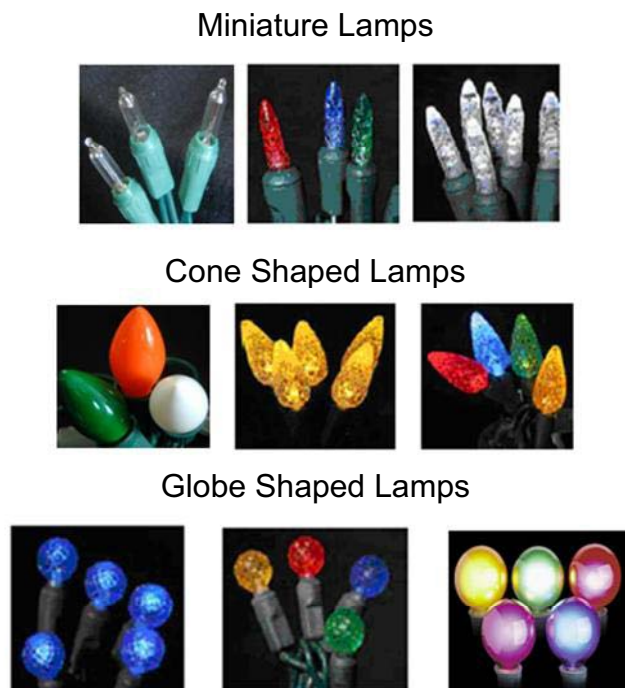


Rope Light

Lamp Shape

Decorative light strings are available with an array of lamp sizes and shapes. The most common lamp shapes are miniature, cone, and globe, illustrated in Figure 2.

Figure 2. Common Decorative Light String Shapes



Along with the more common decorative light string lamp shapes, molded plastic diffusers that cover individual lamps allow for an assortment of designs (Figure 3).

Figure 3. Examples of Molded Plastic Novelty Lamps



The proposed standard categorizes lamps into three sizes: mini, standard, and jumbo. Lamp sizes are explicitly defined in Table 4 in the Appendix.

Note: Testing and analysis began in 2006, with an update of product availability and pricing in 2009. Further research was then postponed due to higher priority Title 20 research topics. The findings and recommendations below are based on the data collected in 2006 and

2009. We believe that a current analysis would show increased compliant product availability and improved cost-effectiveness for this measure.

Overview

Description of Standards Proposal	We recommend that California adopt a two tiered standard. Tier 1 limits decorative light strings to 0.20 watts per lamp. This would allow low-wattage incandescent and LED products to be sold, and aligns with the current requirements for ENERGY STAR decorative light strings (Version 1.4). We suggest that the first tier would take effect in the near term, with Tier 2 subsequently. Tier 2 allows for products that consume less than 0.1 watts per lamp, such that only LED products (or other technologies that would draw equal or less power than LED products) would qualify to meet the standard.
California Stock and Sales	We estimate that there are currently more than 45 million decorative light strings across California. We estimate that 12.5 million decorative light strings were sold in California in 2010 (the most recent year that data are available), with every household acquiring an average of more than one string per year. Of those 12.5 million, approximately half were traditional mini-incandescent light strings, with LED mini light strings, standard, jumbo and rope light strings (incandescent and LED) representing the remainder of sales (Table 5).
Energy Savings and Demand Reduction	The estimated 45 million decorative light strings in California use nearly 600 GWh every year—enough electricity to power more than 86,000 California households. The proposed Tier 1 standard would save more than 380 GWh per year—enough electricity to power 54,000 California households. Under Tier 2 , the annual energy savings would be an additional 100 GWh, which is enough electricity to operate more than 14,000 California households. We estimate peak demand reduction to be 5.1 MW and 2.9 MW respectively.

Economic Analysis	<p>We compared the lifecycle costs of baseline units against that of Tier 1 and Tier 2 requirements. To ensure equivalent costs, we evaluated decorative light strings on a per lamp basis.</p> <p>Despite the added first cost of some light strings that draw less power (e.g. LEDs), the proposed standard is cost effective for each unit under Tier 1, with an average lifecycle benefit to cost ratio of 10.9 and an average net present value of lifetime energy savings of \$9.45 for all three size categories.</p> <p>It is important to note that the cost benefit analysis for rope lighting is not applicable because we estimate that the majority of rope lighting currently on the market already meets the proposed Tier 1 standard. The incremental cost per unit for Tier 2 is \$4 per light string (rope lights not included); however, the present value of the lifetime energy savings per unit is \$11 assuming a 6 year lifetime. Updated cost information for Tier 2-compliant rope lighting will need to be collected to determine cost effectiveness as the current dataset for LED rope lights is considered out of date given the decline in LED prices over the last few years.</p> <p>Avoided energy costs after stock turnover is approximately \$57 million.</p>
Non-Energy Benefits	<p>Aside from energy savings, LED decorative light strings have other consumer benefits including:</p> <ul style="list-style-type: none"> • In general, a market shift to LEDs has environmental benefits both upstream and downstream, particularly in terms of embedded energy and greenhouse gas reduction at the power generation source, helping California to meet its AB 32 goals (1990 levels by 2020). • Cool to the touch. LED lamps produce less heat than incandescent lamps. Tests run in the Ecos lab demonstrate that incandescent light string lamps often can reach 150° F; LED lamps typically are no warmer than 80° F. • Bright color that does not fade over a normal product's lifetime. Incandescent lamps produce white light and require a colored diffuser, while LEDs naturally produce colored light. • Increased durability. LEDs have no filament or glass to break. • Long lamp life. Some LED lamps claim to last more than 100,000 hours (though they become dimmer with age and claims of very long product lifetimes take a long time to verify and are likely overstated in some cases). • Reduced need to replace burned out light strings and individual bulbs. Traditional and low-wattage incandescent products require replacement twice as often as LED strings. This additional benefit increases under Tier 2 because all products are LED. • Unlike some incandescent lamps, LED lamps do not contain lead solder.

Environmental Impacts	We have not identified any negative environmental impacts of a Title 20 standard for decorative light strings.
Acceptance Issues	<p>Some stakeholders may object to LEDs because they prefer the “warmth” of the yellowish-white incandescent lamps. They may not accept the bluish-white LEDs that were first used in decorative light strings as equal substitutes. However, warm white LEDs are increasingly common in multiple decorative and general purpose lighting applications.</p> <p>Consumer satisfaction with LED decorative light strings and reduced electricity bills is frequently cited in press.</p> <p>The proposed Tier 1 standard would require all decorative light strings to meet ENERGY STAR’s power limits. ENERGY STAR is widely recognized by consumers as a mark of product quality and desirability.</p> <p>Several CA utilities already promote LED decorative light strings.</p>
Federal Preemption or other Regulatory or Legislative Considerations	No federal preemption issues anticipated.

Methodology and Modeling used in the Development of the proposal

During 2006 and 2007, we purchased and tested more than 80 decorative light strings to assess the range of power demand, energy use, and potential for energy savings. The power demand of decorative light strings depends upon the number of lamps per string, lamp type and lamp size. Power demand per bulb can vary between similar lamp types and sizes.

For the purpose of testing and analysis, we categorized decorative light string bulbs into four types: mini, standard, jumbo, and rope. These are defined by lamp size. See Table 4 and Figure 4 in the Appendix.

Test Method

There are a number of safety-focused testing methods created by UL and one ENERGY STAR test method. For Title 20, we recommend following the ENERGY STAR Program Requirements for Decorative Light Strings Test Procedure and Eligibility Requirements (Version 1.4, March 2008). The purpose of the test is to measure the power demand and quality of decorative light strings. See Appendix for details. We followed this test procedure to measure bulb power, with one modification. Because decorative light strings that provide an option of blinking or “all-on” are not addressed in the test procedure, we suggest the following addendum:

- Blinking products should be treated as follows: when a product allows the user to select between blinking and all-on modes, testing should examine the mode which draws the most power. Specifically, given the option of a “blink” mode or an “all-on” mode, tests should examine lamps on the string when “all-on.”

Estimated California Existing Stock

To predict total decorative light string energy use and saving opportunities in California, we developed estimates for annual sales and total stock. Our estimates are based on in-store product surveys and US import data scaled to California by population. Now that ENERGY STAR has had a decorative light string specification in effect for three years, a next step for this analysis should be to review sales and penetration data that they have gathered. We calculated national stock by summing the annual imports of decorative light strings from 2008 to 2010. We chose this timeframe because of the estimated three year useful lifetime of mini traditional incandescent light strings, which currently represent the majority of decorative light string sales. (See Table 5 in the Appendix.) We based estimates for distribution of light source technologies and lamp sizes on retail store inventory surveys conducted by Energy Solutions staff members in California (December 2009) as well as US import data.

Duty Cycle Assumptions

The proposed standard assumes that light strings operate for 240 hours per year in residential settings and 440 hours per year in commercial settings. See Table 6 in the Appendix.

Lamps per String Assumption

In order to calculate the energy use of the installed stock of decorative light strings in California, we developed an average for the number of lamps per string type based on the initial products tested in the lab (2006/2007) and updated that assumption to account for new information collected during in-store retailer surveys conducted in December 2009. See Table 7 in the Appendix.

Data, Analysis, and Results

Testing Results

Decorative light strings draw a range of power per lamp. See Table 1. Traditional incandescent lamps draw anywhere from 0.3 watts per lamp to 6.7 watts per lamp. Low-wattage incandescents draw from 0.15 watts per lamp to 0.23 watts per lamp, and LEDs draw between 0.006 and 0.320 watts per lamp.

Table 1. Decorative Light String Test Results from Ecos Lab (2006-2007)

	Baseline Unit	Number of Units Tested ^a	Average Power Demand (watts/lamp) ^b	Range of Power Demand (watts/lamp)
Mini	Mini (traditional incandescent)	19	0.40	0.31 - 0.66
	Mini (low-wattage incandescent)	10	0.22	0.20 - 0.23
	Mini (LED)	10	0.04	0.006 - 0.08
Standard	Standard (traditional incandescent) ^b	7	2.00	0.37 - 4.4
	Standard (low-wattage incandescent)	NA	NA	NA
	Standard (LED)	8	0.05	0.02 - 0.08
Jumbo	Jumbo (traditional incandescent) ^b	16	2.59	0.43 - 6.7
	Jumbo (low-wattage incandescent)	NA	NA	NA
	Jumbo (LED)	8	0.14	0.05 - 0.32
Rope	Rope (traditional incandescent)	NA	NA	NA
	Rope (low-wattage incandescent)	4	0.21	0.15 - 0.23
	Rope (LED)	2	0.07	0.06 - 0.08

^a NA indicates that the baseline unit was not in the data set.

^b The large power draw range for standard and jumbo traditional incandescent lamps is due to varying lamp types. Lower end values are mini-lamps concealed under a diffuser, the upper end is C7 and C9 lamps.

Estimated Energy Use of Installed Stock

Based on the estimated installed stock, lab test results (power by bulb type/size), duty cycle assumptions, and the estimated number of lamps per decorative string, we calculated the cumulative annual electricity consumed by each string type, outlined in Table 2 below.

Table 2. Estimated Annual Installed Stock Energy Consumption by String Type

	Baseline Unit	Average Power Draw (watts/lamp)	Lamps Per String	Installed Stock (millions)	Annual Stock Energy Use (GWh) ^a
Mini	Mini (traditional incandescent)	0.40	134	23.3	470
	Mini (low-wattage incandescent)	0.22	134	1.3	14.4
	Mini (LED)	0.04	134	10.7	7.9
Standard	Standard (traditional incandescent)	2.00	37	2.7	43.2
	Standard (low-wattage incandescent)	NA	37	NA	NA
	Standard (LED)	0.05	37	1.7	1.1
Jumbo	Jumbo (traditional incandescent)	2.59	28	1.9	54.4
	Jumbo (low-wattage incandescent)	NA	28	NA	NA
	Jumbo (LED)	0.14	28	1.3	0.9
Rope	Rope (traditional incandescent)	NA	156	NA	NA
	Rope (low-wattage incandescent)	0.21	156	0.3	4.9
	Rope (LED)	0.07	156	0.1	0.09
Total					597

^a The calculation for installed stock annual energy use assumes that 75% of decorative light strings are operated in residential settings for 240 hours per year. The remaining 25% are operated in commercial settings for 440 hours per year.

Proposed Standards and Recommendations

We recommend a two-tiered standard approach for decorative light strings because ENERGY STAR is already established at a level that is appropriate for near term mandatory standards. There are now more than 56 qualified brands of decorative light strings currently in the ENERGY STAR database. However, because of the rapid advance of LED technology and its ideal applicability for this particular end use, a more stringent Tier 2 standard is a feasible goal after Tier 1 has been in effect for one to two years, and would save CA an additional 100 GW/yr. Alternatively, if ENERGY STAR increases the stringency for its specification to require LED or similar technology, California could consider aligning with this more stringent specification as a Tier 2. We are not aware if ENERGY STAR has plans to revise its decorative light string specification, or if so, what the new requirements would be. Our Tier 2 analysis is based on the level proposed below—0.1 W per lamp.

We recommend the following standard: The power draw of decorative light string lamps sold after (Date, Year) shall not be more than the Tier 1 values shown in Table 3; and the power draw of decorative light string lamps sold on or after (Date, Year) shall not be more than the Tier 2 values shown in Table 3.

Table 3. Standards for Decorative Light Strings

Standards Options	Maximum Power/Lamp
Tier 1	0.20 W
Tier 2	0.10 W

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Appendices

Appendix A

Table 4. Size Definition for Baseline Units

Lamp Type	Size (inches)	Example Bulbs
Mini	< 1	Mini-lamp
Standard	≥ 1 to ≤ 1.75	C7
Jumbo	> 1.75	C9
Rope	any lamp encased in a plastic tube	Mini-lamp

The appearance of the lamp or diffuser as sold determines the size classification. Thus, a mini-lamp concealed under a standard or jumbo sized diffuser is classified as standard or jumbo (Figure 4).

Figure 4. Example of a Mini-Incandescent Lamp Under a Standard Diffuser



Mini-incandescent Lamp
with Standard Size Diffuser
Removed



Mini-incandescent Lamp
with Standard Size Diffuser as
Sold

Table 5. Estimated Installed Stock of Decorative Light Strings in California

	Baseline Unit	Estimated Existing CA Stock (millions)	Percent of Total (%)
Mini	Mini (traditional incandescent)	23.3	53.8%
	Mini (low-wattage incandescent)	1.3	3.0%
	Mini (LED)	10.7	24.6%
Standard	Standard (traditional incandescent) ^b	2.7	6.1%
	Standard (low-wattage incandescent)	NA	NA
	Standard (LED)	1.7	4.0%
Jumbo	Jumbo (traditional incandescent) ^b	1.9	4.5%
	Jumbo (low-wattage incandescent)	NA	NA
	Jumbo (LED)	1.3	2.9%
Rope	Rope (traditional incandescent)	0.03	0.1%
	Rope (low-wattage incandescent)	0.3	0.7%
	Rope (LED)	0.1	0.3%

Table 6. Duty Cycle Assumptions

Sector	Application	Hours Per Day	Days Per Year	Distribution by Sector
Primary Residential	Holiday Decoration	8 hours	30 days/year	98%
Secondary Residential	Summertime Outdoor Ambiance Lighting	4 hours	45 days/year	2%
Primary Commercial	Holiday Displays	8 hours	60 days/year	98%
Secondary Commercial	Non-Seasonal Decoration	12 hours	365 days/year	2%

Table 7. Lamps per String Assumption used for Analysis

Baseline Unit	Lamps Per String Assumption
Mini	134
Standard	37
Jumbo	28
Rope	156

Appendix B

ENERGY STAR Decorative Light String Test Procedure ([Version 1.4](#)):

1. Inspection:
 - Count the number of lamps on a string
 - Note if the lamps are plug-in or sealed
 - Ensure that the product is safety certified and labeled
2. Seasoning, Power, and Over-Voltage Test:
 - Operate a string for a 24 hour “seasoning” period at 120 volts ac
 - Determine the power and current at 120 volts ac
 - Calculate the power per lamp by dividing the total power by the number of lamps
 - Energize a string at 132 volts for one hour and examine it for failure
3. Lifetime Test:
 - Assemble the decorative light string into a testing configuration by bundling the string together so that all lamps are directed outward.
 - Measure the light output of the assembly in an integrating sphere while operating at 120 volts AC. Measure the light output of the assembly following the guidelines contained in CIE Publication 84-1989, *The Measurement of Luminous Flux*
 - Keep the test assembly intact and operate it continuously for 1000 hours outside of the integrating sphere.
 - Conduct a second light output measurement and calculate the number of failed lamps as a percentage of total lamps on the string.
4. Accelerated Weathering Test:
 - Assemble the string into the test configuration and measure light output.
 - Being careful not to disturb the assembly, load it into a testing chamber and subject the string to the exposure conditions contained in Cycle 7 of Table X2.1 of ASTM (formerly known as the American Society for Testing and Materials) G154-05. The decorative light string shall be operated for the duration of the test at 120 volts ac. Each cycle of the test includes 8 hours of UV light at 60°C, 0.25 hours of water spray, and 3.75 hours of condensation at 50°C. The string shall be subjected to 10 consecutive cycles, for a total of 120 hours.
 - Take a second light output measurement and count number of failed bulbs.