Codes and Standards Enhancement (CASE) Initiative For PY2008: Title 20 Standards Development

Title:
Analysis of Standards Options for Decorative Light Strings

Prepared for:
Pat Eilert
Gary Fernstrom
Ed Elliott

Prepared by:
Gregory Zimmerman (Ecos)

Version: Preliminary CASE Report
Last Modified: January 30, 2008

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

TABLE OF CONTENTS

1 Executive Summary

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for decorative light strings.

There are currently about 40 million decorative light strings in California homes, using almost 720 gigawatt-hours every year—enough energy to power more than 100,000 California households. Our analysis indicates that the majority of these light strings are traditional incandescent lamps, which were historically the only technology option. Recently, light emitting diode (LED) and low-wattage incandescent lamps have emerged as alternatives to traditional incandescent decorative light strings.

Our testing shows that decorative light string lamps use a range of power. Traditional incandescent lamps require anywhere from 0.3 watts per lamp to 6.7 watts per lamp. Low-wattage incandescents require from 0.15 watts per lamp to 0.23 watts per lamp, and LEDs require between 0.006 and 0.320 watts per lamp. Given the variation in power usage among technology options, there is an opportunity for mandatory standards to save a substantial amount of energy in California.

Because of the rapidly advancing LED market, we recommend a two-tiered standard approach to achieve energy savings for California. Tier 1 sets a maximum power use at 0.25 watts per lamp and will save a minimum of 390 gigawatt-hours per year, enough energy to power 56,000 California households. The standard would require manufacturers to produce low-wattage incandescent or LED type lamps. Tier 2, which would take effect two years later, sets the maximum power use at 0.1 watts per lamp and will save an additional 259 gigawatt-hours per year. This is enough energy to operate more than 37,000 California households. Under Tier 2, the majority of decorative light string lamps would utilize LED technology. California could realize a 90% savings over current decorative light string energy consumption.

The proposed standard is cost effective for all products under Tier 1 and Tier 2, with the exception of rope lights. The benefits to the consumer will continue to increase as the price of LED lamps decreases and light quality increases.

We designed the proposed standard to regulate the input power demand of decorative light strings without restricting decorative utility. LED light strings are sold in an assortment of colors, shapes and sizes, comparable to traditional incandescent decorative light strings. The ability to decorate effectively will not be limited.

Note: Preliminary data on rope light retail prices and power measurements are included in this report; however, rope lighting energy savings are not included in the statewide energy savings estimates. Additional analysis on rope lighting is underway and will be included in an amended report. Any claims made about energy savings and cost-effectiveness of the proposed standards on rope lights will be re-evaluated in pending rope light analysis.

2 Product Description

The proposed standard covers decorative light strings, which are defined as any plug-in fixture consisting of light sources connected in series or parallel attached to a common electric wire. The product class includes:

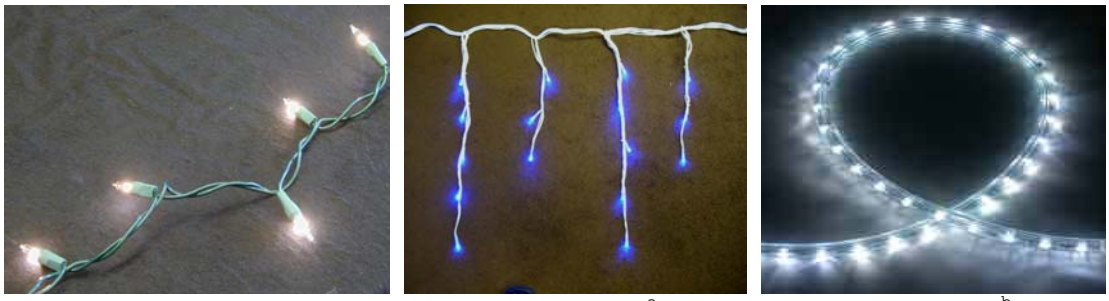
- Christmas lights, which commonly adorn landscapes, residences, and public spaces during the holiday season
- light strings used in residential, non-seasonal applications to decorate decks, patios, patio furniture, and interiors
- light strings, including rope lights, used to decorate service establishments such as retailers, restaurants, bars, hotels, and kiosks
- light strings, including rope lights, used in public spaces to decorate trees, courtyards, and streetscapes

Three product categories listed by the Underwriter Laboratories (UL) are included in the standard: 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. All products under UL 588 decorative light strings are included, which are 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). The standard covers products that consist of a decorative light string with a lampshade or diffuser over the lamp listed by UL 588 decorative outfits. It also includes all products listed as UL 2388 Flexible Lighting Products, which are 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 (Figure 1).

Figure 1. Common String Displays



Basic Light String | Icicle Light[a] | Rope Light[b]

[a] (Chien Hwa Trading Co. 2007)
[b](Pegasus Associates Lighting 2007)

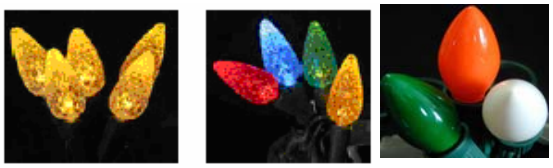
Lamp Shape

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 Lamp Shapes[a,b]

Miniature Lamps

Cone Shaped Lamps



Globe Shaped Lamps

[a] (Vladimer 2006)
[b](Betty's Christmas House 2007)

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 defined in Table 1; measurements are made as shown in Table 7. 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).

Table 1. Size Definition for Baseline Units

Baseline Unit	Size (inches)
Mini	< 1 in
Standard	≥ 1 in, ≤ 1 3/4 in
Jumbo	> 1 3/4 in
Rope	Any Lamp Incased in a Plastic Tube

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

Some decorative light strings are designated as commercial grade by the manufacturer. Commercial light strings utilize a thicker gauge wire than residential grade string lights, allowing more light strings to be connected on end.

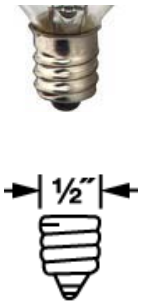
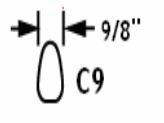
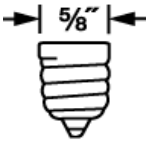
Technologies

Incandescent Lamps

Incandescent decorative light string lamps are typically:

- 2.5 to 3.5 watt miniature lamps with a push-in base
- 5 watt C7 lamps with a screw-in candelabra base
- 7 watt C9 lamps with a screw-in intermediate base (Table 2).

Table 2. Common Incandescent Lamps

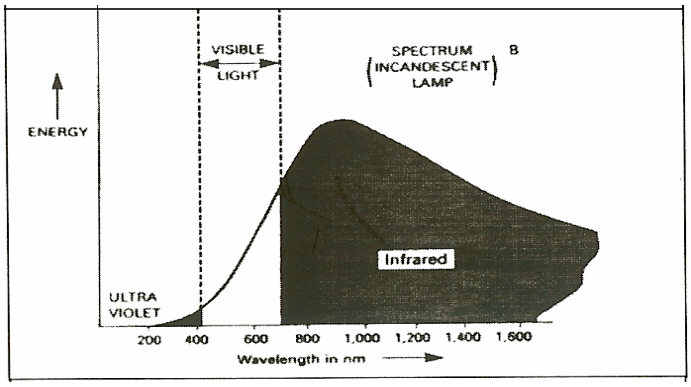
Miniature	C7		C9	
	Cone Shaped Lamp	Candelabra base	Cone Shaped Lamp	Intermediate Base
				
				

Source: (McMaster-Carr 2006)

Incandescent string lamps produce visible light using the same physical processes that standard general service incandescent lamps do. A tungsten filament inside a gas-filled chamber (lamp) is heated with electricity until it produces visible light.

Incandescent lamps used in decorative light strings represent the lower end of the range of efficacy (lumens per watt) afforded by incandescent lamps. In decorative string lights less than 12% and perhaps as little as 6% of electrical input is emitted in the visible wavelengths. Most is emitted as infrared (Illuminating Engineering Society of North America (IESNA) 2000) (Figure 5).

Figure 5. Spectrum of an Incandescent Lamp



Source: (Bijker 1995)

A colored diffuser placed over an incandescent lamp allows light to pass through in a limited spectrum in the visible range, wasting the remaining light. For example, a red diffuser placed over a mini-incandescent lamp absorbs all wavelengths of light except red and, therefore, red light is reflected diffusely.

Some decorative light strings consist of low-wattage incandescent lamps. A variety of technologies exist for reducing lamp power consumption, including changes to fill gas or filament design or both. These technologies are detailed in the Analysis of Standards options for General Service Incandescent Lamps (Ecos Consulting, Davis Energy Group et al. 2004).

LED

Light emitting diodes (LEDs) produce monochromatic light, unlike the multi-spectral white light produced by incandescent bulbs. The color is determined by the semiconductor material that makes up the diode. LEDs are available in red, orange, yellow, green, blue, and purple. A variety of techniques are used to yield white light, including placement of two or more colors of LEDs very close together to create the appearance of white light, or using a blue or ultraviolet LED inside a phosphor-coated casing. When excited by the light from the blue LED, the phosphors emit a red/yellow light. The combination of the blue or ultraviolet LED light with the red/yellow phosphor light appears white to the human eye.

LEDs produce highly directional light, which is an advantage in some lighting applications, but can be a disadvantage with decorative light strings where an omnidirectional effect is desired. The problem is resolved by covering LEDs with diffusers to scatter the light, creating a more uniform distribution of light output.

Table 3. LED Illustrations[a]

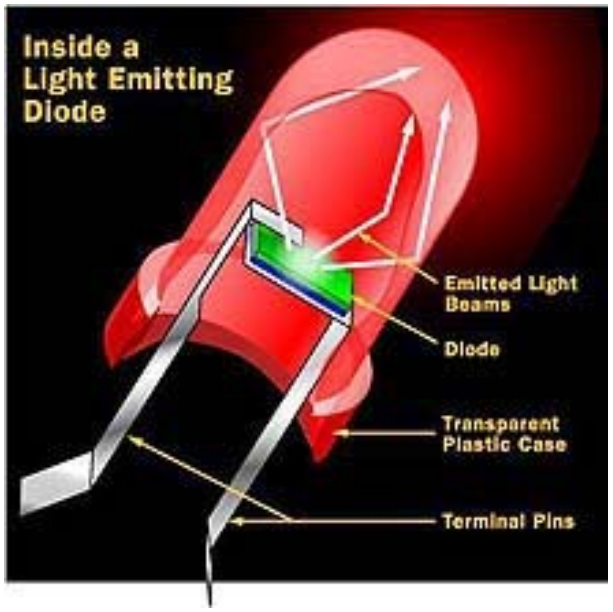


Diagram of an LED[b]

Single LED Bulb
(0.8" tall)[c]

Four LED Bulb Cluster
(1.1" tall)[c]

[a] Images not to scale
[b] (Courtesy of HowStuffWorks.com)
[c] (McMaster-Carr 2006)

Lamp Efficiency

Because of extensive differences in lamp color, size, shape, and directionality, it is not practical to create a lumens-per-watt efficiency test procedure or metric for decorative light strings. Likewise, it would not be fair to simply measure total power consumption of a string, since different strings contain different numbers of lamps. The compromise that we propose is to regulate decorative light strings with a power consumption standard that considers total ac power input per lamp. Power consumption is calculated by measuring the input power demand of a string of lamps and dividing that figure by the number of lamps. Incandescent strings use anywhere from 0.15 watts per lamp for a low-

wattage mini-incandescent lamp up to 6.7 watts per lamp for jumbo incandescent lamps. LED light strings use between 0.006 watts and 0.32 watts per lamp.

3 Manufacturing and Distribution Channel Overview

The vast majority of decorative light strings are produced abroad by lighting manufacturers in China, the Philippines, Taiwan, and Thailand and imported to the United States (Table 4) (U.S. International Trade Commission 2006), (Watkins 2007).

Table 4. Top Four Producers of Decorative Light Strings

Country	Average Annual Imports (light stings), 1996-2005
China	18,357,025
Philippines	589,445
Taiwan	224,788
Thailand	206,926

Once they reach the United States, light strings are distributed through three main channels:

1. Do-it-yourself, hardware, and discount retail stores such as Wal-Mart, Ace Hardware, and Home Depot. These retailers carry a wide selection of decorative light strings, particularly around the Christmas season.
2. Internet sites. Some specialize solely in holiday light distribution, while others offer light strings for more general applications.
3. Electrical wholesalers. Distribute lights to commercial consumers (Vladimer 2006).

Hardware and retail stores, Internet sites, and electrical wholesalers offer a variety of incandescent and LED light strings. Our analysis shows that LED products have recently experienced a growing market share across all three distribution channels.

Residential consumers generally purchase decorative string lights from either hardware and retail stores or Internet sites. Commercial consumers usually purchase light strings through electrical wholesalers. Despite the variation in distribution, commercial and residential light strings are virtually identical products, covered by UL 588 (see Section 2).

4 Energy Usage

During 2006 and 2007 we tested more than 80 products to assess the range of energy use and potential for energy savings in the decorative light string marketplace. The power use of decorative light strings depends upon the number of lamps per string, lamp type and lamp size. Energy usage also varies between similar lamp types and sizes.

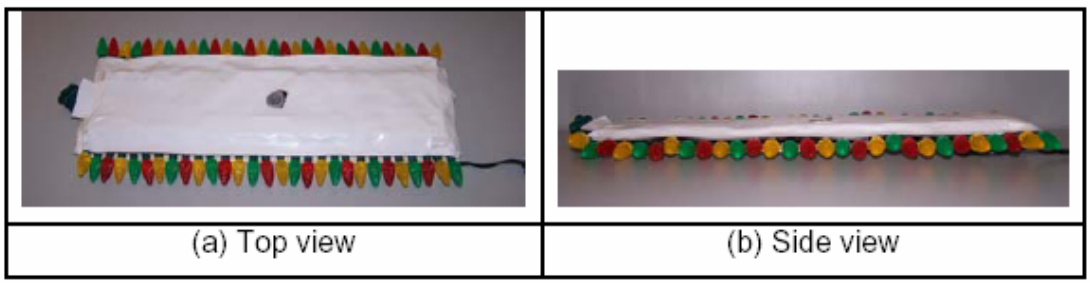
4.1 Test Methods

4.1.1 Current Test Methods

There are a number of safety-focused methods created by UL and one ENERGY STAR® test method currently in draft form. This method, the *ENERGY STAR Program Requirements for Decorative Light Strings Test Procedure and Eligibility Requirements Draft Version 1.2.1.*, is intended to be applied to decorative light strings to establish eligibility for the ENERGY STAR program (ENERGY STAR 2006). The purpose of the test is to measure the power consumption and quality of decorative light strings. It consists of the following elements:

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 (Figure 6).

Figure 6. Sample Test Configuration



   - 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 know 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.

4.1.2 Proposed Test Methods

For the purpose of the proposed California standard, we recommend the adoption of the final test procedure outlined in Section 4 of the ENERGY STAR Program Requirements for Decorative Light Strings Test Procedure and Eligibility Requirements scheduled to be completed in first quarter of 2007. Decorative light strings that provide an option of blinking or "all-on" are not addressed in the test procedure and so 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 uses the maximum amount of power. Specifically, given the option of a "blink" mode or an "all-on" mode, tests should examine lamps on the string when "all-on".

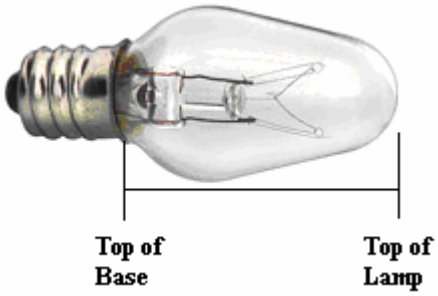
We also suggest the implementation of a minimum 3-year warranty against all product defects to ensure quality.

4.2 Baseline Energy Use Per Product

For the purpose of testing and analysis we categorized decorative light strings into four baseline units: mini, standard, jumbo, and rope. These are defined by lamp size (Table 1). Lamps are measured from the top of the base to the top of the lamp (Figure 7). Mini strings contain lamps that are approximately the size of a mini-lamp, or smaller. Standard strings include lamps about the size of a C7 incandescent lamp. A jumbo string consists of lamps larger than C7s, most typically C9-size lamps. Finally, rope lights consist of lamps enclosed in a flexible plastic tube.

Strings with varying sized lamps are categorized by the largest lamp on the string. Thus, a string containing both C7 and mini-lamps are considered a standard-sized decorative light.

Figure 7. Baseline Size Measurement



Source: Modified from (McMaster-Carr 2006)

Under each baseline unit there are three potential lamp technologies, which were discussed in Section 2: traditional incandescent, low-wattage incandescent, and LED. Table 5 defines the power consumption per lamp for traditional incandescent and low-wattage incandescent lamps.

Table 5. Incandescent Power Consumption Range

Technology	Power Usage (watts/lamp)
Traditional Incandescent	> 0.25 watts/lamp
Low-wattage Incandescent	≤ 0.25 watts/lamp

Lab testing revealed that light strings can consume anywhere from 0.006 watts per lamp up to 6.7 watts per lamp (Table 6). We discovered no manufacturers producing low-wattage incandescent products in standard and jumbo sizes. All rope lights tested consisted of low-wattage incandescent or LED technology.

Table 6. Decorative Light String Power Use, Test Results from Ecos Lab 2006-2007

	Baseline Unit	Number of Units Tested[a]	Average Power Draw (watts/lamp)[a]	Range (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 products with mini-lamps concealed under a diffuser, the upper end is C7 and C9 lamps.

United States import data indicate that the majority of decorative light strings are miniature, accounting for 78% of units sold. The remaining 22% of sales are split between the other decorative light string varieties (U.S. International Trade Commission 2006). Traditional incandescent lamps comprise the majority of sales for both miniature and other decorative light strings. The demand for LED light strings is currently small but increasing annually. For example, one retail outlet manager (Kroegers ACE Hardware) stocked no LED holiday lights over the 2005 holiday season, but 13 LED products during the 2006 holiday season. They expect to stock as many as 40 LED holiday light varieties in 2007 (Kroegers Ace Hardware 2007). Low-wattage incandescent lamps possess a limited market share. We encountered only three manufacturers of mini low-wattage light strings during the course of this research. For the purpose of the standard, we assumed that sales patterns in California are similar to that of United States and can be scaled on the basis of population.

The primary application for decorative light strings in both the residential and commercial sectors is holiday decoration in December and January. Light strings are less commonly operated as summertime deck and patio decoration in the residential sector and as non-seasonal decorative lighting in the commercial sector (Table 7) (Vladimer 2006).

Table 7. Decorative Light Strings Applications and Usage Times

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

Source: (Vladimer 2006)

The proposed standard assumes that the annual operation time for a residential decorative light string is 240 hours and a typical commercial string operation time is 440 hours.[1] Furthermore, of all decorative light strings sold, 75% are utilized in a residential setting, while the remaining 25% are utilized in a commercial setting (Table 8) (Christmas Lights Etc. 2006).

Table 8. Annual Operation Time by Sector

Sector	Annual Operating Time (hours/year)	Percent of Stock Found in Sector
Residential	240	75%
Commercial	440	25%

This standard assumes that the majority of strings are operated during off-peak hours—in the winter and at night. Only 0.5% of all strings are subject to peak pricing—lights that operate during the summer in the commercial sector.[2] Peak pricing is in effect from May 1st through October 31st between 1:00pm and 7:00pm (Pacific Gas & Electric Co. 2006).

Table 9 outlines the baseline energy use for decorative light strings. Annual unit energy consumption ranges from 15 watt-hours per lamp to 715 watt-hours per lamp.

[1] Assumes that in the residential setting 98% of decorative light strings are installed for 30 days during the holiday season and are used for eight hours a day. The remaining 2% are used four hours per day, 60 days per year. In the commercial sector, 98% of decorative light strings are operated eight hours per day for 45 days per year. The remaining 2% are used 365 days per year and twelve hours per day.

[2] The only decorative light strings subject to peak pricing are strings that operate 365 days per year and twelve hours per day in the commercial sector.

Table 9. Baseline Energy Use Per Product

	Baseline Unit	Power Draw (watts/lamp)	Percent of Units Operating During Peak Period	Residential Annual Operating Hours	Commercial Annual Operating Hours	Annual Unit Energy Consumption (Whr/lamp) [a]
Mini	Mini (traditional incandescent)	0.40	0.5%	240	440	117
	Mini (low-wattage incandescent)	0.22	0.5%	240	440	64
	Mini (LED)	0.04	0.5%	240	440	13
Standard	Standard (traditional incandescent)	2.00	0.5%	240	440	580
	Standard (low-wattage incandescent)	NA	0.5%	240	440	NA
	Standard (LED)	0.05	0.5%	240	440	15
Jumbo	Jumbo (traditional incandescent)	2.59	0.5%	240	440	752
	Jumbo (low-wattage incandescent)	NA	0.5%	240	440	NA
	Jumbo (LED)	0.14	0.5%	240	440	40
Rope	Rope (traditional incandescent)	NA	0.5%	240	440	NA
	Rope (low-wattage incandescent)	0.21	0.5%	240	440	62
	Rope (LED)	0.07	0.5%	240	440	20

[a] The calculation for annual unit energy consumption assumes that 75% of decorative light strings sold are operated in a residential setting for 240 hours per year. The remaining 25% are operated by the commercial sector for 440 hours per year.

4.3 Efficiency Measures

As mentioned in Section 2, using efficacy (the ratio of light output to power) as a metric for efficiency of decorative string lights presents numerous challenges. Chiefly, there is not an established method for comparison of light output between LED and incandescent lamps. However, the ability of light strings to illuminate is not greatly important since the primary application is decorative.

As a result of measurement challenges, we compared decorative light string fixtures by measuring the power input per lamp. The lamps that use the most power are the larger incandescents found in standard and jumbo sizes; mini LEDs consume the least power.

The energy usage of decorative light strings can be decreased by encouraging the production of lamps with low power requirements, while prohibiting lamps with power draws greater than 0.25 watts per lamp.

4.4 Standards Options Power Use Per Product

We propose a two-tier standard for decorative light strings. Tier 1 sets a maximum power input at 0.25 watts per lamp. The standard would require manufacturers to offer

decorative light strings using low-wattage incandescent and LED lamps. The sale of strings containing C7 and C9 lamps may be eliminated, but standard and jumbo lamps can be designed utilizing a diffuser over a mini-incandescent lamp or an LED package (Figure 4). Tier 2 sets the maximum power draw at 0.1 watts per lamp. We expect that when Tier 2 is adopted, the majority of decorative light strings will consist of LED technology, unless an incandescent lamp is produced with an advanced filament design, superior fill gas, or both.

Figure 8 illustrates tested products that pass Tier 1 and Tier 2 conditions. This chart displays only lamps whose input power was measured between 0 and 1.0 watts. While we did test lamps whose power demand was greater than 1.0 watt (up to 6.7 watts), these products are not included in the chart so that it is easier to decipher the values in and around the proposed standards. Table 10 shows the power use per product under the standards options. The maximum annual unit energy consumption is 73 watt-hours per lamp under Tier 1 and 29 watt-hours per lamp under Tier 2.

Figure 8. Tested Products <1.0 W atts that Pass and Fail Standard

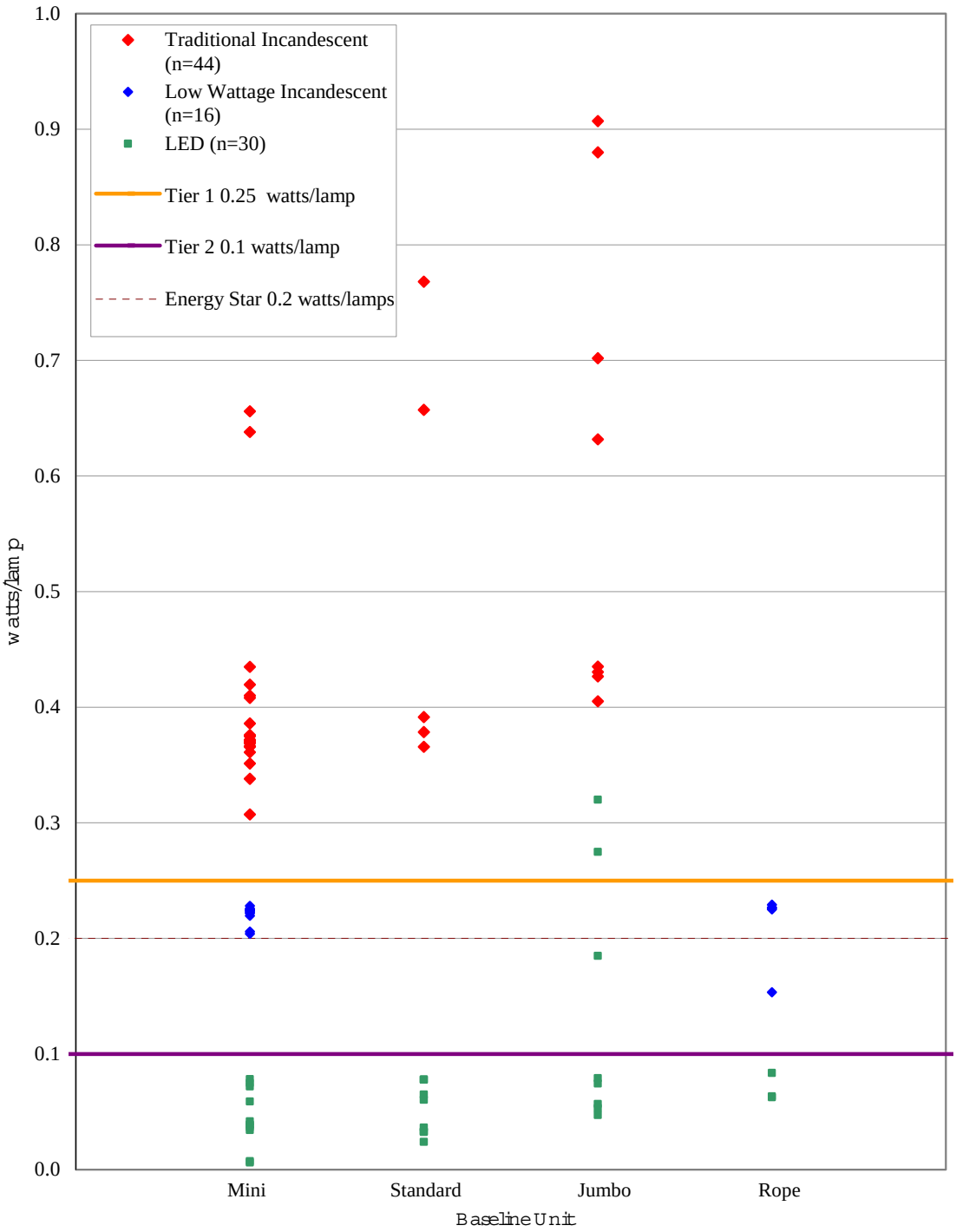


Table 10. Standards Options Energy Use Per Product

Standards Options	Maximum watts/lamp	Percent of Units Operating During Peak Period	Residential Annual Operating Hours	Commercial Annual Operating Hours	Annual Unit Energy Consumption (Whr/lamp)
Tier 1					
Mini	0.250	0.5%	240	440	73
Standard	0.250	0.5%	240	440	73
Jumbo	0.250	0.5%	240	440	73
Rope	0.250	0.5%	240	440	73
Tier 2					
Mini	0.100	0.5%	240	440	29
Standard	0.100	0.5%	240	440	29
Jumbo	0.100	0.5%	240	440	29
Rope	0.100	0.5%	240	440	29

5 Market Saturation and Sales

5.1 Current Market Situation

5.1.1 Baseline Case

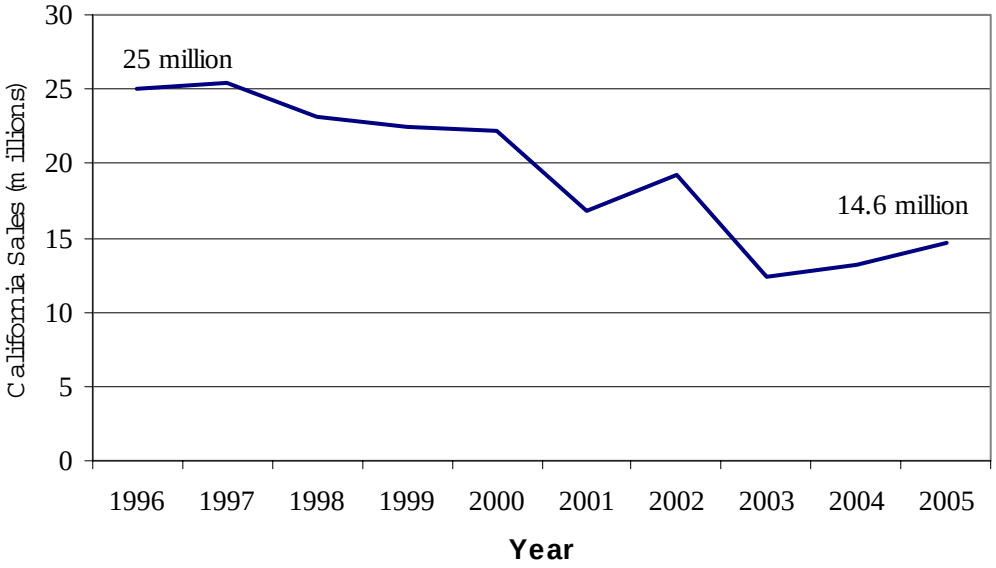
The US International Trade Commission (USITC) tracks the imports of decorative light strings under "lighting sets of a kind used for Christmas trees." The data is aggregated into miniature lights and other lights. For the purpose of this report, we assumed that composition of the decorative light strings market in California is not significantly different from the United States. We scaled the national market based on population (U.S. Census Bureau 2005).

There were more than 14.7 million decorative light strings sold in California in 2005 (the most recent year that data are available), with every household acquiring an average of more than one string per year. Of those 14.7 million, the majority of sales were traditional mini-incandescent light strings, with LED mini light strings, standard, jumbo and rope light strings representing a much smaller market share (Table 11).

The stock of light strings in California is the total sales from 2003 through 2005 (Table 11). We assumed that the functional lifetime of incandescent lights is three years, and the lifetime of LEDs is 6 years, but LED light strings have only been widely available on the market for three years. (See section 7.2 for LED and incandescent design life assumptions.) There are currently over 40.5 million decorative light strings across California. According to U.S. import data, Californians purchased more than 24 million strings in 1996, a number that decreased by more than 58% by 2005 (Figure 9). There is no market indication that people are purchasing fewer decorative light strings today than

a decade ago. For the purposes of this report, we assume that the data are correct. Even with fewer lights in California, the potential energy savings from the proposed standard are quite large.

Figure 9. Light String Imports: California 1996-2005



Source: (U.S. International Trade Commission 2006)

5.1.2 High Efficiency Options

Light strings with low-wattage incandescent and LED lamps qualify under Tier 1; only light strings with LED lamps qualify under Tier 2. While LEDs have gained popularity in the decorative lighting market, they remain only a small percentage of stock and sales in California. Traditional incandescent light strings hold the largest market share.

Table 11. California Stock and Sales

		California Stock [a]			California Annual Sales (2005) [b]		
	Baseline Unit	# of Light Strings in Households and Businesses	# of Light Strings per 1000 Households	# of Light Strings per 1000 Businesses	# of Light Strings Sold Annually	Annual Household Purchases per 1000 Households	Annual Small Commercial Purchases per 1000 Businesses
Mini	Mini (traditional incandescent)	28,214,165	1,749	583	9,259,881	574	191
	Mini (low-wattage incandescent)	1,356,098	84	28	731,043	45	15
	Mini (LED)	3,443,406	213	71	2,193,130	136	45
Standard	Standard (traditional incandescent)	3,204,225	199	66	994,800	62	21
	Standard (low-wattage incandescent)	0	0	0	0	0	0
	Standard (LED)	411,644	26	9	233,348	14	5
Jumbo	Jumbo (traditional incandescent)	3,204,225	199	66	994,800	62	21
	Jumbo (low-wattage incandescent)	0	0	0	0	0	0
	Jumbo (LED)	411,644	26	9	233,348	14	5
Rope	Rope (traditional incandescent)[c]	NA	NA	NA	NA	NA	NA
	Rope (low-wattage incandescent)	361,587	22	7	122,815	8	3
	Rope (LED)	72,317	4	1	24,563	2	1
	Total	40,679,311	2,522	840	14,787,728	917	307

[a] Total stock in California is derived from USITC decorative light string import numbers from 2003-2005 and scaled to California. These values assume that incandescent string lights only last three years before replacement and LED light string have only been a presence in the market place for the past three years.
[b] California annual sales are derived from the 2005 USITC decorative light string import numbers.
[c] Stock and sales of traditional incandescent rope lights is not applicable because the casing does not allow for traditional incandescent lamps. Stock and sales of standard and jumbo low-wattage incandescents is 0 because we did not find any during research.

5.2 Future Market Adoption of High Efficiency Options

In recent years, LED technology has gained popularity as an alternative to incandescent lamps. A retail survey conducted by Energy Solutions demonstrated that 13% of decorative light string products on retail shelves are LED. Although LEDs are gaining popularity because of their novelty and decreasing cost, they are unlikely to gain large market share in the absence of a mandatory power consumption standard. We found LED technology in all lamp sizes and string displays covered by this report.

Low-wattage incandescent light strings are even less common than LED light strings because they do not have the novelty of LED lamps and look identical to standard incandescent lamps. Power consumption standards would have a substantial effect on the adoption of this technology in the marketplace. In a survey of available products, only two manufacturers—Holiday Home and Seasonal Specialties—publicize the products' energy savings. The only other manufacturer that we found producing a low-wattage mini-incandescent light string is Yule Rite, who advertises their product as commercial grade, but not low-wattage. All incandescent rope lights tested qualify as low-wattage incandescent.

6 Savings Potential

6.1 Statewide California Energy Savings

The 40.7 million decorative light strings in California currently use over 730 GWh every year—enough energy to operate over 104,000 California households[3] (Table 12).

Under the proposed standard, Tier 1 would save over 390 GWh per year—enough energy to power 56,000 California households. Under Tier 2, the annual energy savings would be an additional 259 GWh, which is enough energy to operate more than 37,000 California households (Table 13).

[3] According to California Energy Commission 2005 energy statistics, the average California household consumed 6,987 kWh of electricity (California Energy Commission (2006). California Electricity Consumption by Sector.

Table 12. California Statewide Baseline Energy Use

	Baseline Unit	For First-Year Sales		For Entire Stock	
		Coincident Peak Demand (kW) [a]	Annual Energy Consumption (GWh/yr) [b]	Coincident Peak Demand (kW) [a]	Annual Energy Consumption (GWh/yr) [b]
Mini	Mini (traditional incandescent)	3217	187	9801	569
	Mini (low-wattage incandescent)	138	8	257	15
	Mini (LED)	28	2	44	3
Standard	Standard (traditional incandescent)	278	16	897	52
	Standard (low-wattage incandescent)	NA	NA	NA	NA
	Standard (LED)	3	0.15	5	0.27
Jumbo	Jumbo (traditional incandescent)	477	28	1536	89
	Jumbo (low-wattage incandescent)	NA	NA	NA	NA
	Jumbo (LED)	3	0.17	5	0.29
Rope	Rope (traditional incandescent)	NA	NA	NA	NA
	Rope (low-wattage incandescent)	36	2	106	6
	Rope (LED)	0.31	0.02	1	0.05
	Total	4181	243	12652	734

[a] The only decorative light strings subject to peak pricing are a small portion of strings that operate 365 days per year and twelve hours per day in the commercial sector. Peak pricing is in effect from May 1st through October 31st between 1:00pm and 7:00pm (Pacific Gas & Electric Co. 2006).

[b] Annual energy consumption is the aggregate of annual unit energy consumption (watt-hours/lamp), average number of lamps per string for each baseline unit, and annual California sales from USITC light strings data (U.S. International Trade Commission 2006).

Table 13. Estimated California Statewide Energy Savings for Proposed Standards Options

Baseline Unit	For First-Year Sales[a]		After Entire Stock Turnover[a]	
	Coincident Peak Demand Reduction (kW)	Annual Energy Savings (GWh/yr)	Coincident Peak Demand Reduction (kW)	Annual Energy Savings (GWh/yr)
Tier 1				
Mini	1343	78	4573	265
Standard	225	13	736	43
Jumbo	438	25	1417	82
Rope	NA	NA	NA	NA
Total	--	116	--	390
Tier 2[b]				
Mini	526	31	2361	137
Standard	203	12	670	39
Jumbo	421	24	1367	79
Rope	25	1	73	4
Total	--	68	--	259

[a] Savings are relative to the annual energy consumption of the baseline units and the maximum possible energy consumption of standards options given that Tier 1 products cannot exceed 0.25 watts/lamp and Tier 2 products cannot exceed 0.1 watts/lamp. Accordingly, annual energy savings is the minimum possible savings under both Tier 1 and Tier 2.
[b] Additional savings, after the implementation of Tier 1.

6.2 Other Benefits and Penalties

Aside from energy savings, LED decorative light strings have other consumer benefits including:

- Cool to the touch. LED lamps produce much less heat than incandescent lamps. Tests run in the Ecos lab demonstrate that incandescent light string lamps often can become 150° Fahrenheit, whereas LED lamps are typically no warmer than 80° Fahrenheit.
- 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. LED lamps can last upwards of 100,000 hours (though they become dimmer with age).
- Unlike some screw based incandescent lamps, LED lamps do not contain lead solder[4]

[4] All decorative light strings are listed by the state of California under Proposition 65. Proposition 65 was a California voter initiative passed to inform consumers of potential exposure to substances that cause cancer or reproductive toxicity. LEDs do not contain lead solder, as do screw-base incandescent lamps. However,

(ENERGY STAR 2006; BC Hydro 2006)

Understanding that decorative light strings are an important product to consumers— demonstrated by the competitiveness of home decorating around the holiday season— we designed the proposed standard so that homeowners, businesses, and municipalities will not be prevented from decorating effectively. In fact, analysis by Ecos found that the majority of novelty lamps are LEDs, along with more common decorative light string lamps available as LEDs. In the marketplace we found that LED lamps have more design options than incandescents because they typically consist of molded plastic diffusers, whereas incandescent lamps are generally glass, which is more expensive to mold and ship. Figure 3 demonstrates a few novelty lamps available; the lamp on the far left is an incandescent C7 with a plastic diffuser, the three lamps on the right are LEDs with molded plastic diffusers sealed to the LED package.

Despite their advantages, some LED light strings have not met consumers' quality expectations. Opponents have argued that LEDs are not sufficiently bright for decorative lighting purposes. While it is true that LED lights have a lower light output than their incandescent counterparts, we and others assume that consumers generally purchase light strings for decoration only and are content with the brightness of LEDs (Navigant Consulting Inc. 2006).

Besides brightness, some object to the correlated color temperature (CCT)[5] of white LED lights. Consumers enjoy the "warmth" of yellowish-white incandescent lamps with a low CCT and may not accept the bluish-white LEDs with a high CCT as an equal substitute.

Additionally, many LED light strings have the lamp sealed to the string so they cannot be lost or dislodged; however, the means that they cannot be replaced if one fails to operate as can incandescent light string lamps.

To acquire more information concerning the benefits and drawbacks of LED decorative light strings, we propose to conduct a consumer focus group to understand preferences that drive decorative light string choices. This would allow us to better understand the tastes and preferences of the average consumer, including subjective assessments of product brightness, color quality, build quality, cost, etc.

---

the vinyl wire coating on all string lights may contain a lead additive used as a softener for flexibility. Thus, both LED and incandescent decorative light strings are identified as potentially hazardous (http://www.calprop65.com/pvc.html).

[5] The temperature of the blackbody whose chromaticity most closely matches that of the light source (Illuminating Engineering Society of North America (IESNA) 2000).

7 Economic Analysis

7.1 Incremental Cost

LED decorative light strings often have a higher incremental cost than traditional incandescent light strings; however, some LED products are similarly priced to incandescents. Figure 10 illustrates the price versus the power use of decorative light string lamps tested in the Ecos lab. Some outlier products fall beyond the graph's range. Typical LED products (represented by the blue points below) can range anywhere from less than $0.10 per lamp up to almost $1.0 per lamp. Low-wattage incandescent decorative light string lamps (green points) are comparatively priced to traditional incandescent lamps (red points).

Figure 10. Lamp Cost and Power Use

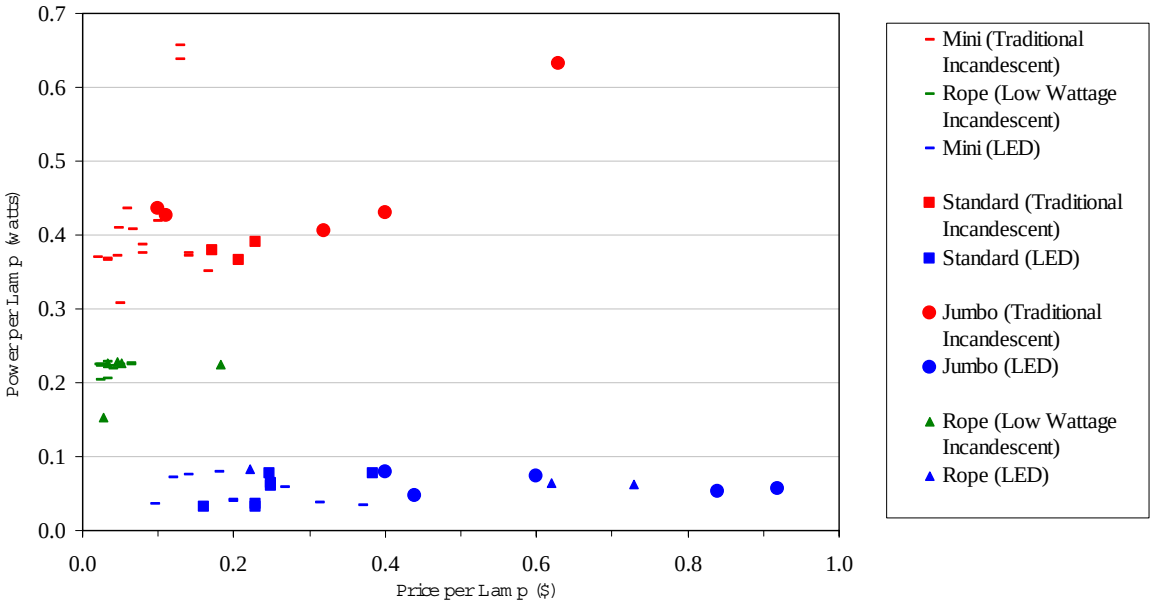


Table 14 shows the average added first cost of purchasing an LED string instead of an incandescent string.

Table 14. Average Added First Cost per Lamp for an LED Decorative Light String Calculated in Ecos Lab 2006-2007

Baseline Unit	$/lamp
Mini (LED)	0.13
Standard (LED)	0.02
Jumbo (LED)	0.16
Rope (LED)	0.63

7.2 Design Life

We assume that traditional and low-wattage incandescent strings have a design life of three years. Incandescent lamps often claim a lifetime of upwards of 3,000 hours, but we and others assume that after three years of use, approximately one third to one half of the lamps are likely to have failed and the string is likely to be disposed of (Navigant Consulting Inc. 2003). LED lamps claim a lifetime of upwards of 100,000 hours. However, LEDs use only a fraction of their life by the end of the life of the decorative light string wiring and fixture. This is because the wiring and plug connector are better determinants of useful life than the theoretical lamp life. Therefore, we assume that LED light strings last six years. The standard assumes that under Tier 1, 50% of sales in California will be low-wattage incandescent light strings with a 3-year lifetime and the remaining 50% LED strings with a 6-year lifetime. All products under Tier 2 have a design life of six years.

7.3 Lifecycle Cost/Net Benefit

In order to identify the net costs and benefits of the proposed standards, we compared the lifecycle costs and benefits 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.

Since LED decorative light strings are more expensive than traditional incandescent strings, an added first cost is incurred under Tier 1 and Tier 2 (Table 15). This cost was calculated using light strings tested in the Ecos lab. The added first cost is the per lamp price difference between strings that pass the proposed standard's power demand requirements and traditional incandescent strings that do not pass the standard's requirements. The calculation is made with products in the same baseline category (mini, standard and jumbo). In other words, jumbo products that pass the standard are compared with traditional jumbo incandescent products that do not pass the standard.

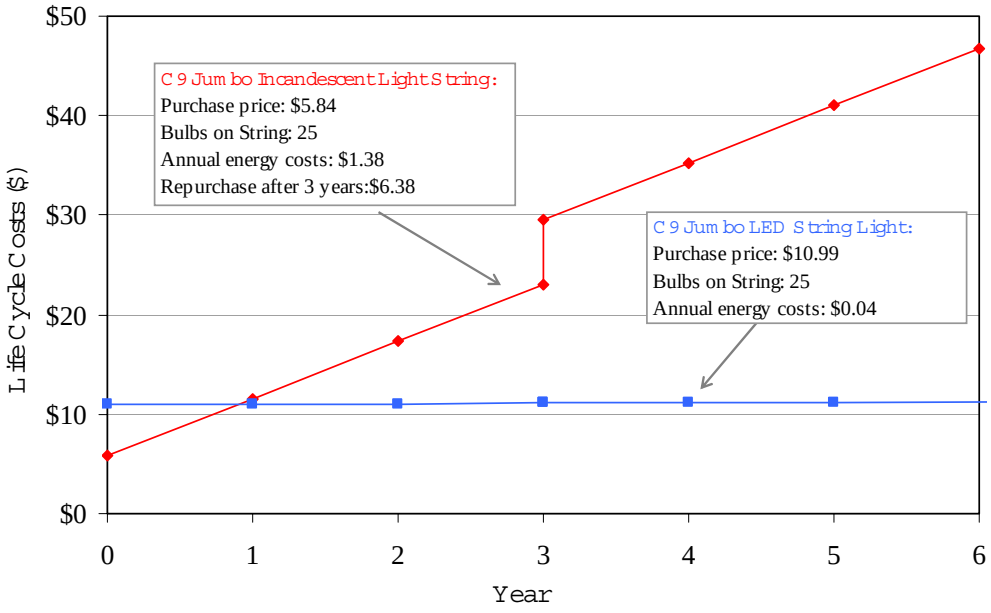
Despite the added first cost of some light strings that require less power, the proposed standard is cost effective for each baseline unit under Tier 1. Cost effectiveness is indicated by a positive net present value, signifying a reduced total cost of ownership over the life of the product (Table 16). The cost benefit analysis for rope lighting is not applicable because all rope lighting currently on the market meets Tier 1 conditions.

Tier 2 requirements are clearly cost effective for standard and jumbo decorative light strings. Mini lights meet the minimum cost effectiveness requirements at current retail prices, with a lifetime net cost/benefit of 1.0 (Table 16). There is a potential for a small monetary loss to the consumer for mini lights under the standard (see Section 7.4). Cost benefit analysis reveals a significant loss to the consumer for rope lighting.

Along with energy savings, the proposed standard should also reduce the need to replace burned out light strings. Traditional and low-wattage incandescent products require replacement twice as often as an LED string. The additional benefit increases under Tier 2 because all products are LED.

Figure 11 illustrates that despite the added first cost of an LED string, after only one year a jumbo LED light string begins saving the consumer money. By the end of 6 years, a consumer saves over $35 for purchasing an LED string instead of a traditional jumbo incandescent string.

Figure 11 Life Cycle Cost Comparison[6]



[6]After three years consumers of traditional jumbo incandescent light strings encounter a replacement cost higher than the original cost because of inflation.

Table 15. Costs and Benefits per Unit for Standards Options

Baseline Unit	Low-wattage Incandescent Life (years)	LED Design (years)	Lifecycle Costs per Lamp (Present Value $) Added First Cost	Add'l Costs[a]	Total PV Costs	Lifecycle Benefits per Lamp (Present Value $) Energy Savings	Add'l Benefits[c]	Total PV Benefits
Tier 1								
Mini	3	6	$0.03	$0	$0.03	$0.03	$0.05	$0.07
Standard	3	6	$0.02	$0	$0.02	$0.19	$0.12	$0.31
Jumbo	3	6	$0.16	$0	$0.16	$0.27	$0.26	$0.54
Rope	NA	NA	NA	NA	NA	NA	NA	NA
Tier 2[c]								
Mini	--	6	$0.13	$0	$0.13	$0.03	$0.09	$0.13
Standard	--	6	$0.02	$0	$0.02	$0.19	$0.25	$0.44
Jumbo	--	6	$0.16	$0	$0.16	$0.27	$0.53	$0.80
Rope	--	6	$0.63	$0	$0.63	$0.01	$0.04	$0.05

PV = Present Value

[a]Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2004).

[b] Additional benefits include not having to replace an incandescent string every 3 years. The additional benefit is only obtained by consumers that purchase LED light strings. Accordingly, only 50% of decorative strings in Tier 1 carry the additional benefit, while all benefit under Tier 2.

[c] Tier 2 is compared against today's market, rather than the market after implementation of tier 1.

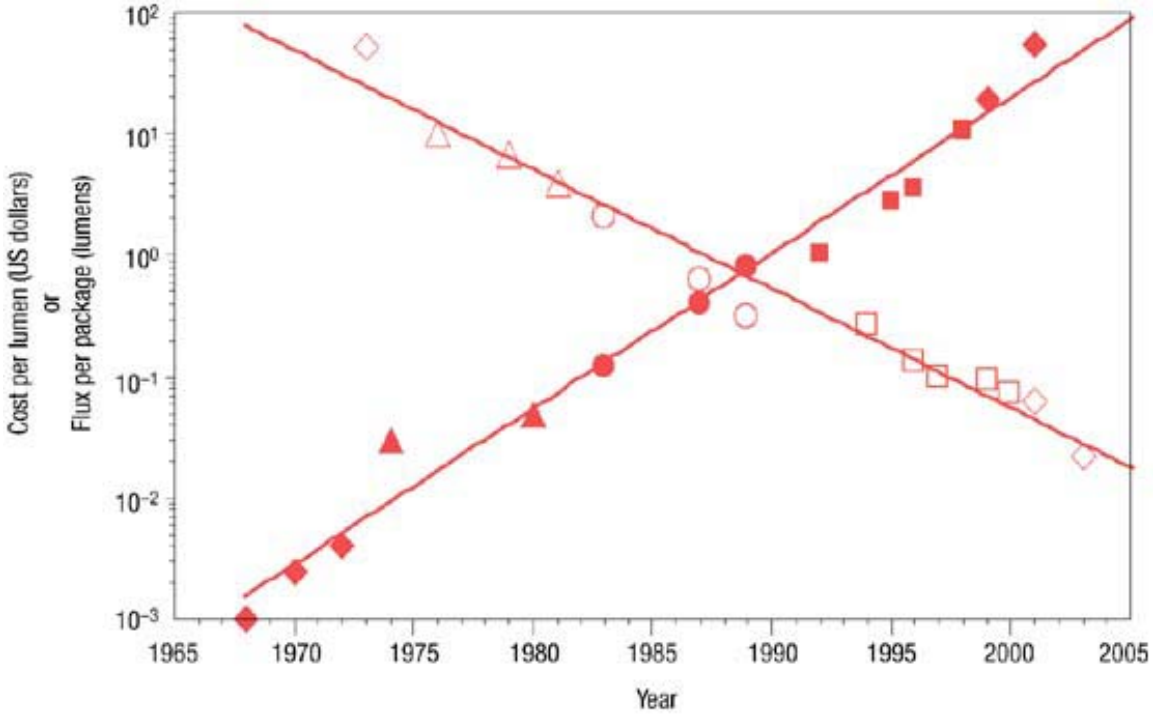
Table 16. Lifecycle Costs and Benefits for Standards Options

Design Options	Lifecycle Benefit / Cost Ratio[a]	Net Present Value ($)[b]			
		Per Lamp	Per String [c]	For First Year Sales (strings)	After Entire Stock Turnover (strings) [c]
Tier 1					
Mini	2.2	$0.04	$5.27	$64,227,088	$174,028,427
Standard	14.5	$0.29	$10.65	$13,084,684	$38,523,460
Jumbo	3.5	$0.38	$10.51	$12,906,536	$37,998,961
Rope	NA	NA	NA	NA	NA
Tier 2					
Mini	1.0	$0.00	$0.00	$0.00	$0.00
Standard	20.3	$0.42	$15.20	$18,666,213	$54,956,395
Jumbo	5.2	$0.65	$17.78	$21,838,746	$64,296,854
Rope	0.08	-$0.58	-$90.66	-$13,361,936	-$39,339,733

[a] Total present value benefits divided by total present value costs.
[b] Positive value indicates a reduced total cost of ownership over the life of the appliance.
[c] The net present value (NPV) per string was estimated with a lamp per string assumption calculated in the lab as an average lamp/string of tested strings. Mini strings average 134 lamps, standards strings average 37 lamps, jumbo strings average 28 lamps, and rope strings average 156 lamps.

While Tier 2 requirements are not currently cost effective for mini LED decorative light strings, trends indicate that the proposed standard will be beneficial to the consumer by its effective date. Figure 12 illustrates that, since the invention of the red LED in the late 1960s, the light output per lamp (luminous flux per package) has increased by a factor of 20 every decade while the cost for the improvement (price per lumen) has decreased by a factor of 10 every decade. This trend is known as "Haitz's Law." Open symbols on the graph below indicate cost per lumen (in US dollars) and the filled symbols indicate flux per package (in lumens) (Steele 2007). As this trend continues, prices will continue to fall as the quality of LED decorative light strings improve, increasing the cost effectiveness of the proposed standard for all LED units.

Figure 12. LED Technology Has Improved, while Prices Have Decreased Over the Last Four Decades. (This figure is for red LEDs only.)



Source: (Steele 2007)

8 Acceptance Issues

8.1 Infrastructure issues

Infrastructure currently exists to accommodate the proposed standard. Low-wattage incandescent lamps are likely to be manufactured in the same facilities as traditional incandescent lamps because they are nearly identical product with different fill gases or filament designs.

LED manufacturing is widespread due to the variety of applications using LED technology including: cell phones, stop lights and exit signs. Decorative light strings provide a use for the least expensive LED technologies that were cutting edge a few years ago but are now inadequate for other industries.

8.2 Existing Standards

Decorative light strings and rope lights are subject to UL product safety testing. The standard covers all products listed as Decorative Lighting Products under UL 588 and some products listed as Decorative Outfits under UL 588 (Underwriters Laboratories Inc. 2000). Rope lights fall under UL 2388, Flexible Lighting Products. The UL Seasonal and Decorative Products test procedure specifies a variety of safety tests including

current leakage tests, abnormal operation tests, temperature tests, flexing tests, rain tests, UV tests, and water immersion tests.

ENERGY STAR is in the process of creating a program to reduce seasonal energy consumption by promoting decorative light strings that consume less than 0.2 watts per lamp. ENERGY STAR program requirements consist of a test procedure that seeks to ensure the quality of products by testing the lifetime and light intensity of strings (ENERGY STAR 2006).

The ENERGY STAR test procedure references the CIE 84-1989, *The Measurement of Luminous Flux* and ASTM G154 – 05, *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*. CIE 84-1989 is a technical report that defines the terminology required for luminous flux measurements. It also outlines the method for measuring luminous flux in an integrating sphere. ASTM G154-05 describes procedures for using fluorescent UV light and water apparatus intended to replicate the weathering effects that occur when materials are exposed to sunlight and moisture (ASTM International (ASTM) 2007; Commission Internationale de l'Eclairage (CIE) n.d.).

California assemblyman Lloyd Levine is expected to introduce the "How Many Legislatures Does it Take to Change a Light Bulb Act", which would ban incandescent light bulbs in the state by 2012, in favor of energy efficient alternatives. The legislation indicates that the state of California is prepared to advance beyond incandescent technologies.

8.3 Stakeholder Positions

Although we did not solicit stakeholder positions in preparation for this version of the CASE Initiative, we assume that manufacturers who create LED and low-wattage incandescent light strings would be in favor of a power consumption standard. Other manufacturers who focus solely on traditional incandescent decorative light strings would be in opposition to the standard. This would need to be confirmed in future stakeholder outreach discussions.

Pierrette LeBlanc with Natural Resources Canada, who is currently leading the development of a North American ENERGY STAR criterion for decorative light strings, indicated that in their January 2006 stakeholder meeting, manufacturers approved of the test procedure outlined by *ENERGY STAR Program Requirements for Decorative Light Strings Test Procedure and Eligibility Requirements Draft Version 1.2.2*. The purpose of the UL test procedure is to inspect products for safety. The tests outlined by ENERGY STAR examine product quality and lifetime. To limit test burden, ENERGY STAR plans to create product families with similar mechanical, electrical, and optical characteristics that can be grouped during testing. One stakeholder did have concern that the some of the proposed tests in the ENERGY STAR procedure are covered by the UL. Since decorative light string manufactures already have to pay the cost of UL certification, he suggested that any additional testing should be kept to a minimum (Parker 2006).

It is likely that stakeholders in the retail services will object to the exclusive use of LEDs because they prefer the "warmth" of the yellowish-white incandescent lamps. They may not accept the bluish-white LEDs as an equal substitute. Warm white LEDs do currently exist, but they are the among least efficacious and most expensive LED lamps.

9 Recommendations

9.1 Recommended Standards Options

Based on our analysis, we recommend that California adopt a two tiered standard. Tier 1 limits decorative light strings to using no more than 0.25 watts per lamp. This would allow low-wattage incandescent and LED products to be sold. We suggest that the first tier would take affect with a one year lead time. Tier 2 allows for products that consume under 0.1 watts per lamp and would allow the sale of only LED products. We suggest that the second tier take effect two years subsequent to the start of Tier 1. We recommend using the final ENERGY STAR test procedure with the blinking light addendum outlined in section 4.1.2 to measure the products. The rope lighting market is not currently suitable for standards because the product class currently consists of low-wattage incandescent products. At present, the incremental cost of producing LED rope lights is extremely high and not cost effective to the consumer.

9.2 Proposed Changes to the Title 20 Code Language

We propose the following language:

Decorative Light Strings. The power draw of decorative light string lamps sold after XXX date shall not be more than the Tier 1 values shown in Table 17; and the power draw of decorative light string lamps sold on or after XXY date shall not be more than the Tier 2 values shown in Table 17.

Table 17. Standards for Decorative Light Strings

Standards Options	Maximum watts/lamp
Tier 1	0.25
Tier 2	0.10

10 References

ASTM International (ASTM) (2007). Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.
BC Hydro. (2006). "Holiday LED Lights (Christmas Lights)." Power Smart at Home, from http://www.bchydro.com/powersmart/elibrary/elibrary8849.html.

Betty's Christmas House. (2007). "Betty's Christmas House Website." from http://www.bettyschristmashouse.com/lights/images/G40_twinkle.jpg.

Bijker, W. E. (1995). "The Majesty of Daylight: The Social Construction of Fluorescent Lighting," in *Of Bicycles, Bakelites and Bulbs: Towards a Theory of Sociotechnical Change*. Cambridge, MA, MIT Press.

California Energy Commission (2006). California Electricity Consumption by Sector.

Chien Hwa Trading Co., L. (2007). "Icicle Light ", from http://www.all-lighting.com/icicle_light.htm.

Christmas Lights Etc. (2006). Numbers estimated by sales representative at Christmas Lights Etc. G. Zimmerman.

Commission Internationale de l'Eclairage (CIE) (n.d.). The Measurement of Luminous Flux.

Ecos Consulting, Davis Energy Group, et al. (2004). Analysis of Standards Options For General Service Incandescent Lamps. Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development. San Francisco, CA, Pacific Gas and Electric Company.

ENERGY STAR (2006). ENERGY STAR® Program Requirements for Decorative Light Strings.

How Stuff Works. (2006, 11/11/2006). "What Is The Difference Between a Fluorescent Light and a Neon Light?" from http://science.howstuffworks.com/question293.htm.

Illuminating Engineering Society of North America (IESNA) (2000). Lighting Handbook; References and Applications.

Kroegers Ace Hardware (2007). Personal Communication with Store Manager of Kroeger's Ace Hardware, Durango, CO. G. Zimmerman. Durango.

McMaster-Carr (2006). Light Bulbs/Bulb Style/Incandescent Bulbs/Standard.

Navigant Consulting Inc. (2003, November 2003). "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications." from http://www.netl.doe.gov/SSL/PDFs/Niche%20Final%20Report.pdf.

Navigant Consulting Inc. (2006). Development of an ENERGY STAR Program for Seasonal Decorative Light Strings, Natural Resources Canada.

Pacific Gas & Electric Co. (2006). "Residential Customers: Low-income Rate Options " Retrieved 01/9/2007, from http://www.pge.com/rates_regulations/rate_info/rate_options/res/.

Parker, C. (2006, 12/20/2006). "COMMENTS ON PROPOSED ENERGY STAR LABELLING SEASONAL LED SETS." from http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/Carillon_Comments_on_Draft1_Proposed.pdf.

Pegasus Associates Lighting. (2007). "Rope Light." from http://www.pegasusassociates.com/products/RopeLights/RopeLights.html.

Steele, R. V. (2007). "The story of a new light source." Nature Photonics, 2007, from http://www.nature.com/nphoton/journal/v1/n1/pdf/nphoton.2006.44.pdf.

U.S. Census Bureau. (2005). "California 2005 American Community Survey Data Profile Highlights." American FactFinder, from http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&geo_id=01000US&_geoContext=01000US%7C04000US06%7C05000US06001&_street=&_county=&_cityTown=&_state=04000US06&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=010&_submenuId=factsheet_1&ds_name=ACS_2005_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry=.

U.S. International Trade Commission. (2006). "USITC Interactive Tariff and Trade DataWeb." from http://dataweb.usitc.gov/scripts/user_set.asp.

Underwriters Laboratories Inc. (2000). UL 588 Seasonal and Holiday Decorative Products.

Underwriters Laboratories Inc. (2007). "UL 588 - Seasonal and Holiday Decorative Products ", from http://www.ul.com/lighting/ul588.html.

Underwriters Laboratories Inc. (2007). "UL 2388 - Flexible Lighting Products." from http://www.ul.com/lighting/ul2388.html.

Vladimer, M. (2006, June 27, 2006). "ENERGY STAR Requirements for Decorative Light Strings, Overview of Seasonal Decorative Light String Market." from http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/dec_lightstrings_workshop_report082206.pdf.

Watkins, R. (2007). Personal Communication with Ralph Watkins. G. Zimmerman. Durango.

Appendix A: Confidential Information

Through our research, we have created list of manufacturers for future stakeholder outreach activities. These are listed below.

Company Name	Contact Name	Phone Number
Holiday Creation	Jim Bruno	215-321-9755
Holiday Creation	Colorado Location	303-694-1121
Holiday Creation	--	800-628-9623
Bethlehem Lights	Larry D. Goerne	815-674-5549
Bright Source Ltd.	Lane Lian	86-574-87508665, 87507290
Taizhou Lisheng Decorative Light & Electrical Equipment Co., Ltd.	Alice	86-576-2713988
Xiamen Sino-Handcrafts Trade Co., Ltd.	Glen Hong	86-592-8486564
Hedera International Trade Co., Ltd.	Monica	86-755-25029894
Changsha Prettyhome Deco Lighting Co., Ltd.	Elaine Loo	86-731-5218116
Shanghai Hous Group Co., Ltd.	Kelly	86-21-54382372
Dongyang Lanyue Arts&Crafts Co., Ltd.	Hansan Wu	86-579-6978155
Orient-Star Decorative Lighting Co., Ltd.	Kacy	86-516-7775798
Hongji Christmas & Rope Lights Co., Ltd.	Lifa Hong	86-576-2430768
Century Marble Trading Co.	Mr. C.T. Gao	886-03-5430956
H.S. Craft Mfg Co.	George Tsai	886-2-27210522
Top Lights Co. Ltd.	Ms. Nancy Tseng	86-791-8609603
Excellence Optoelectronics Inc	--	514-694-7710
Ming Chuan Industrial Co.	--	(86 752) 3333020 / (86 752) 3629685
Shenzhen Yong Liang Industrial Co. Ltd.	--	--
Starpress Industrial Ltd.	Chi-Ping Tse	(852) 2334-8389
Wonderful Lites Corp.	Kwang Ming Cheng	886-3-5712258, 3-5716036

GE Lighting	--	1-800-435-4448 1.877.398.7337
Angelo Brothers (Westinghouse)	--	(800) 999-2226
Philips Lumileds	--	(408) 964-2900
Osram	--	(978) 777-1900
Cree	--	(919) 313-5300
Gelcore	--	(216) 606-6555
Color Kinetics	--	(617) 423.9999
Seasonal Specialties	Steven Altamura	--
GREENLITE Lighting Corporation	Nina Gupta	(877) 255-0004
Home Hardware	Kerry House	--
Everstar Merchandise	Joe Lincoln	--
LEDesign Works	Brian Owen	--
LEDUP	Jerry Yu	--