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

Title:
Analysis of Standards Options for Nightlights

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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 nightlights.

While a single nightlight consumes little energy over the course of a year—an average of 10 kWh—there are approximately 12.6 million nightlights currently in use in California. In total, we estimate that all the nightlights in California consume more than 130 GWh annually, enough electricity for more than 18,000 California households for one year.

Of the 65 nightlights we tested, we encountered six light source technologies, five control mechanisms, and a wide range designs. Active power ranged from 0.01 to 6.4 watts. Among nightlights with a standby mode, the standby power ranged from 0.01 to 0.9 watts. Annual energy use estimates were based on measured power in active and standby modes combined with duty cycle assumptions for each of the five control mechanisms; estimates ranged from 0.12 to 48.7 kWh.

Nightlights are logical products to target for efficiency standards. The nightlight that we estimated to use the least energy annually used just 0.3% of the energy required by the nightlight with the highest estimated annual energy use. Additionally, most of the manufacturers we encountered already offer low-energy designs as part of their product lines.

We recommend that California adopt a ≤ 3.0 kWh standard for annual energy use per nightlight, with a 0.5 W maximum limit for standby power. Nightlights that currently do not meet this standard could comply through the use of low-power light sources or by reducing the "on" time of high-power light sources with automatic switches.

More than a third of the nightlights in our dataset meet the proposed standard, and their average price is $0.65 less than the average price of the non-compliant nightlights in our dataset. The annual energy savings possible from replacing an average non-compliant nightlight (15.5 kWh/year) with an average compliant nightlight (1.5 kWh/year) is 14 kWh per year, worth about $1.70 annually.

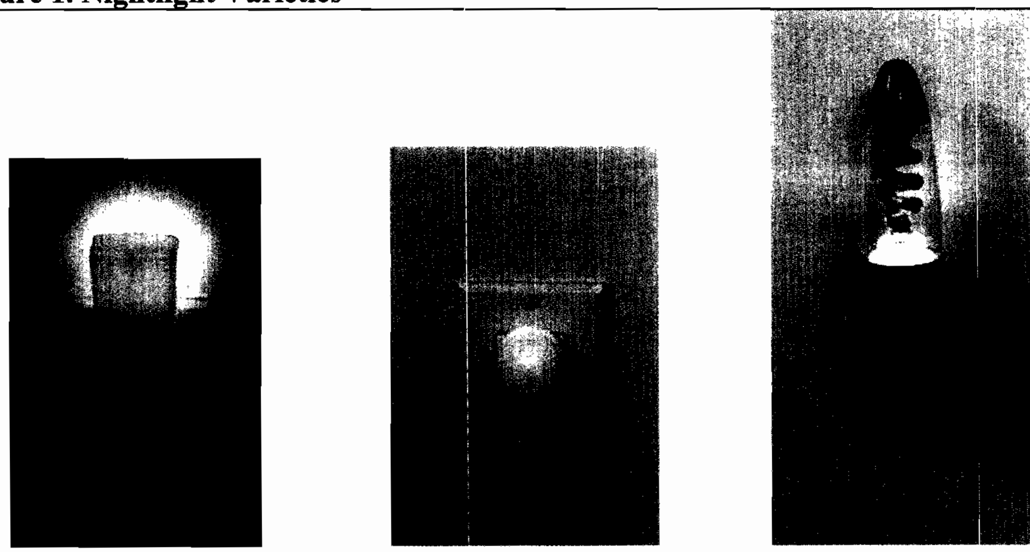
An 85% reduction in nightlight energy use could be realized with the adoption of the proposed standard. The resulting annual savings once the entire nightlight stock meets the proposed standard would be:

- 111 GWh—enough for nearly 16,000 California households
- 50,000 ton reduction in carbon dioxide (CO_2) emissions—equivalent to removing nearly 8,000 cars from the road for one year

2 Product Description

Nightlights are small, plug-in, lighting devices used primarily in residences to provide low-level lighting at night or in dark spaces. We estimate that there are approximately 12.6 million nightlights in use in California—just over 1 per household (Porter, Moorefield et al. 2006). Nightlights are available in seemingly limitless combinations of light source technologies, control mechanisms, and designs. We encountered six light source technologies, five control technologies, and designs ranging from the most basic to purely decorative.

Figure 1. Nightlight Varieties



Basic incandescent way-finding nightlight	Neon signal nightlight	Incandescent novelty nightlight

Nightlights are often used in bedrooms, bathrooms, and hallways, and frequently associated with the needs of children (comfort) and the elderly and disabled (safety). Nightlights with high light output levels can illuminate an area's floors, walls, and other surfaces thereby functioning as way-finding devices. Nightlights with low light output function as signal lights indicating the location of walls or room wall switches, but do not illuminate room surfaces well. Novelty nightlights integrate the light source with decorative features to produce effects such as changing colors of light, bubbling liquids, and sparkling glitter.

In this report, we use the common Underwriters Laboratories, Inc. (UL 1786) and Canadian Standards Association (CSA C22.2 No. 256) classifications of nightlights. Only direct plug-in, parallel slot receptacle nightlights are covered. Maximum voltage is 125 V (ac); maximum wattage is 10 watts. Nightlights that include one extra outlet are covered under the UL nightlight standard, while nightlights with more than one extra outlet are not covered. Battery operated nightlights or those with electrical cords are not covered in this report. Additionally, products which serve several functions (i.e. room deodorizers or insect repellants) are not included in this standards analysis.

In the following paragraphs, we discuss in detail the light source technologies and control mechanisms (switches) that we encountered during this standards analysis. We did not include descriptions of any technologies that are excluded from the proposed standard.

Light Sources

Six light source technologies are commonly used in nightlights. Power demand of these technologies varies widely. Incandescent nightlights can use more than 4 watts while "on". Electroluminescent (EL) and neon nightlights use only a fraction of a watt when "on". See Table 1 below for a list of light source technologies and average power in "on" mode for each technology. A detailed description of each technology follows.

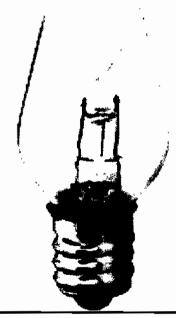
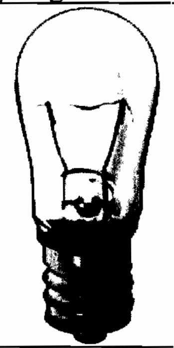
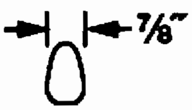
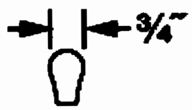
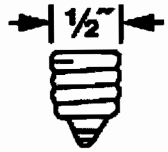
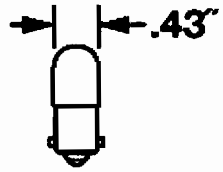
Table 1. Average Power in "On" Mode

Light Source	Average Power in "On" Mode (W)
Electroluminescent (EL)	0.17
Fluorescent	3.15
Incandescent	3.76
Light Emitting Diode (LED)	0.59
Mini-Incandescent	1.58
Neon	0.25

Incandescent Bulb

Incandescent nightlight bulbs are typically C7 (conical shaped) or S6 (straight-sided) bulbs with screw-in candelabra bases. Most incandescent nightlights require a 4 or 7 watt bulb that is easily replaced by the owner. However, some incandescent nightlights employ non-replaceable 60 V, 2.5 watt miniature bulbs. (See illustrations in Table 2 below.) Incandescent nightlight bulbs produce visible light just as medium base standard 60 watt household incandescent bulbs do. A tungsten filament inside a gas-filled chamber (bulb) is heated with electricity until it produces visible light.

Table 2. Incandescent Nightlight Bulbs

			
			
C7	**S6**	**Candelabra base**	**Miniature bayonet base bulb**

Diagrams & photos from: (McMaster-Carr 2006), images not to scale

Light Emitting Diode (LED)

LEDs consist of very thin semiconductors layered to form a diode. Applying a voltage across the different semiconductive layers causes the LED to emit light. The diode is encased in a transmissive epoxy and fitted with heat sinks, reflective material, and metal contacts before it is incorporated into a product like a night light.(Ton, Foster et al. 2003)

LEDs produce monochromatic light, unlike the multi-spectral white light produced by incandescent bulbs. The color is determined by the material used in the semiconductors found in 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 three or more colors of LEDs very close together to create the appearance of white light, or covering a blue or ultraviolet LED with phosphors.. When excited by the light from the blue LED, the phosphors emit a yellowish light. The combination of the blue or ultraviolet LED light with the yellowish phosphor light appears white to the human eye.

Table 3. LED Illustrations[a]

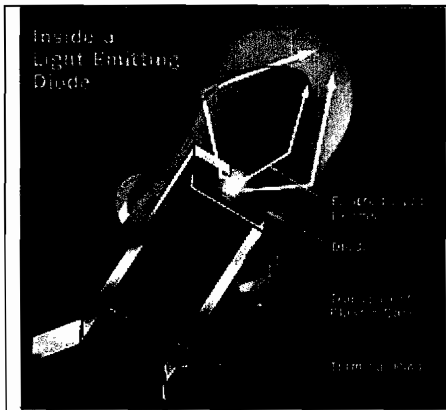
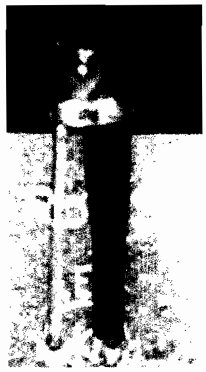
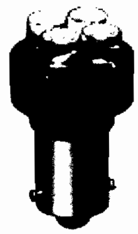
		

Diagram of an LED[b]	**Single LED from Nightlight (0.625" tall)**	**Four LED Cluster (1.1" tall)[c]**

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

Electroluminescent (EL)
An electroluminescent panel is a sandwich-like structure with two outer layers of transparent flexible plastic conductors and a phosphor layer in between. The panel acts like a capacitor in the circuit. When alternating voltage is applied to the outer layers, the phosphors in the center layer become excited and emit visible light. The color of an EL panel is controlled by either tinting the outer plastic layer, or placing a tinted transparent film in front of the EL panel in the nightlight casing. The color can also be altered by changing the amplitude or frequency of the applied voltage. (Micro Electronics Inc. 2007)

Figure 2. Cross Section of an Electroluminescent Sheet

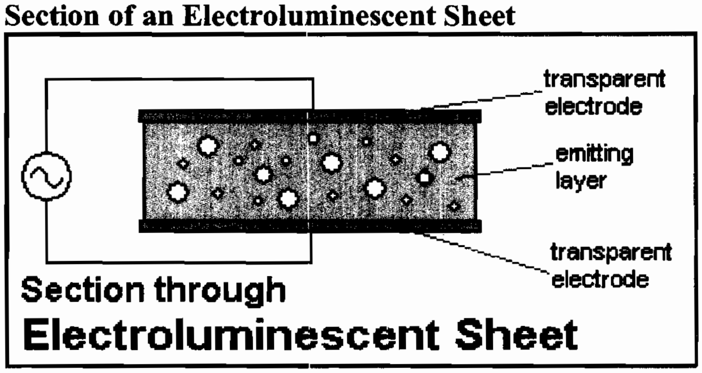


Image source: (Talking Electronics 2006)

Fluorescent

A fluorescent bulb is made of a glass tube whose interior surface is coated with phosphors. The tube is filled with an inert gas and a small amount of mercury, then is sealed under a slight vacuum. When an electric current is applied to electrodes on the ends of the tube, the mercury inside is energized and gives off ultra-violet (UV) light. UV light is not visible to the human eye; however, the phosphors absorb it and they, in turn, emit a visible light. (Calwell, Granda et al. 1999)

Neon

Neon technology is similar to fluorescent technology. The most basic neon bulbs (including those found in nightlights) utilize sealed glass tubes filled with neon at a low pressure. Electrodes are secured to ends of the tube. When a current is applied to the electrodes, the neon atoms are excited and emit visible red/orange light that is typical of neon nightlights. (Goldwasser and Klipstein 1999; How Stuff Works 2006; Micro Electronics Inc. 2007)

Figure 3. Fluorescent and Neon Technologies

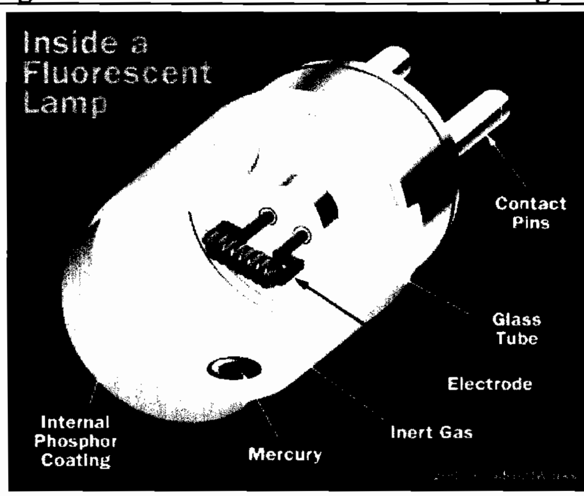


Diagram of a Fluorescent Lamp[a]

Neon Bulb[b]

[a] Courtesy of HowStuffWorks.com

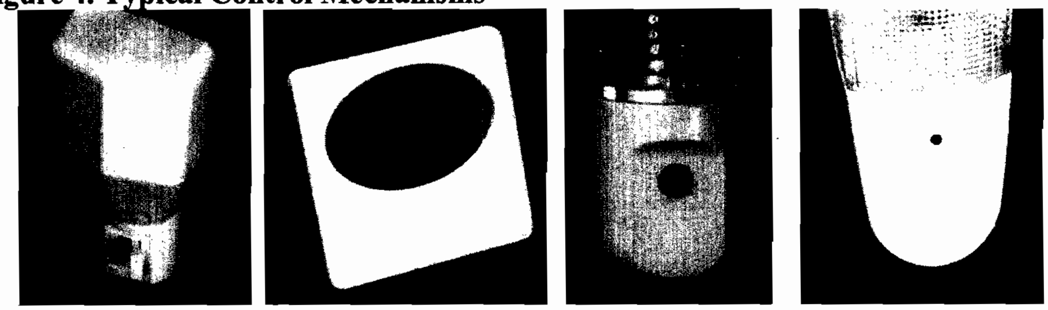
[b] (McMaster-Carr 2006) Images not to scale. Overall length: ¾"

Control Mechanisms

Four control mechanisms typically found in nightlights include:

- hard on/off switch
- no switch (always "on" when plugged in)
- photosensor (often referred to on packaging as "on at dusk, off at dawn")
- motion detector (turns nightlight on for a short period of time when movement is detected)

Figure 4. Typical Control Mechanisms



Hard Switch　　No Switch　　Photosensor　　Motion Detector

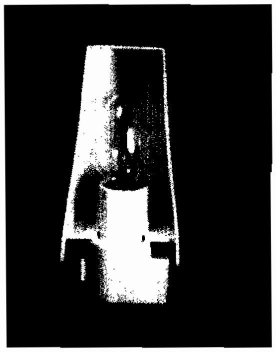
Some nightlights combine operational control mechanisms for more precision. The two nightlights we tested with motion detectors also utilize photosensors so that the light turns on only when motion is detected and the room is dark. Another nightlight gives the user the option of turning the nightlight on and off manually with a hard on/off switch or allowing the nightlight to operate automatically with a photosensor. We also found one model which combined a photosensor with a sound detector; this was the only such model we encountered. Table 4 and Figure 5 provide an overview of the many different attributes and combinations of technologies that we observed in our nightlight sample set. Certainly other configurations are possible. The variety of nightlights on the market today illustrates the many options that nightlight manufacturers have for fine-tuning the operation of their products.

Table 4. Overview of Nightlight Features in Sample Set

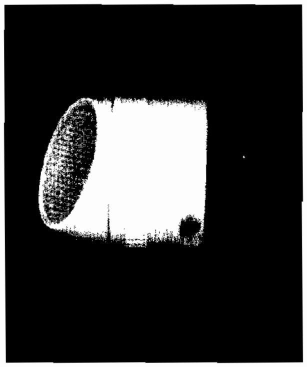
Light Source	Average Power (W)	Design Life of Light Source (hours)	Replaceable Bulb?	Power Controls			
				No Switch	Hard On/Off Switch	Photo-sensor	Motion Detector
Incandescent	3.7	3,000 [a]	Yes	No	Yes	Yes	Yes
Mini-Incandescent	1.8	10,950 [b]	No	No	No	Yes	No
Fluorescent	3.2	8,760 [c]	No	No	Yes	Yes	No
Neon	0.2	10,950 [d]	No	Yes	No	Yes	No
LED	0.8	100,000+ [e]	No	Yes	Yes	Yes	No
EL	0.2	100,000+ [f]	No	Yes	No	Yes	No

[a] Based on packaging claims from multiple manufacturers.
[b] Based on conversation with Amerelle customer service representative.
[c] Based on conversation with GE Jasco customer service representative.
[d] Based on conversation with Amerelle customer service representative.
[e] Based on packaging claims on multiple LED nightlights and conversation with Amerelle customer service representative
[f] Based on packaging claims

Figure 5. Nightlight Examples

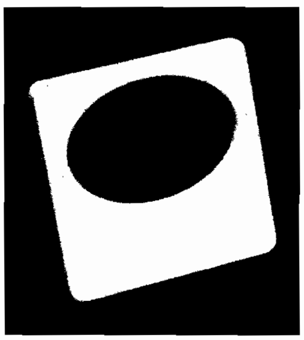


Incandescent
- standard design
- hard on/off switch
- annual energy use: 32 kWh



Mini-incandescent
- "spotlight" design
- photosensor
- annual energy use: 7 kWh

LED
- designed to resemble standard incandescent fixture
- photosensor
- annual energy use: 1 kWh



EL
- no switch
- annual energy use: 0.2 kWh

Neon
- no switch
- annual energy use: 2 kWh

Fluorescent
- hard on/off switch
- photosensor
- annual energy use: 17 kWh

3 Manufacturing and Distribution Channel Overview

The vast majority of nightlights are products of China[1]. Nightlights are manufactured by several types of companies:

- major lighting manufacturers (e.g., General Electric (GE), Leviton, and Osram Sylvania)
- lighting and other home accessories manufacturers (e.g., Amertac/Amerelle)
- hardware store brands (e.g., Ace brand for Ace Hardware)
- safety products manufacturers (e.g., First Alert)
- product design companies (e.g., Salamander Graphics, Mary Elle Fashions)

[1] Of the 65 nightlight samples we obtained for testing, all were made in China except for five. Two were made in Turkey; one was made in Mexico; one was made in Taiwan, R.O.C., and one was made in the U.S.

- manufacturers that specialize in a particular light source technology (e.g., EI Products)

Nightlights are typically sold at grocery stores, drug stores, hardware stores, and general purpose retail outlets such as Target, K-Mart, and Wal-Mart. They are also available at numerous online retailers.

4 Energy Usage

The energy usage of a nightlight light is a result of the nightlight's power demand in "on" and "standby" modes (if applicable) and the time the nightlight spends in each mode. The control mechanism determines which modes a nightlight operates in. A nightlight with no switch has only one mode: "on." The only way to turn the nightlight off is to unplug it. A nightlight with a motion detector has two modes: "on" and "standby." When motion is detected, the light turns on. When no motion is detected, the light is off; however, the motion detector still requires a small amount of power in "standby" mode. A nightlight with a hard on/off switch uses power in "on" mode, but has no power demand in "off" mode. For possible modes according to control technology, see Table 5. Note that some nightlights utilize combinations of the control mechanisms listed below.

Table 5. Modes of Operation

Control Mechanism	"On" Mode	"Standby" Mode	"Off" Mode
Hard on/off switch	x		x
No switch	x		
Photosensor	x	x	
Motion detector	x	x	

4.1 Test Methods

4.1.1 Current Test Methods

We did not find any established test methods for comparing nightlight efficiency. As mentioned earlier, UL and CSA share a common safety standard for nightlights; however, this standard does not include a test method for efficiency. Pending standards from other organizations may include useful test procedures; however, these standards are not yet published. See section 7.2 for more information on standards.

4.1.2 Proposed Test Methods

Due to the absence of an existing standard, we developed the following test method for the purposes of testing nightlights in our data set.

Set-up:

1. Meter: Yokogawa WT1600 Digital Power Meter
2. Standard voltage source set to 120 VAC

3. If nightlight has a photosensor, cover photosensor with black electrical tape[2].
4. If nightlight has a dimmer, adjust for maximum light output.
5. If nightlight has a motion detector, wave hand in front of motion detector until light turns on.

"On" Mode:

6. Record power (watts) in "on" mode
7. Record power factor in "on" mode
8. If power values fluctuate, use Integration setting to integrate power values for two minutes to determine an average power value.

"Standby" Mode—record for nightlights with photocell or motion detector:

9. If nightlight has a photosensor, remove tape and wait for light to turn off.
10. If nightlight has a motion detector, wait for light to turn off.
11. Record power (watts) in "standby" mode.
12. If power values fluctuate, use Integration setting to integrate power values for two minutes to determine an average power value.
13. Record power factor in "on" mode

A more detailed test procedure that we propose for use with the standard is included in a H=hard on/off switch, HP=hard switch and photocell, MP=motion detector and photocell, N=no switch, P=photocell

[2] In one instance, a photocell was housed in a decorative cover such that it was not possible to cover with tape. To compensate, we turned the room light off in order to cause the nightlight to turn on. "On" mode power was then recorded.

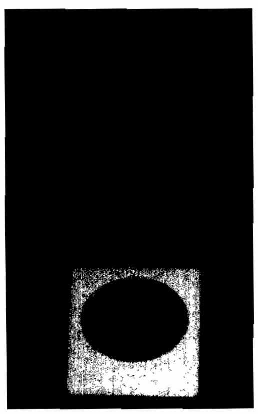
Appendix C: Proposed Test Procedure for Standard.

4.2 Baseline Energy Use Per Product

Annual energy use of a nightlight is determined not only by the power used in "on" and "standby" modes but also by the way a nightlight is operated. A nightlight's operation is a function of the consumer's behavior and the type of control mechanism (switch) incorporated into the nightlight. Nightlights with photocells and motion detectors have some power draw in "standby" mode, however, it is typically very low. Standby power values in our sample set were under 0.01 watts except for two samples with standby power values of 0.5 and 0.31 watts.

The average annual energy use of a nightlight is approximately 11 kWh per year. In our sample set, the estimated annual energy use ranged from 0.12 kWh (EL, no switch) to 48.7 kWh (incandescent, hard on/off switch). These same nightlights also represented the extremes in power demand in "on" mode. The EL nightlight used 0.01 watts in "on" mode while the incandescent drew 6.4 watts in "on" mode. See Figure 6 below.

Figure 6. Nightlights with Lowest and Highest Power and Energy Use



EL

- no switch
- power in "on" mode: 0.01 W
- annual energy: 0.12 kWh

Incandescent

- hard on/off switch
- power in "on" mode: 6.4 W
- annual energy use: 48.7 kWh

To determine baseline energy use, we measured the power demand in watts of 65 nightlights. Power was measured in "on" mode and in "standby" mode, if applicable. We then used the duty cycle assumptions outlined in Table 6 below to estimate annual energy use per nightlight.

Nightlight duty cycles have not been well researched. Ecos Consulting attempted to measure nightlight duty cycles as part of our California Energy Commission-funded residential field measurement research (Porter, Moorefield et al. 2006); however, our findings were inconclusive because many nightlights operate at power levels below the threshold that our meters could accurately record. Therefore, in many instances, we were uncertain if a nightlight was on, in "standby" mode, off, or plugged in at all. The duty cycles below are estimates developed by our team. Based on experience and observation, we assumed that most people leave the nightlights they regularly use turned on and plugged in throughout the day. We assumed that nightlights with photosensors operate on average for 10 hours per day—eight hours at night, and two additional hours to account for the times that photosensors activate nightlights during the day (e.g. interior hallways, bathrooms with opaque window coverings). We estimated that a nightlight activated by a combination of a motion detector and a photocell operates in "on" mode for a total of one hour per day. These nightlights turn on only when the room is dark and there is motion. Once activated, they typically stay on for one to five minutes. Because these duty cycles play an integral role in this CASE analysis, further research about how consumers operate nightlights in their homes would be useful.

Table 6. Nightlight Annual Operation in Hours

Nightlight Control Mechanism	"On" Mode (hours/year)	"Standby" Mode (hours/year)
No switch[a]	8760	NA
Hard on/off switch[b]	7592	NA
Photosensor[c]	3650	5110
Hard on/off switch & photosensor[d]	4161	4599
Photosensor & motion detector[f]	183	8577

Assumptions:

a. No switch : 100% are "on" 24 hours/day
b. Hard on/off switch: 80% are "on" 24 hours/day, 20% are "on" 8 hours/day
c. Photosensor: 100% are "on" for 10 hours/day and in "standby" for 14 hours/day
d. Hard on/off switch and photosensor: 10% are "on" for 24 hours/day, 90% are "on" for 10 hours/day and in "standby" for 14 hours/day
e. Motion detector: 100% are "on" for 1 hour/day and in "standby" for 23 hours/day
f. Motion detector and photosensor: 100% are "on" for 0.5 hour/day and in "standby" for 23.5 hours/day

Our sample set of 65 nightlights[3] contained 14 different configurations of light source technologies and control mechanisms. Even more configurations exist in the marketplace that were not included in our sample set. To simplify our analysis, we categorized nightlights by their annual energy usage rather than their physical characteristics. By doing so, we created two categories of nightlights that cover all nightlight configurations:

[3] Our sample set consisted of 65 nightlights purchased in California, Colorado, New Mexico, and New York. In order to make the technology distribution in our dataset match the technology distribution found in our survey of California nightlight retailers, we removed 6 nightlights from categories that were over-represented in our dataset, and replaced those 6 items with average power measurements from the under-represented technologies.

1. Those that use ≤ 3.0 kWh per year
2. Those that use >3.0 kWh per year

It is important to note that power draw in some nightlights is for features other than a single light source. For example, a nightlight may demand extra power to operate multiple different colored LEDs for color-changing effects.

See Table 7 for a comparison of estimated unit annual energy use broken down by annual energy-use category. For comparison, see Table 8 for annual energy use broken down by light source technology.

Table 7. Annual Energy Use per Nightlight by Energy-Use Category

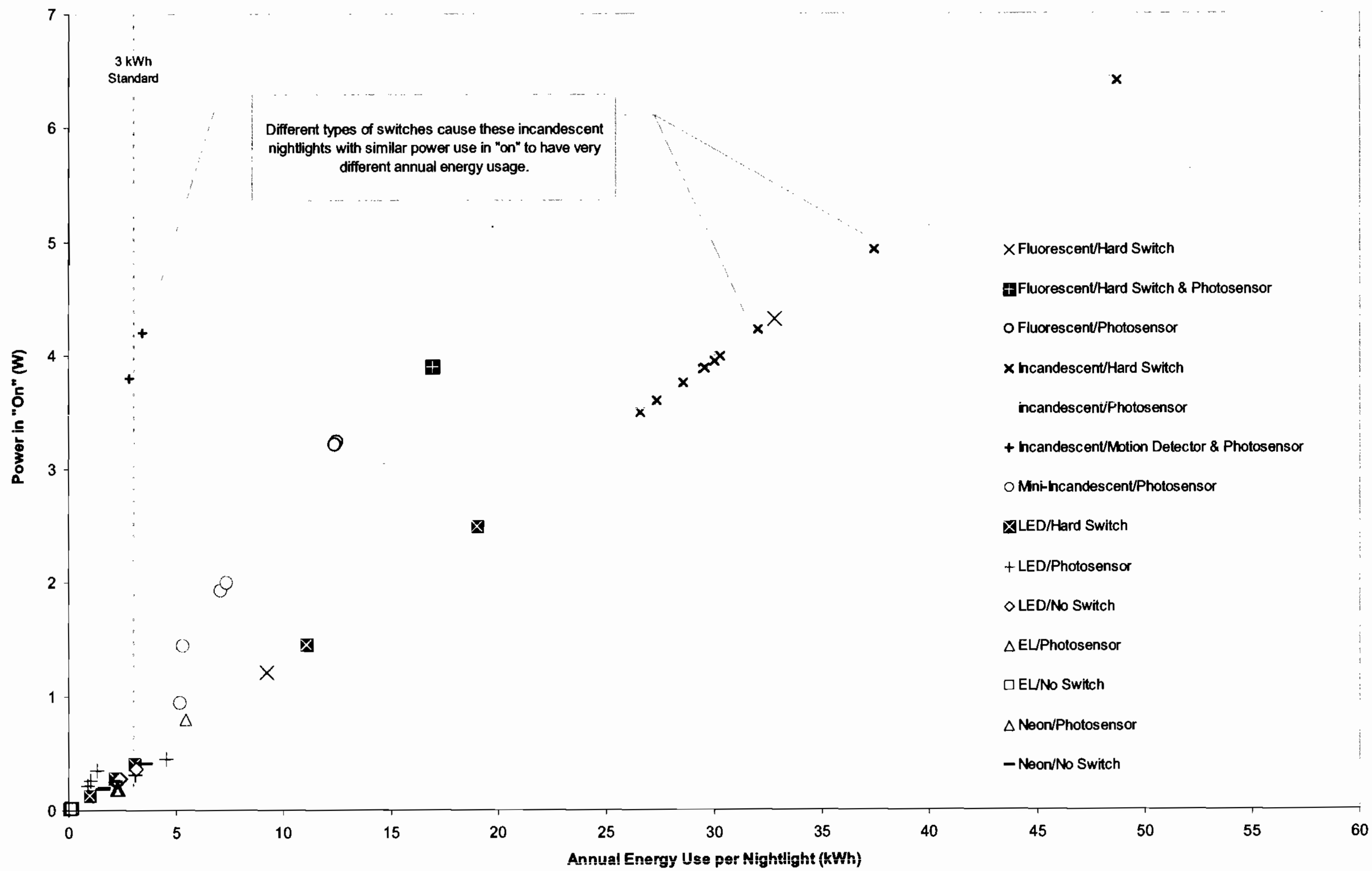
Annual Energy-Use Category	On (kWh/year)	Standby (kWh/year)	Total (kWh/year)
≤ 3.0 kWh per year	1.29	0.23	1.52
> 3.0 kWh per year	15.00	0.54	15.54

Table 8. Annual Energy Use per Nightlight by Light Source Technology

Light Source Technology	Total (kWh/year)
EL	1.22
Fluorescent	19.65
Incandescent	19.33
LED	3.95
Mini-Incandescent	6.24
Neon	2.46

Figure 7 below illustrates the impact that various control mechanisms have on annual energy use. Note the range of annual energy usage of incandescent nightlights. The two incandescent nightlights with motion detectors use far less energy than those with hard switches. The energy usage of incandescent nightlights with photosensors falls between those with motion detectors and hard switches. Also note the nightlights in the lower left corner of the graph. Many of these have no switch and therefore were estimated to operate in "on" mode 100% of the time. However, because these nightlights use extremely low-power light sources, they use very small amounts of energy annually. The wide range of energy use by LED nightlights is in part due to the type of control mechanism, but also affected by auxiliary components such as resistors. In this graph, multiple points overlap, particularly in the lower left corner. There are 27 nightlights plotted to the left of the 3 kWh line, and 40 nightlights plotted to the right of the 3 kWh line.

Figure 7. Comparison of "On" Mode Power, Type of Control Mechanism, and Annual Energy Usage



4.3 Efficiency Measures

In lighting applications, efficiency is typically described as efficacy, that is, the service provided—light output measured in lumens—divided by energy input measured in watts. However, our recommendation is that the service that nightlights provide should not be characterized solely based on light output. While all nightlights are intended to provide small amounts of light in dark spaces, the different services of nightlights require different amounts of light. The three basic services of nightlights in different applications are:

- Way-finding—purpose is to illuminate room surfaces (e.g., walls, floors, stairs) to aid occupant in navigation of a dark space. Way-finding nightlights are often used for safety.
- Signal—purpose is to provide a small beacon of light to indicate the location of a wall, outlet, or room wall switch. Signal nightlights are not intended to illuminate room surfaces.
- Novelty—purpose is primarily decorative; light may change colors or dim. Some novelty nightlights utilize heat produced by incandescent bulbs to cause encapsulated liquids to move or bubble.

A nightlight may serve one or more of the above purposes. For example, signal and way-finding nightlights may have decorative covers, and novelty nightlights may illuminate a wall or floor. In all cases, if a nightlight operates in "on" mode in an otherwise well-lit space, the nightlight is not serving its general service of providing light in a dark space. In these cases, energy is being used but the function is not being fulfilled.

In our sample set, we observed many novelty and signal nightlights that met their purposes using small amounts of energy overall. This was achieved primarily through the use of light source technologies with very low power demand (i.e., EL, LED, and neon).

Way-finding nightlights, however, need to provide more light to fulfill their service of illuminating dark spaces. In light measurement tests that we conducted for the purposes of this report, the light source that provided the most light output—the incandescent bulb—also used the most power in "on" mode. In some nightlight applications, high light output serves an important safety purpose. Therefore, this higher power demand in "on" mode is used in order for the nightlight to fulfill its purpose. On the other hand, if a high-power way-finding nightlight operates when it is not needed (i.e. in a well-lit space or when occupants are not present), it draws power needlessly and no longer serves a purpose. (See Table 20 in Appendix A: Luminance and Illuminance Measurements for light output measurements of selected nightlights.)

For the reasons listed above, we recommend a standard that regulates annual energy consumption rather than input power or light output. Therefore, the proposed standard allows for any light source to be used if combined with a control mechanism such that its annual energy consumption does not exceed 3.0 kWh and its standby power does not exceed 0.5 W.

Under the proposed standard, nightlights can achieve energy reductions through two measures: 1) using a low-power light source (LED, EL, or neon), and/or 2) using automated controls to turn the nightlight off when it is not needed (photosensors and motion detectors). The combination of a motion detector with a photosensor restricts the active operation of a nightlight the most, allowing the light to turn on only when motion is detected and the room is dark.

Manufacturers have the freedom to determine the optimal combination of energy reduction measures that best fit their product design requirements. See Table 9 below for examples of two efficient nightlights with very different "on" mode power demands. Both use less than 3.0 kWh annually while meeting their different purposes.

Table 9. Comparison of Two Nightlights that Meet the Proposed Standard

Light Source	Control Type	Service	Power in "On" Mode (W)	"On" Mode (Hours/ Year)	Power in "Standby" Mode (W)	"Standby" Mode (Hours/ Year)	Annual Energy Use (kWh)
EL	No switch	Signal	0.014	8760	NA	NA	0.12
Incan-descent	Motion detector & photo-sensor	Way-finding	3.8	183	0.25	8577	2.8

Another theoretical option for improving the efficiency of incandescent bulbs is to replace the argon gas typically used as fill-gas in incandescent bulbs with xenon or krypton. Xenon and krypton are both used in limited models of incandescent bulbs, often low-voltage dc flashlight bulbs. These gasses have higher insulating properties than argon, and therefore enable bulb filaments to maintain their required temperature with less input power. The result is improved efficacy (lumens/watt) as well as increased bulb life due to a slower vaporization rate of the filament (Ecos Consulting, Davis Energy Group et al. 2004). Further research is needed to determine if efficiency improvements are feasible in incandescent nightlight bulbs through the use of these alternative gasses.

4.4 Standards Options Energy Use Per Product

We propose a standard for California's nightlights that allows all light source technologies to comply: nightlights that have a total annual energy use of less than or equal to 3.0 kWh and a maximum power of 0.5 W in "standby" mode would meet the California requirement. Nightlights with a total annual energy use of more than 3.0 kWh or with a standby power greater than 0.5 W would not meet the California standard. Nightlight manufacturers may use any combination of light source and control technologies to meet the 3.0 kWh limit.

Table 10. Standards Options Energy Use Per Product

Proposed CA Standard	Active Power Draw (W)	Standby Power Draw (W)	Percent of Units Operating During Peak Period	Annual Operating Hours Active	Annual Operating Hours Standby	Unit Electricity Consumption (kWh/yr)
≤ 3.0 kWh per year and ≤ 0.5 W "standby" power draw	< 10 W [a]	≤ 0.5 W	67% [b]	TBD based on "on" mode power[a]	Dependent on control mechanism	**≤ 3.0 kWh**

[a] Manufacturers may use any combination of light source and power control technology to meet annual kWh limit. Less than 10 watts is specified for active and standby modes because that is the maximum limit for UL certification as a nightlight.
[b] Percentage of nightlights estimated to operate in "on" (active) mode for 24 hours per day. See duty cycle assumptions in Table 6.

Annual energy use to be calculated using the formula found in a H=hard on/off switch, HP=hard switch and photocell, MP=motion detector and photocell, N=no switch, P=photocell

Appendix C: Proposed Test Procedure for Standard.

5 Market Saturation and Sales

5.1 Current Market Situation

5.1.1 Baseline Case

Although field research confirms that nightlights are found in most U.S. homes (Porter, Moorefield et al. 2006), precise sales data for nightlights are not readily available. We found no market research or import data that tracked nightlights separately from portable lighting, which includes products like floor and table lamps. However, in 1999, Calwell estimated national annual sales of incandescent nightlights and nightlight bulbs to be 76 million (Calwell, Granda et al. 1999). This estimate was derived from manufacturer and market research data on sales of 4 and 7 watt incandescent light bulbs that are commonly used in nightlights.

We were able to gain current insight into the penetration rate of nightlights in California households though a plug load field research study conducted by Ecos Consulting (Porter, Moorefield et al. 2006). Fifty households participated in this study. Researchers counted all electronic plug load products in each home, and metered a select group of these products for one week. Fifty-two nightlights that meet the nightlight definition used in this standard proposal were counted in these 50 homes indicating a penetration rate of 104%—just over 1 nightlight per California household. Using this penetration rate, we estimate that the existing California nightlight stock is approximately 12.6 million.

In order to determine the distribution of light source technologies in California, Energy Solutions conducted in-store surveys of three nightlight retailers in California: Home Depot (3838 Hollis Ave, Emeryville, CA 94608), Target (211 W Iowa Ave, Sunnyvale, CA 94086), and Lowes (811 E Arques Ave., Sunnyvale, CA 94085). These surveys were conducted in December 2006. Surveyors counted all nightlights displayed in each store, and recorded the features of each nightlight counted. Of the 50 nightlights counted, five were excluded because of missing information or the nightlights did not qualify as nightlights as defined in this report. Table 11 below shows the distribution of light sources found in nightlights at these California retailers.

Table 11. Distribution of Light Source Technologies

Light Source	CA Survey
Incandescent	47%
LED	28%
Neon	15%
EL	6%
Fluorescent	4%

The tested sample set includes more LED, EL, and fluorescent nightlights and fewer incandescent nightlights than were counted at California retailers. In order to make our tested dataset match the distribution of light source and control technologies found in the California retailers as closely as possible, we normalized our dataset first by light source, then by control technology. We removed data for the following nightlights from our dataset: fluorescent/photosensor (2), LED/hard switch (2), neon/photosensor (1), EL/no switch (1). We then replaced the removed data with average data to represent six 4-watt incandescent nightlights with photosensors. Therefore, baseline energy use of the current California nightlight sales is likely to be equivalent to that projected in this standards analysis.

We do not have a precise sales growth projection because we were not able to locate historical sales data for all nightlights. However, we expect annual sales of nightlights to remain level overall.

5.1.2 High Efficiency Options

Current market estimates suggest that 37% of the nightlights sold in 2006 already meet the proposed 3.0 kWh annual energy use standard. See Table 12 below. Nightlights in our tested sample set achieved low energy use in three ways:

- used light source technology with minimal power demand (e.g., EL and neon) and no switch or photosensor
- combined photosensor with low-power light source technology (e.g., LED operated with a photosensor)
- combined traditional light source technology with a control mechanism that greatly reduced the time a nightlight spent in "on" mode (e.g., incandescent operated by a motion detector)

Table 12. California Stock and Sales[a]

	California Stock[b]		California Annual Sales	
Annual Energy Use	Units (millions)	Saturation (%)	Units (millions)	Saturation (%)
≤ 3.0 kWh	4.65	37%	0.58	37%
> 3.0 kWh	7.94	67%	1.00	63%
CA Total	12.58	100%	1.58	100%

[a]Saturation rate based on tested sample set. (Percent of sample set * annual CA sales or entire CA stock)
[b]Saturation rates of California stock are based on our data set. All samples were purchased in 2006. Because the use of efficient light source technologies has grown in recent years, the actual saturation rate of low-energy nightlights for California stock is likely to be lower than the 37% we observed from our 2006 purchases. The reason is that many nightlights that are currently in use in homes were purchased prior to the recent widespread introduction of low-power nightlight light sources.

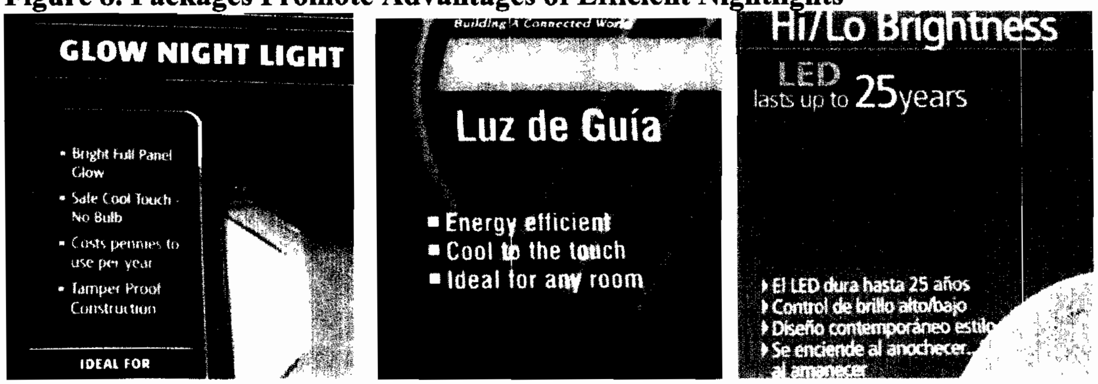
5.2 Future Market Adoption of High Efficiency Options

Already, packaging for nightlights that use lower-power light sources (EL, LED, and neon) frequently contains information about energy efficiency or energy savings. Manufacturers also promote the long life of LED and EL nightlights, and are incorporating these low-power light source technologies into appealing designs. Many nightlights with automated control mechanisms are also present in the marketplace. About 1/3 of the nightlights in our tested sample set have photocells, while motion detectors are used less frequently. Such claims and product designs indicate that consumers are interested in saving energy.

Additionally, a growing interest in LEDs has spurred the development of several new standards that address their performance and safety (U.S. Department of Energy n.d.). This pending standardization, along with recent increases in efficacy and decreases in pricing, is likely to cause manufacturers to incorporate LEDs into more and more products.

At the same time, products like the very familiar incandescent nightlights with hard on/off switches are likely to persist in the marketplace in the absence of a standard. Consumers are comfortable with the operation and performance of this model, and may already own replacement bulbs.

Figure 8. Packages Promote Advantages of Efficient Nightlights



6 Savings Potential

6.1 Statewide California Energy Savings

California has an opportunity to realize significant energy savings from its 12.6 million nightlights. The baseline energy use of California's current annual nightlight sales is 16.4 GWh per year[4]. Annual energy use of California's existing nightlight stock is 130 GWh—enough electricity for more than 18,000 households for one year.[5] We estimate that the statewide peak demand from all nightlights in California is currently 9.3 MW. Peak demand from nightlights is due to nightlights being left on during the day and therefore during daily peak. The peak demand caused by the current stock of nightlights in California is equivalent power demand of more than 105,000 televisions operating in "on" mode simultaneously[6]; or more than 1/3 of the 25.5 MW of renewable energy that PG&E plans to purchase from the Geysers Geothermal Field in Northern California[7].

Table 13. California Statewide Baseline Energy Use

	For First-Year Sales		For Entire Stock	
Annual Energy Use	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)
≤ 3.0 kWh	0.14	0.9	1.1	7.1
> 3.0 kWh	1.03	15.5	8.2	123.3
Total	1.2	16.4	9.3	130.4

If California were to implement a 3.0 kWh annual limit for all nightlights, the state would realize an 85% reduction in the energy use of nightlights[8]. The annual energy savings for first-year sales would be 14 GWh—equivalent to the annual electricity consumption of 2,000 households. The savings after entire stock turnover would be 111 GWh—equivalent to the annual electricity consumption of nearly 16,000 Californian households[9]. Peak demand from nightlights would be reduced by 68%.

Table 14. Estimated California Statewide Energy Savings for Proposed Standard

[4] Annual sales of 1.58 million nightlights multiplied by average annual energy use per unit of 10.37 kWh
[5] Annual electricity use per California household estimated at 6,987 kWh. This figure was derived from 2005 residential electricity use of 84,527 million kWh (California Energy Commission 2006) and 12.1 million households in California (U.S. Census Bureau 2005).
[6] Average power demand in "on" of televisions found in California homes is 88 watts (Porter, Moorefield, et al. 2006)
[7] Source for PG&E's recent plans to purchase geothermal power: Pacific Gas and Electric Company 2007
[8] Assumes average current nightlight (18.2 kWh per year) would be replaced by average compliant nightlight (2.45 kWh per year).
[9] Annual electricity use per California household estimated at 6,987 kWh. This figure was derived from 2005 residential electricity use of 84,527 million kWh (California Energy Commission 2006) and 12.1 million households in California (U.S. Census Bureau 2005).

For First-Year Sales		After Entire Stock Turnover	
Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)
0.8	14.0	6.4	111.2

6.2 Other Benefits and Penalties

Nightlights that comply with the proposed standard have several attributes that are important to consumers:

- LED and EL nightlights have very long design lives. Many come with lifetime warranties. For the consumer, this means greatly reduced nightlight replacement costs and no future costs to replace burnt-out incandescent bulbs.

- Photocells and motion detectors reduce the time nightlight spends in "on" mode thereby extending the lives of replaceable bulbs or nightlights without replaceable bulbs. For the consumer, this means spending less money to replace burnt-out bulbs.

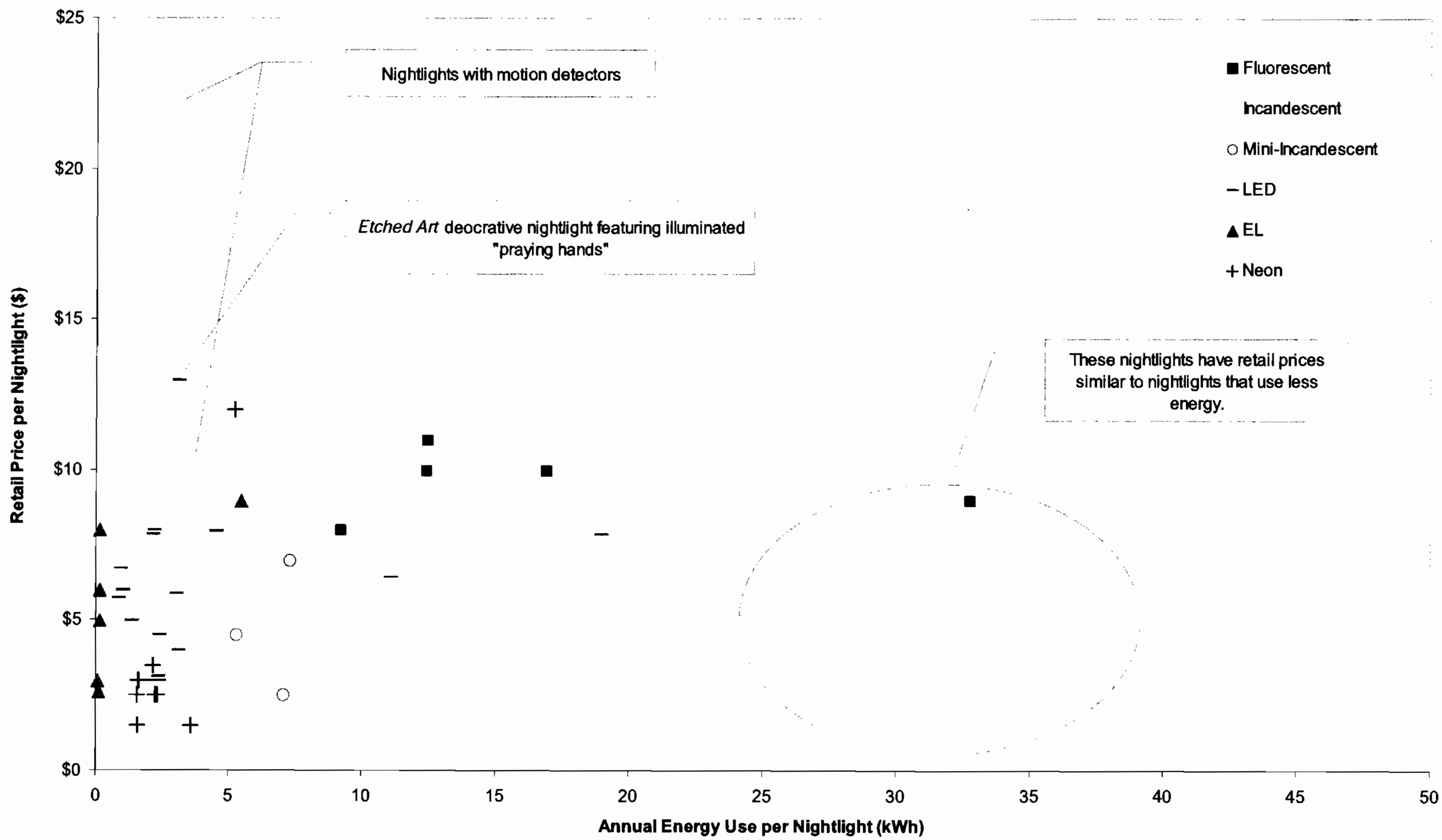
- Low-power light source technologies are safer. These technologies operate at cooler temperatures than incandescent bulbs do thereby decreasing the likelihood of burns or fires. Additionally, the danger to children of accessible fragile glass bulbs is eliminated.

7 Economic Analysis

7.1 Incremental Cost

The average price of nightlights in our sample set that meet the proposed standard is $5.16, which is $0.65 less than the average price of the nightlights in our sample set that do not meet the proposed standard. Similar prices can be found at all efficiency levels. Additionally, nightlight technologies that draw the least power often have significantly longer design lives and lower lifecycle costs due to the elimination of replacement bulb costs. (See analysis in section 7.3.) See Figure 9 below for a comparison of annual energy use and purchase price. Retail prices for nightlights in our sample set are on the vertical axis, while estimated annual energy use per nightlight is on the horizontal axis.

Figure 9. Comparison of Annual Energy Use to Purchase Price



7.2 Design Life

Design lives of nightlights vary widely—-from less than a year of continual operation to 25 years[10]. LED and EL technologies have the longest design lives, while 4 and 7 watt incandescent bulbs have the shortest lives at approximately 3,000 hours of continual operation. See Table 15. The weighted average design life of all technologies is approximately 8 years. In this analysis, we capped design lives for all technologies at 10 years (87,600 hours) under the assumption that most consumers would replace a nightlight after that time even if it continues to operate.

Table 15. Design Life

Type of Nightlight or Replaceable Bulb	Design Life (hours)
C7 Incandescent Bulb[a]	3,000
Incandescent Nightlight Fixture (uses replaceable bulb)[b]	87,600
EL Nightlight[c]	87,600
Fluorescent Nightlight[d]	8,760
LED Nightlight[e]	87,600
Miniature Incandescent Nightlight[f]	10,950
Neon Nightlight[g]	10,950

a. As per bulb specifications on packaging, multiple brands
b. As per Leviton customer service representative. Said fixture could last a "lifetime;" fixture comes with 1-year warranty
c. As per claim on nightlight packaging of a design life of up to 100,000 hours.
d. As per GE customer service representative. Stated that a fluorescent nightlight would last between 1 and 3 years with 8 hours of operation per day.
e. As per claim on nightlight packaging of > 25 year design life. Also, Amerelle customer service representative said their LED nightlights have a 25 year warranty.
f. As per Amerelle customer service representative. Design life estimated at 10,000 hours. Rounded up in this analysis to reflect 1.25 years.
g. As per Amerelle customer service representative. Design life estimated at 10,000 hours. Rounded up in this analysis to reflect 1.25 years.

7.3 Lifecycle Cost / Net Benefit

Due to the wide variety of nightlights available, their varying design lives and maintenance costs, we evaluated the costs and benefits of individual nightlights rather than averaging values for our entire data set. We conducted life cycle cost analyses for five scenarios. See Table 16. To ensure equivalent pricing structure, we compared nightlights from the same retailer in all scenarios except for scenario 5.

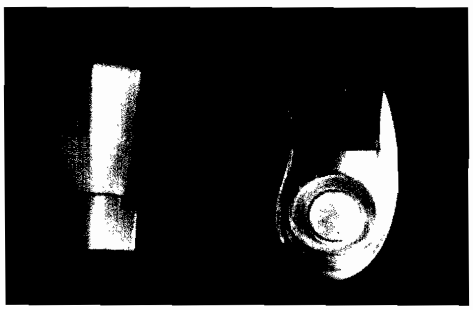
[10] Based on manufacturer claims

Table 16. Five Scenarios Used for Lifecycle Cost Comparisons

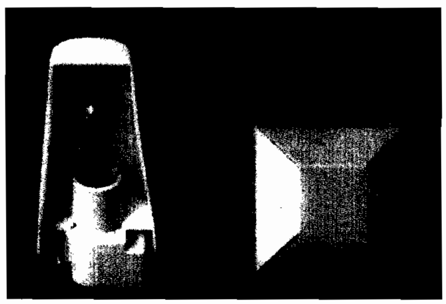
	Base Case (>3 kWh/yr)			Improved Case (≤ 3 kWh/yr)		
Scenarios	**Light Source**	**Style**	**Control Mechanism**	**Light Source**	**Style**	**Control Mechanism**
Scenario 1	Incandescent	Basic	Hard on/off switch	Incandescent	Basic	Motion detector & photosensor
Scenario 2	Incandescent	Basic	Hard on/off switch	EL	Basic	None
Scenario 3	Incandescent	Novelty	Hard on/off switch	LED	Novelty	Hard on/off switch
Scenario 4	Incandescent	Basic	Photosensor	LED[a]	Basic	Photosensor
Scenario 5	Mini-incandescent	Basic	Photosensor	LED	Basic	Photosensor

[a] LED nightlight packaging typically advertises design lives of more than 10 years; however, packaging for this particular nightlight claims a 5 year lifetime. Therefore, we used a 5 year design life for this product in the following cost-benefit analysis.

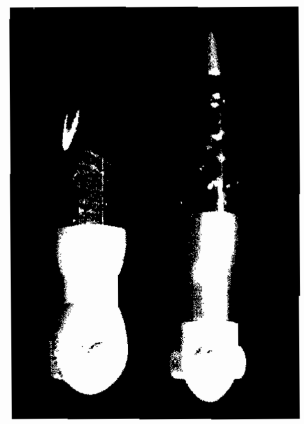
Figure 10: Cost-Benefit Analysis Scenarios



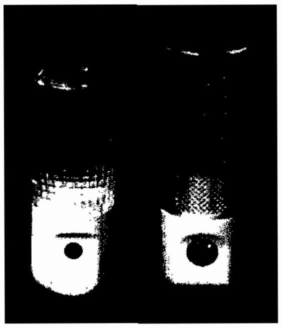
Scenario 1
Left: incandescent with hard switch
Right: incandescent with motion detector and photocell



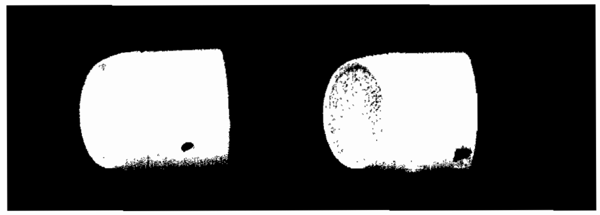
Scenario 2
Left: incandescent with hard switch
Right: EL with no switch



Scenario 3
Left: LED with hard switch
Right: Incandescent with hard switch



Scenario 4
Left: LED with photosensor
Right: Incandescent with photosensor



Scenario 5
Left: LED with photosensor
Right: Mini-incandescent with photosensor

We used a 10-year overall timeframe for all comparisons. Lifecycle costs include:

- replacement costs for incandescent bulbs after every 3,000 hours of "on" time,
- replacement costs for nightlights with design lives shorter than 10 years,
- annual energy costs

Table 17. Costs and Benefits per Unit for Standards Options[a]

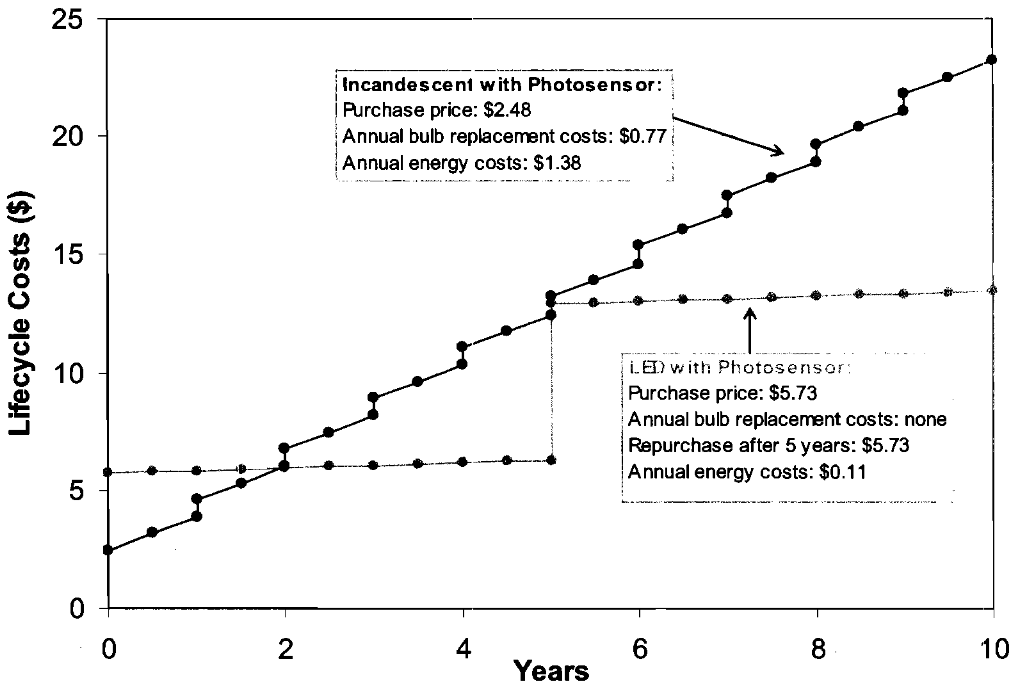
Scenarios	Design Life (years)	Lifecycle Costs per Unit (Present Value $)			Lifecycle Benefits per Unit (Present Value $)		
		Added First Cost	Add'l Costs[b]	**Total PV Costs**	Energy Savings[c]	Add'l Benefits[d]	**Total PV Benefits**
Scenario 1	10	$20.02		**$20.02**	$27.29	$21.11	**$48.40**
Scenario 2	10	$5.00		**$5.00**	$28.20	$21.11	**$49.31**
Scenario 3	10	$2.02		**$2.02**	$27.19	$21.11	**$48.30**
Scenario 4	10	$3.25	$6.64	**$9.90**	$10.68	$8.78	**$19.45**
Scenario 5	10	$2.48		**$2.48**	$5.69	$8.98	**$14.66**
Average	10	$6.55	$1.33	**$7.88**	$19.81	$16.22	**$36.02**

PV = Present Value
[a] This table illustrates the costs and benefits of individual nightlights that meet the proposed 3.0 kWh standard.
[b] Re-purchase price for nightlight fixtures with design lives shorter that 10 years.
[c] Calculated using the California Energy Commission's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2004).
[d] Efficient nightlights have reduced (or zero) bulb replacement costs when compared to traditional incandescent nightlights due to automated controls that reduce the "on" mode operation (photosensors and motion detectors), or light sources with very long design lives (EL and LED).

See Figure 14 below for a comparison of life cycle costs for scenario 4 outlined above. We chose to illustrate the lifecycle costs of nightlights in scenario 4 because this scenario includes the cost of re-purchasing the improved case nightlight (LED with photosensor).

The reason for re-purchase is that the manufacturer of the nightlight model used for the improved-case claims a 5-year product life. Packages for other LED nightlights claim design lives up to 25 years. Therefore, we wanted to show that a compliant nightlight that may need replacement after five years is still more cost-effective than the alternative—replacing incandescent nightlight bulbs and paying for more energy over the course of 10 years.

Figure 11. Comparison of Lifecycle Costs for Scenario 4



We then averaged the net present values from the five scenarios in order to scale the savings to annual nightlight sales and entire stock. Because we estimate that 37% of existing nightlight sales and stock already meet the proposed standard, we calculated the average net present value only for the non-compliant share (63%) of existing nightlights. See results in Table 18 below.

Table 18. Lifecycle Costs and Benefits for Standards Options

Scenarios	Lifecycle Benefit / Cost Ratio[a]	Net Present Value ($)[b]		
		Per Unit	For First Year Sales	After Entire Stock Turnover
Scenario 1	2.42	$28.38	[illegible]	[illegible]
Scenario 2	9.86	$44.31	[illegible]	[illegible]
Scenario 3	23.91	$46.28	[illegible]	[illegible]
Scenario 4	1.97	$9.56	[illegible]	[illegible]
Scenario 5	5.91	$12.18	[illegible]	[illegible]
Average	4.57	$28.00	$28,709,262	$228,790,734

[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 nightlight.

8 Acceptance Issues

8.1 Infrastructure issues

Thirty-seven percent of nightlights we tested meet the proposed 3.0 kWh per year standard. The other 63% of nightlights could meet the proposed standard through the use of established light source technologies and control mechanisms that are present in the marketplace at competitive prices. Additionally, many manufacturers already sell nightlights that appear identical yet use different light source technologies. See scenario 5 in Figure 10 for one example of these look-alike products. Such products demonstrate that appearance to consumers will not be sacrificed by more designs that use less power or energy. Furthermore, some manufacturers are utilizing the small size and low heat output of efficient light sources such as LED and neon in decorative designs that are not possible with larger, hotter incandescent bulbs.

8.2 Existing Standards

UL and CSA share a common nightlight safety standard. (See UL 1786 and CSA C22.2 No. 256.) We did not locate any performance standards for nightlights. With the recent technological advances and growing interest in LEDs, several entities are developing standards pertaining to the performance and safety of LEDs. In March 2006, the U.S. Department of Energy (DOE) held an LED Industry Standards Workshop in order to coordinate various organizations work on LED standards. Attendees included:

- Illuminating Engineering Society of North America (IESNA),
- National Institute of Standards and Technology (NIST),
- National Electrical Manufacturers Association (NEMA),

- American National Standards Institute (ANSI),
- Underwriters Laboratories (UL),
- International Electrotechnical Commission (IEC),
- International Commission on Illumination (CIE), and
- Canadian Standards Association (CSA)

(U.S. Department of Energy 2006)

Several of these organizations currently have LED standards in development[11], including:

- DOE/ENERGY STAR®—program expected to be finalized in the Spring of 2007 (U.S. Department of Energy 2007)
- ANSI—standard expected to be published June 2007
- IESNA—standard expected to be published June 2007 (Richman 2007)
- UL—standard publication date unknown

8.3 Stakeholder Positions

Although stakeholders were contacted, no stakeholder positions were elicited for the preliminary draft. However, we anticipate that the strongest argument against a nightlight standard will be safety. Because nightlights are often used to aid in the navigation of dark spaces, limiting the availability of the higher wattage nightlights could be seen as jeopardizing safety, especially of the elderly and disabled. We conducted preliminary measurements of light output on selected nightlights to determine if the more lower power light sources provided the same level of light as the high power light sources; they did not. See Appendix A: Luminance and Illuminance Measurements for light-metering results. The technology that consistently provided the most illumination of room surfaces (floors, walls, stairs, etc.) was the replaceable incandescent bulb.

The intent of the proposed standard is not to jeopardize safety. The proposed standard is written to allow the higher wattage light sources to remain in the market. However, nightlights that utilize higher wattage technologies will need to use automatic control mechanisms such as photocells and motion detectors to reduce their annual energy usage. Light source technologies with the highest wattages will need motion detectors or other automated controls that significantly reduce their time in "on" mode in order to meet the 3.0 kWh standard. That being said, we do anticipate some stakeholder resistance to the duty cycle assumptions in Table 6 of section 4.2. Duty cycles in this analysis are assumptions as this data was not otherwise available. The analysis could be strengthened by conducting consumer surveys about the ways people operate nightlights in their homes.

By writing the standard in a way that does not require light measurements, we have eliminated another potential stakeholder concern—expensive testing and certification. Power measurements and energy calculations required by this standard can be conducted in basic testing labs.

[11] The LED industry is changing rapidly. Dates provided are based on best available information; however, they are likely to change.

A final concern we anticipate from manufacturers is that under this standard they will not be able to produce the same styles of nightlights that they currently make. This is a valid concern as expensive molds and patterns may have been produced in order to manufacture a specific style. However, most nightlight manufacturers currently offer a wide variety of styles of compliant nightlights and therefore would not need to re-tool their entire product line. Some nightlights may need only partial re-design, such as the addition of a photocell or motion detector, in order to meet the standard. We encountered several examples of nightlights with different light source technologies with the exact same plastic housing. The nightlight styles that are likely to be in jeopardy are those that utilize heat from incandescent bulbs or large resistors to create visual effects such as bubbling or moving of encapsulated liquids.

9 Recommendations

9.1 Recommended Standards Options

Based on our analysis, we recommend that California adopt a 3.0 kWh standard for annual energy use per nightlight. In addition, we recommend a power limit for "standby" mode of 0.5 W. While many nightlight manufacturers are already offering compliant designs, a standard would accelerate the transition to energy-saving technologies. The proposed test method is included in Appendix C.

9.2 Proposed Changes to the Title 20 Code Language

The annual energy use of nightlights sold in California on or after XXX date shall not be more than the value shown in Table 19 below. Annual energy use values to be calculated according to test procedure described in Appendix C.

Table 19. Proposed California Nightlight Standard

Proposed CA Standard	Active Power Draw (W)	Standby Power Draw (W)	Annual Operating Hours Active [a]	Annual Operating Hours Standby	Unit Electricity Consumption (kWh/yr)
≤ 3.0 kWh per year and ≤ 0.5 W "standby" power draw	< 10 W [b]	< 0.5 W [b]	TBD based on "on" mode power[b]	Dependent on control mechanism [b]	**≤ 3.0 kWh**

[a] Annual operating hours defined in Table 6.
[b] Manufacturers may use any combination of light source and power control technology to meet annual kWh limit. Less than 10 watts is specified for "active" ("on") mode because that is the maximum limit for UL certification as a nightlight.

References

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

Calwell, C., C. Granda, et al. (1999). Lighting the Way to Energy Savings: How Can We Transform Residential Lighting Markets?, Natural Resources Defense Council.

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.

Goldwasser, S. M. and D. L. Klipstein. (1999, 11/09/2006). "Sam's and Don's D-Lamp FAQ: Gas Discharge Lamps, Ballasts, and Fixtures." from http://members.misty.com/don/dschlamp.html.

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.

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

Micro Electronics Inc. (2007, 11/08/2006). "In The Lab: Build Your Own PC Chapter 8: Lighting Technologies." Random Access, from http://www.microcenter.com/random_access/newsletters/04_newsletters/0604/in_the_lab.html.

Pacific Gas and Electric Company. (2007, 5/10/2007). "Pacific Gas and Electric Company Adds More Geothermal Energy to the Renewable Energy Mix." Retrieved from http://www.pge.com/news/news_releases/q2_2007/070510a.html

Porter, S., L. Moorefield, et al. (2006). Final Field Research Report, California Energy Commission

Richman, E. E. (2007). Personal communication with Eric E. Richman, LC of Pacific Northwest National Laboratory. L. Moorefield. Durango CO.

Talking Electronics. (2006, 11/08/2006). "Electroluminescence Theory: How EL Works." from http://www.talkingelectronics.com/Projects/Electroluminescence/LitELine02.html.

Ton, M., S. Foster, et al. (2003). LED Lighting Technologies and Potential for Near-Term Applications, Northwest Energy Efficiency Alliance: 14.

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=&_city

Town=&_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. Department of Energy (2006). Standards Development for Solid-State Lighting. Energy Efficiency and Renewable Energy.

U.S. Department of Energy (2007). DOE Launches ENERGY STAR Program for Solid-State Lighting. Energy Efficiency and Renewable Energy.

U.S. Department of Energy (n.d.). White LED Benchmark of 65 Lumens Per Watt Achieved. Energy Efficiency and Renewable Energy.

Appendix A: Luminance and Illuminance Measurements

As part of this analysis, we conducted preliminary light metering of selected nightlights. These measurements are intended to roughly characterize the light output from different nightlights. Illuminance readings were taken at varying distances from the nightlight on the same vertical plane as the electrical outlet that the nightlight was plugged into, as well as on the horizontal plane (floor) in front of the electrical outlet. Luminance readings were taken at approximately 3" from the nightlight at the point on the nightlight that appeared to be the brightest. Determining the location of the brightest point was a somewhat subjective process because nightlight shades or diffusers typically do not emit light evenly in all directions.

Table 20: Luminance and Illuminance Measurements from Selected Nightlights[a]

Light source	Power in "On"	Illuminance Avg (lux)	Illuminance Max (lux)	Illuminance Min (lux)	Luminance Max (cd/m^2)	Luminance Min (cd/m^2)
EL	0.01	U	U	U	7.0	6.1
LED	0.22	0.4	2.1	0.02	13.0	2.0
LED	0.22	U	U	U	U	U
LED	0.28	U	U	U	U	U
Neon	0.41	U	U	U	45.8	U
EL	0.80	0.1	0.1	0.02	22.2	22.2
Mini-Incandescent	0.94	0.9	2.6	0.15	457.7	U
Mini-Incandescent	1.45	1.3	5.9	0.03	1200.0	20.0
Incandescent	2.16	1.8	7.0	0.08	805.6	U
Incandescent	3.18	U	U	U	U	U
Fluorescent	3.22	2.1	6.8	0.32	1878.0	1094.0
Incandescent	3.29	U	U	U	U	U
Incandescent	3.60	0.8	1.5	0.13	U	U
Incandescent	3.80	9.5	40.6	0.13	3180.0	1500.0
Incandescent	3.80	0.5	4.3	0.06	0.6	0.3
Incandescent	4.06	2.3	9.0	0.11	1780.0	420.5
Incandescent	4.20	4.8	23.5	0.13	2580.0	1000.0
Fluorescent	4.32	9.6	35.0	0.49	1806.0	370.0
Incandescent	6.41	U	U	U	806.2	144.3

U=Unknown. Light meter unable to record.

a) Gigahertz Optik HCT-99 Color meter used for all measurements. Illuminance readings (lux) recorded to 0.0000 then rounded by Excel function to 0.00; Luminance readings taken at variable distances (and angles up to 180 horizontal degrees) to locate extremes,

at approximate distance of three inches from the face of the lens of the nightlight. The nightlight was operated directly on a 120 V ac universal power supply (UPS). Power demand was recorded using a "Kill-A-Watt" meter which was operated on the same 120 V ac UPS. Any photocell was covered with black electrical tape. Any dimmer was adjusted to maximum light output.
Measurements taken by K. M. Conway, 2007

Appendix B: Sample Set

Table 21. Selected Data from Ecos Nightlight Sample Set

Manufacturer	Model Number	Light Source	Control Type[a]	Retail Price	Power in "On" Mode (W)	Power in "Standby" Mode (W)	Estimated Annual Energy Use (kWh)
ML Meridian	HFNLO1	EL	N	$2.62	0.01		0.12
Leviton	16509-2PK	EL	N	$5.00	0.02		0.15
Amerelle	71192	EL	N	$5.99	0.02		0.17
NightOwlz	EL-302A	EL	N	$7.99	0.02		0.18
Salamander Graphix	1X 23	LED	H	$6.73	0.13		0.99
Salamander Graphix	WZ-HS	LED	H	$6.73	0.13		0.99
Amerelle	71050	Neon	N	$2.50	0.18		1.58
Amerelle	71046	Neon	P	$2.50	0.18	0.31	2.24
Amertac	71050L	Neon	N	$1.49	0.18		1.58
Amertac	75022GL	Neon	N	$2.98	0.18		1.61
Amertac	75020RL	Neon	N	$2.98	0.19		1.65
Leviton	48580-wht	LED	P	$0.00	0.22	0.02	0.89
Leviton	48580-BLU	LED	P	$5.73	0.22	0.02	0.91
Leviton	OUTLT-AMB	LED	P	$7.99	0.22	0.28	2.23
Amerelle	71081	LED	N	$2.99	0.25		2.19
Ace	32552	Neon	N	$3.50	0.25		2.19
Leviton	49563-lgt	LED	N	$0.00	0.26		2.28
Amertac	71190L	LED	P	$5.98	0.26	0.02	1.05
Leviton	49563-PLM	LED	N	$3.14	0.27		2.37
Leviton	49563-SWL	LED	N	$4.49	0.28		2.41
Amertac	71282L	LED	N	$2.99	0.28		2.43
Mary Elle Fashions	GF-14009	LED	H	$7.86	0.29		2.18
First Alert	TLED6-1	LED	P	$3.99	0.31	0.39	3.13
Amertac	71052L	LED	P	$4.98	0.35	0.02	1.37
GE	99WM	LED	N	$12.99	0.36		3.15
Leviton	49567	Neon	N	$1.50	0.41		3.59
Amerelle	71194	LED	P	$7.97	0.45	0.57	4.56
Salamander Graphix	not specified	Neon	H	$11.99	0.69		5.24
AmerTac	E-22A	EL	P	$8.97	0.80	0.50	5.48
GE	GE3922-ETL71D	Mini-Incandescent	P		0.94	0.34	5.18
GE	GE3923-71D	Fluorescent	H	$7.99	1.22		9.23
Leviton	49566-2W	Mini-Incandescent	P	$4.50	1.45	0.01	5.34
Amerelle	72052	Mini-Incandescent	P	$2.50	1.93	0.01	7.10

Leviton	48568-W	Incandescent	P	$1.97	1.98	0.01	7.29
Amerelle	71190	Mini-Incandescent	P	$6.97	2.00	0.01	7.34
Ace	3031697	Incandescent	P	$4.99	2.12	0.02	7.82
GE	GE3911-GL71D	Incandescent	P	$2.00	2.16	0.01	7.95
Mary Elle Fashions	LEDG01	LED	H	$7.86	2.50		18.98
Mary Elle Fashions	LENL01	LED	H	$7.86	2.50		18.98
Amerelle	71056	Incandescent	P	$2.48	3.18	0.01	11.65
Leviton	51012	Incandescent	P	$5.99	3.29	0.90	16.61
Amertac	71108L	Incandescent	H	$2.98	3.50		26.57
Amertac	75057L	Incandescent	P	$5.98	3.51	0.01	12.86
Leviton	48566-2PW	Incandescent	H	$2.00	3.60		27.33
Ace	3031895	Incandescent	H	$2.99	3.76		28.55
Amertac	71058L	Incandescent	P	$3.98	3.76	0.01	13.72
GE	GE3935APIR-21D	Incandescent	MP	$21.99	3.80	0.25	0.69
Salamander Graphix	Cat.6605	Incandescent	H	$6.84	3.88		29.46
Salamander Graphix	44039B4658	Incandescent	H	$5.84	3.89		29.53
GE	56651	Fluorescent	HP	$9.97	3.90	0.15	16.23
Mary Elle Fashions	LP22-006	Incandescent	H	$5.84	3.95		29.99
Amerelle	71030	Incandescent	H	$1.97	3.99		30.29
GE	52194	Incandescent	P	$3.99	4.06		14.82
Amerelle	71029	Incandescent	MP	$9.97	4.20	0.31	0.77
Sav-on Osco	47199	Incandescent	H	$2.00	4.22		32.04
GE	GE3921-71D	Fluorescent	H	$8.99	4.32		32.80
Salamander Graphix	44039B4658	Incandescent	H	$7.99	4.33		32.87
Mary Elle Fashions	LANLO1	Incandescent	H	$5.84	4.93		37.43
Northeastern Plastics	113702-1012	Incandescent	H	$1.00	6.41		48.66

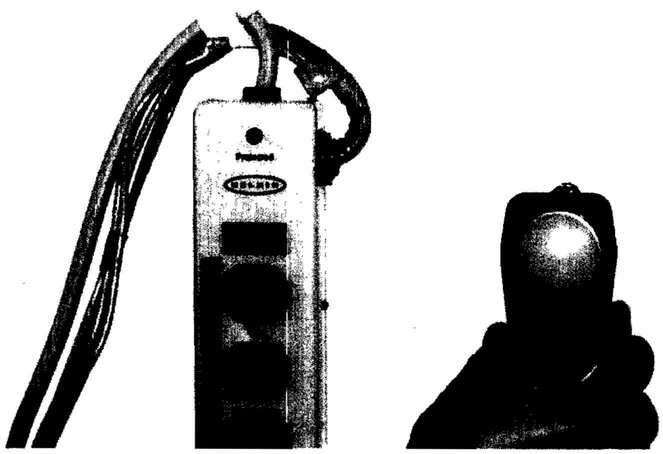
Tested but removed from dataset so that light source distribution of the dataset would reflect the light source and control type distribution found in California retailers:							
Amerelle	73068	Fluorescent	P	$9.96	3.22	0.13	12.41
First Alert	TELNL1-2	EL	N	$5.99	0.01		0.10
Amertac	73068L	Fluorescent	P	$10.98	3.24	0.13	12.47
Mary Elle International	NANLO1	LED	H	$6.43	1.46		11.08
Amerelle	71193	LED	H	$5.88	0.40		3.07
Amertac	71046L	Neon	P	$4.98	0.18	0.33	2.34

[a] H=hard on/off switch, HP=hard switch and photocell, MP=motion detector and photocell, N=no switch, P=photocell

Appendix C: Proposed Test Procedure for Standard

1. Power measurements shall be made with a suitably calibrated voltmeter and ammeter or power analyzer as specified under IEC 62301. Measurements of power of 0.5 W or greater shall be made with an uncertainty of less than or equal to 2%. Measurements of power of less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W. The power measurement instrument shall have a resolution of:
    a. 0.01 W or better for power measurements of 10 W or less
    b. 0.1 W or better for power measurements of greater than 10 W up to 100 W
    c. 1 W or better for power measurements of greater than 100 W
2. Use high quality power meter capable of accurate readings down to 0.001 W
3. Nightlight to be plugged into vertically-oriented meter outlet in darkened room.
4. Voltage should be 120 V ac +/- 1 V.
5. To determine power (W) in "on" mode:
    a. The room illumination level[12] should be 0 +/- 1 lux (0 +/- 0.1 footcandle) on the same vertical plane as the meter outlet, and within a 12" diameter of the outlet.
    b. The illumination reading should be taken in the same vertical plane as the meter outlet as illustrated in Figure 12.

Figure 12. Orientation of Light Meter for Measuring Illumination



    c. If a nightlight has a hard switch, regardless if that switch is coupled with other control mechanisms such as photosensors, the nightlight should be turned "on" and allowed to warm up for 15 minutes.
    d. If the nightlight has a dimmer setting, the switch should be adjusted for the greatest light output.

[12] Measurements made with light meter in need of calibration. Levels to be validated with testing with calibrated meter.

   e. Record power in watts. If the power demand of the nightlight varies by more than 0.01 W, the power value should be derived from the average value recorded over 5 minutes.
6. To determine power (W) in "standby" mode (if applicable):
   a. The room should be illuminated so that the lux/footcandle reading on the same plane as the outlet and within a 12" diameter of the outlet is 30 +/- 1 lux (3 +/- 0.1 footcandles).
   b. The nightlight should be allowed to warm up for 15 minutes at this light level.
   c. If it is possible to orient the photosensor in different directions, then the photosensor should be oriented towards the room light source.
   d. Record power in watts. If the power demand of the nightlight varies by more than 0.01 W, the power value should be derived from the average value recorded over 5 minutes[13].
7. Annual energy use to be calculated using the following formula:

$$W_{on} * t_{on} + W_{st} * t_{st} = E_{total}$$

where W_{on} is power in watts in "on" mode, t_{on} is time in hours spent in "on" mode per year, W_{st} is power in watts in "standby" mode, t_{st} is time in hours spent in "standby" mode per year, and E_{total} is total annual energy consumption per nightlight in watt-hours (Whrs).

Time in "on" mode per year and time in "standby" mode per year are as per Table 6. Nightlight in section 4.2.

[13] See IEC 62301 for information on measuring standby power.