DOCKETED	
Docket Number:	19-AAER-04
Project Title:	General Service Lamps
TN #:	229456
Document Title:	Analysis of General Service Lamps Expanded Scope, California Energy Commission, CEC-400-2018-015-SD
Description:	Document Relied Upon. Draft Staff Report. Analysis of General Service Lamps (Expanded Scope). California Energy Commission, CEC-400-2018-015-SD. Previously docketed in 17-AAER-07.
Filer:	Patty Paul
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	8/16/2019 8:46:49 AM
Docketed Date:	8/15/2019

DOCKETED	
Docket Number:	17-AAER-07
Project Title:	General Service Lamps
TN #:	224408
Document Title:	Draft Staff Report - Analysis of General Service Lamps (Expanded Scope)
Description:	N/A
Filer:	Patrick Saxton
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	8/3/2018 4:22:01 PM
Docketed Date:	8/3/2018

California Energy Commission

DRAFT STAFF REPORT

Analysis of General Service Lamps (Expanded Scope)

2018 Appliance Efficiency Pre-Rulemaking

Docket Number 17-AAER-07

California Energy Commission

Edmund G. Brown Jr., Governor

August 2018 | CEC-400-2018-015-SD

California Energy Commission

Patrick Saxton
Primary Author

David Nichols
Supervisor
Electrical Appliance Unit

Kristen Driskell
Manager
APPLIANCES OFFICE

Dave Ashuckian, P.E.
Deputy Director
EFFICIENCY DIVISION

Drew Bohan
Executive Director

PREFACE

On December 3, 2008, the California Energy Commission adopted standards for state-regulated general service incandescent lamps, modified spectrum general service incandescent lamps, and general service lamps. Tier II of the standards for general service lamps requires a minimum efficacy of 45 lumens per watt and is effective for general service lamps manufactured on or after January 1, 2018, and offered for sale in California.

On March 14, 2012, the California Energy Commission issued an order instituting rulemaking to begin considering standards, test procedures, labeling requirements, and other efficiency measures to amend the *Appliance Efficiency Regulations* (California Code of Regulations, Title 20, Sections 1601 through Section 1609). In this order, the Energy Commission identified appliances with the potential to save energy or water. The goal of the rulemaking is to develop proposed appliance efficiency standards and measures to realize these savings opportunities.

On January 27, 2016, the Energy Commission adopted efficiency regulations for small-diameter directional lamps and general service light-emitting diode (LED) lamps. These regulations are effective for small-diameter directional lamps and general service LED lamps manufactured on or after January 1, 2018, and offered for sale in California.

On January 19, 2017, the U.S. Department of Energy published two *Federal Register* notices of final rules adopting a revised definition for general service lamps. The effective date for the final rules is January 1, 2020.

On April 21, 2017, the Energy Commission released an invitation to participate to provide interested parties the opportunity to inform the Commission about the products, markets, and industry characteristics of the appliances identified, including an expanded scope for the existing efficiency standards for general service lamps. On May 11, 2017, Commission staff held a webinar to discuss the invitation to participate. Stakeholders submitted comments by June 11, 2017. On July 21, 2017, Commission staff held a workshop to discuss the comments received from the invitation to participate.

On July 18, 2017, the Energy Commission released an invitation to submit proposals related to efficiency standards, test procedures, and related items for the appliances identified in the invitation to participate. Proposals were submitted by September 18, 2017. On October 24, 2017, Commission staff held a webinar to discuss the proposals received.

The Commission has reviewed all the information received. This report contains the draft proposed regulations to revise the definitions for the existing general service lamp efficiency standards.

ABSTRACT

This report discusses proposed revisions to definitions related to general service lamps in the *Appliance Efficiency Regulations* (California Code of Regulations, Title 20, Sections 1601 to 1609). Staff also proposes to add a definition and set a minimum efficacy standard for low-lumen lamps. These proposed updates are part of the 2018 Appliance Efficiency Pre-Rulemaking (Docket #17-AAER-07). California Energy Commission staff analyzed the cost-effectiveness and technical feasibility of the proposal. Statewide energy use and savings and related environmental impacts and benefits are included.

The proposed definitions would be effective for general service lamps sold on or after January 1, 2020, and low-lumen lamps manufactured on or after January 1, 2020. The proposed definitions would effectively expand the scope of lamps subject to the existing general service lamp efficiency standards, which require a minimum lamp efficacy of 45 lumens per watt. The proposed definitions substantially align with the revised definition for general service lamps adopted by the U.S. Department of Energy.

Expanding the scope of the general service lamp regulations would save more than 4,600 gigawatt-hours of electricity the first year the broader standard is in effect. After existing stock fully turns over, the proposed standard would have an annual electricity savings of more than 13,600 gigawatt-hours. The annual electricity savings equate to more than $2.4 billion in annual savings, after stock fully turns over, to California businesses and individuals. If federal definitions take effect and are enforced on January 1, 2020, then most of the savings are attributable to that federal effort. However, the Energy Commission has proposed to substantially align with the federal definitions to prevent federal backsliding before 2020 and to ensure that the state is prepared to implement and enforce the standards on January 1, 2020.

Staff analyzed available market data and concluded that the updates to the definitions for general service lamps would significantly reduce energy consumption and are technically feasible and cost-effective.

Keywords: Appliance efficiency regulations, appliance regulations, energy efficiency, general service lamps

Please use the following citation for this report:

Saxton, Patrick. 2018. *Analysis of General Service Lamps (Expanded Scope)*. California Energy Commission. Publication Number: CEC-400-2018-015-SD.

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EXECUTIVE SUMMARY

This report presents the California Energy Commission staff's analysis of proposed regulations to add and revise definitions related to general service lamps, define low-lumen lamps, and set minimum efficiency standards for low-lumen lamps. General service lamps are subject to existing state efficiency standards, which require a minimum lamp efficacy of 45 lumens per watt for general service lamps manufactured on or after January 1, 2018, and offered for sale in California.

Staff proposes to amend the definition of general service lamp and to amend and add related definitions in the Appliance Efficiency Standards. These definitions will align with those established in two final rules published by the U.S. Department of Energy on January 19, 2017. Amending the definition of general service lamp in the Appliance Efficiency Standards would broaden the lamp types that are subject to the existing general service lamp standard requiring a minimum lamp efficacy of 45 lumens per watt. This would effectively expand the scope of products for which low-efficacy incandescent, including halogen, lamps could not be offered for sale in California, resulting in significant reductions in the amount of electricity consumed by lighting and in significant utility bill savings for California consumers and businesses. Staff proposes that the amended definition be effective for general service lamps *sold* on or after January 1, 2020. Appliance standards are usually applicable based on the date of manufacture, but the sales prohibition is being proposed to align with federal statute,[1] which sets a "sell by" date of January 1, 2020.

Staff proposes to define low-lumen lamps and to set a minimum efficacy standard of 45 lumens per watt for low-lumen lamps manufactured on or after January 1, 2020. Low-lumen lamps are lamps that would otherwise be general service lamps but for the associated lower amount of light output. Existing state-regulated LED lamp efficiency standards are applicable to lamps with a lumen output of 150 lumens or greater and 2,600 lumens or less. Existing general service lamp efficiency standards are applicable to lamps with a lumen output of 310 lumens or greater and 2,600 lumens or less.

Expanding the scope of the general service lamp regulations would save over 4,600 gigawatt-hours of electricity the first year the broader standard is in effect. After existing stock fully turns over, the proposed standard would have an annual electricity savings of over 13,600 gigawatt-hours. This equates to over $2.4 billion in annual savings, after stock fully turns over, to California businesses and individuals. If federal definitions take effect and are enforced on January 1, 2020, then most of the savings analyzed in this report are attributable to that federal effort. However, the Energy Commission has proposed to substantially align with the federal definitions to prevent federal backsliding before 2020 and to ensure that the state is prepared to implement and enforce the standards on January 1, 2020.

1 United States Code, Title 42, § 6295(i)(6)(A)(v),, available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.pdf.

CHAPTER 1:
Legislative Criteria

Section 25402(c)(1) of the California Public Resources Code mandates that the California Energy Commission reduce the inefficient consumption of energy and water on a statewide basis by prescribing efficiency standards and other cost-effective measures[2] for appliances that require a significant amount of energy and water to operate. Such standards must be technologically feasible and attainable and must not result in any added total cost to the consumer over the designed life of the appliance.

In determining cost-effectiveness, the Energy Commission considers the value of the water or energy saved, the effect on product efficacy for the consumer, and the life-cycle cost to the consumer of complying with the standard. The Commission also considers other relevant factors including, but not limited to, the effect on housing costs, the statewide costs and benefits of the standard over the lifetime of the standard, the economic impact on California businesses, and alternative approaches and the associated costs.

2 These include energy and water consumption labeling, fleet averaging, incentive programs, and consumer education programs.

CHAPTER 2:
Efficiency Policy

The Warren-Alquist Act[3] establishes the California Energy Commission as California's primary energy policy and planning agency. The act mandates that the Commission reduce the wasteful and inefficient consumption of energy and water in the state by prescribing statewide standards for minimum levels of operating efficiency for appliances that consume a significant amount of energy or water.

For nearly four decades, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. Through the Appliance Efficiency Program, appliance standards have shifted the marketplace toward more efficient products and practices, reaping significant benefits for California's consumers. The state's Title 20 Appliance Efficiency Regulations, along with federal appliance standards encompassing a variety of appliance types, saved an estimated 30,065 gigawatt-hours (GWh)[4] of electricity in 2015 alone, resulting in about $4.84 billion in savings[5] to California consumers. In the 1990s, the California Public Utilities Commission (CPUC) decoupled the utilities' financial results from their direct energy sales, promoting utility support for efficiency programs. These efforts have reduced peak load needs by more than 8,645 megawatts (MW) and continue to save about 32,594 GWh per year of electricity.[6] The potential for additional savings remains by increasing the energy efficiency and improving the use of appliances.

Reducing Electrical Energy Consumption to Address Climate Change

Appliance energy efficiency is identified as a key to achieving the greenhouse gas (GHG) emission reduction goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006)[7] and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016),[8] as well as the recommendations contained in the California Air Resources Board's *Climate Change Scoping Plan*.[9] Energy efficiency regulations are also identified as key components in reducing electrical energy consumption in the *2015 Integrated Energy Policy Report*

3 The Warren-Alquist State Energy Resources Conservation and Development Act, Division 15 of the Public Resources Code, § 25000 et seq., available at http://www.energy.ca.gov/2017publications/CEC-140-2017-001/CEC-140-2017-001.pdf.
4 California Energy Commission, *California Energy Demand 2016-2026 Revised Electricity Forecast*, January 2016, available at http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207439_20160115T152221_California_Energy_Demand_20162026_Revised_Electricity_Forecast.pdf.
5 Using current average electric power and natural gas rates of: residential electric rate of $0.164 per kilowatt-hour, commercial electric rate of $0.147 per kilowatt-hour. This estimate does not incorporate any costs associated with developing or complying with appliance standards.
6 California Energy Commission, *California Energy Demand 2016-2026 Revised Electricity Forecast,* January 2016, available at http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207439_20160115T152221_California_Energy_Demand_20162026_Revised_Electricity_Forecast.pdf.
7 AB 32, California Global Warming Solutions Act of 2006, available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32.
8 SB 32, California Global Warming Solutions Act of 2006, available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB32.
9 *Climate Change Scoping Plan* available at http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf.

(*IEPR*)[10] and the 2011 update to the CPUC's *Energy Efficiency Strategic Plan*.[11] Finally, Governor Edmund G. Brown Jr. and the Legislature have identified appliance efficiency standards as a key to doubling the energy efficiency savings necessary to put California on a path to reducing its GHG emissions to 80 percent below 1990 levels by 2050,[12] a commitment made to the Subnational Global Climate Leadership Memorandum of Understanding (Under 2 MOU) agreement along with 167 jurisdictions representing 33 countries.[13]

On October 7, 2015, the Governor signed the Clean Energy and Pollution Reduction Act of 2015, or Senate Bill 350 (De León, Chapter 547, Statutes of 2015), requiring the Energy Commission to establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a doubling of energy savings from buildings and retail end uses by 2030.[14] Appliance efficiency standards will be critical in meeting this goal.[15] In addition, the Energy Commission adopted the *Existing Buildings Energy Efficiency Action Plan* in September 2015 and updated it in December 2016 to transform existing residential, commercial, and public buildings into energy-efficient buildings.[16] Appliance efficiency standards are essential to reducing the energy consumption in existing buildings from plug-in loads.

Loading Order for Meeting the State's Energy Needs

California's loading order places energy efficiency as the top priority for meeting energy needs. The *Energy Action Plan II* strongly supports the loading order, which describes the priority sequence for actions to address increasing energy needs. Energy efficiency and demand response are the preferred means of meeting the state's energy needs.[17]

For the past 30 years, while per-capita electricity consumption in the United States has increased by nearly 50 percent, California's per-capita electricity use has been nearly flat. Continued progress in cost-effective building and appliance standards and ongoing enhancements to efficiency programs implemented by investor-owned utilities (IOUs), publicly owned utilities, and other entities have contributed significantly to this achievement.[18]

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10 California Energy Commission, *2015 Integrated Energy Policy Report*, 2015, available at http://energy.ca.gov/2015_energypolicy/.
11 CPUC, *Energy Efficiency Strategic Plan,* updated January 2011, available at http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.
12 Gov. Edmund G. Brown Jr., 2015 Inaugural Address, available at http://gov.ca.gov/news.php?id=18828.
13 Subnational Global Climate Leadership Memorandum of Understanding, available at http://under2mou.org/background/.
14 *2016 Integrated Energy Policy Report Update*, available at http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN216281_20170228T131538_Final_2016_Integrated_Energy_Policy_Report_Update_Complete_Repo.pdf.
15 Jones, Melissa, Michael Jaske, Michael Kenney, Brian Samuelson, Cynthia Rogers, Elena Giyenko, and Manjit Ahuja. 2017. *Senate Bill 350: Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-06/TN221631_20171026T102305_Senate_Bill_350_Doubling_Energy_Efficiency_Savings_by_2030.pdf.
16 *California's Existing Buildings Energy Efficiency Action Plan – 2016 Update,* available at http://docketpublic.energy.ca.gov/PublicDocuments/16-EBP-01/TN214801_20161214T155117_Existing_Building_Energy_Efficency_Plan_Update_Deceber_2016_Thi.pdf.
17 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF , p. 2.
18 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p. 3.

Governor's Clean Energy Jobs Plan

On June 15, 2010, as a part of his campaign, Governor Brown proposed the *Clean Energy Jobs Plan*,[19] which directed the Energy Commission to strengthen appliance efficiency standards for lighting, consumer electronics, and other products. The Governor noted that energy efficiency is the cheapest, fastest, and most reliable way to create jobs, save consumers money, and cut pollution from the power sector. He also stated that California's efficiency standards and programs have triggered innovation and creativity in the market. Today's appliances are not only more efficient, but they are less expensive and more versatile than ever due, in part, to California's leadership in the area.

19 Office of Edmund G. Brown Jr., *Clean Energy Jobs Plan,* available at http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

CHAPTER 3:
Product Description

General service lamps (GSLs) are light bulbs that produce white light to provide overall illumination, as opposed to task-specific lighting. GSLs typically incorporate one of three primary light source technologies – incandescent (including halogen), fluorescent, or light-emitting diode (LED) – although other technologies such as induction are available.

The California Appliance Efficiency Regulations define general service lamps as general service incandescent lamps, compact fluorescent lamps (CFL), general service LED and organic LED lamps, and any other lamps that the Secretary (of the U.S. Department of Energy) determines are used to satisfy lighting applications traditionally served by general service incandescent lamps. General service lamps do not include any lighting application or bulb shape excluded from the definition of federally regulated general service incandescent lamp, general service fluorescent lamp, or incandescent reflector lamp.[20]

The definition for general service lamps is identical to that found in the Energy Independence and Security Act of 2007 (EISA).[21] Because CFL and LED general service lamps are direct replacements for general service incandescent lamps (GSILs), the definition for GSLs relies heavily on the definition and exclusions for GSILs. GSILs are defined as lamps with medium screw bases, by far the most common base type, that operate at least partially between 110 and 130 volts and that have light output between 310 and 2,600 lumens. Twenty-two types of lamps are excluded from the definition of GSIL and, by extension, from the definition of GSL. The most notable exclusions are incandescent reflector lamps and many incandescent lamps with candelabra bases.[22] Because of the definitions and exclusions, GSILs and GSLs usually consist of the familiar pear shape, omnidirectional lamp, called an A-shape lamp. (See **Figure 3-1**.)

20 California Code of Regulations, Title 20, § 1602(k), definition for "Federally-regulated general service lamp," available at https://govt.westlaw.com/calregs/Document/I8FF21C40D44E11DEA95CA4428EC25FA0?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

21 United States Code, Title 42, § 6291(30)(BB), available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6291.pdf.

22 Ibid., definition for "federally-regulated general service incandescent lamp."

Figure 3-1: Omnidirectional A-Shape Lamp

Source: www.lightbulbu.com

Some common lamp types found in homes that are used to provide general illumination are not defined as general service lamps under the California regulations. Large-diameter reflector lamps, a type of directional lamp, are used in downlights and frequently found in kitchens and hallways. (See **Figure 3-2**.) Decorative lamps rated at 40 watts or less are often found in light fixtures above vanities and in chandeliers. (See **Figures 3-3 and 3-4**.) Broadening the definition to include these general illumination lamps would save significant electricity statewide.

Figure 3-2: Directional Large-Diameter Reflector Lamp

Source: www.lightbulbu.com

Figure 3-3: Decorative Globe-Shape Lamp

Source: www.lightbulbu.com

Figure 3-4: Decorative Flame-Tip Candle-Shape Lamp

Source: www.lightbulbu.com

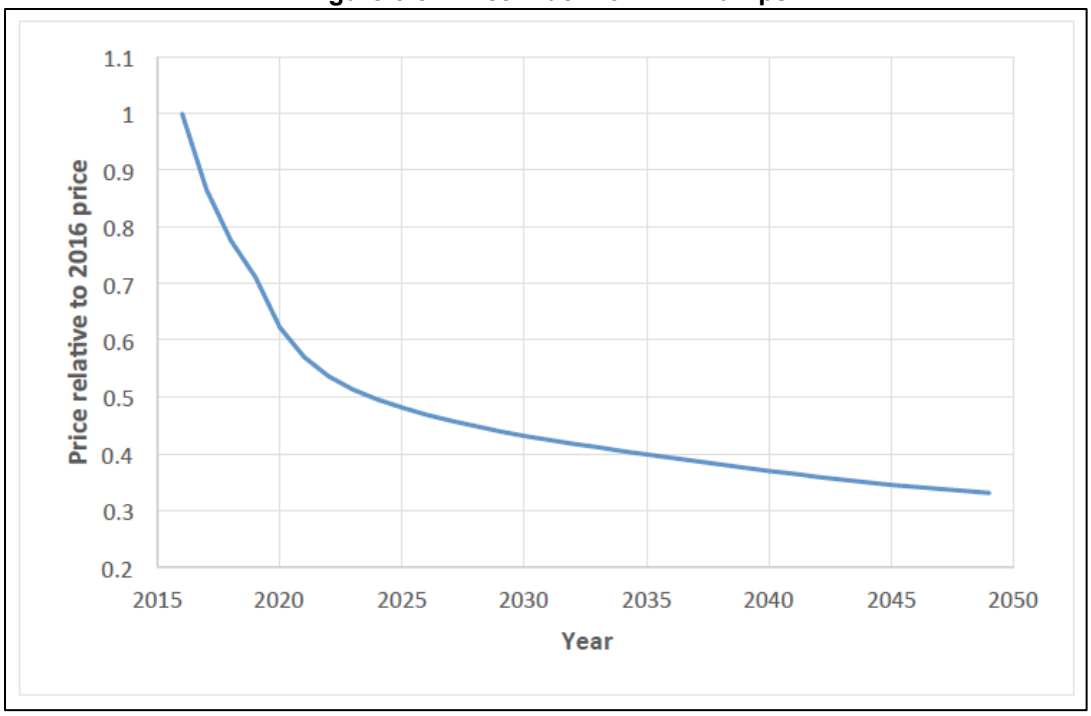
Energy Use

Lamps have a wide range of luminous efficacy (efficacy), depending on the lighting source. *Efficacy* is a measure of the amount of visible light produced by a lamp compared to the amount of electrical power input into the lamp. The units of efficacy are lumens per watt. Halogen incandescent lamps have an efficacy around 17 lumens per watt. CFLs typically have a range of efficacies between 45 and 60 lumens per watt. LED lamps are the most efficient general service lamps available in the market today, reaching efficacies as high as 139 lumens per watt.[2 3] LED lamps are widely available in a variety of shapes and

2 3 EcoSmart 1002459555, available at https://www.energystar.gov/productfinder/product/certified-light-bulbs/details/2293883.

sizes, have rapidly decreased in price, and are declining in both cost to manufacture and consumer price.[24,25,26] (See **Figure 3-5**.)

Figure 3-5: Price Index for LED Lamps



Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps

Lighting remains a large source of residential electricity use. In 2009, before California's most recent lighting standards took effect, the *2009 Residential Appliance Saturation Survey* (RASS) estimated that lighting would consume 22 percent of California residential electricity in 2009.[27] Replacing existing low-efficacy incandescent lamps with high-efficacy CFL or LED lamps can substantially reduce electricity consumption in homes and businesses.

Data from the National Electrical Manufacturers Association for the fourth quarter of 2017 indicate that incandescent, including halogen, lamps account for 55.6 percent of national A-shape lamp shipments.[28] This percentage has remained relatively stable since 2014. (See **Figure 3-6**.) The vast majority of A-shape

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24 California IOUs Response to Invitation to Submit Proposals, pp. 10-14, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN221219_20170918T163557_California_Investor_Owned_Utilities_Comments_Response_to_Invita.pdf.

25 ENERGY STAR® Lamps Version 2.1 Qualified Product List, available at https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

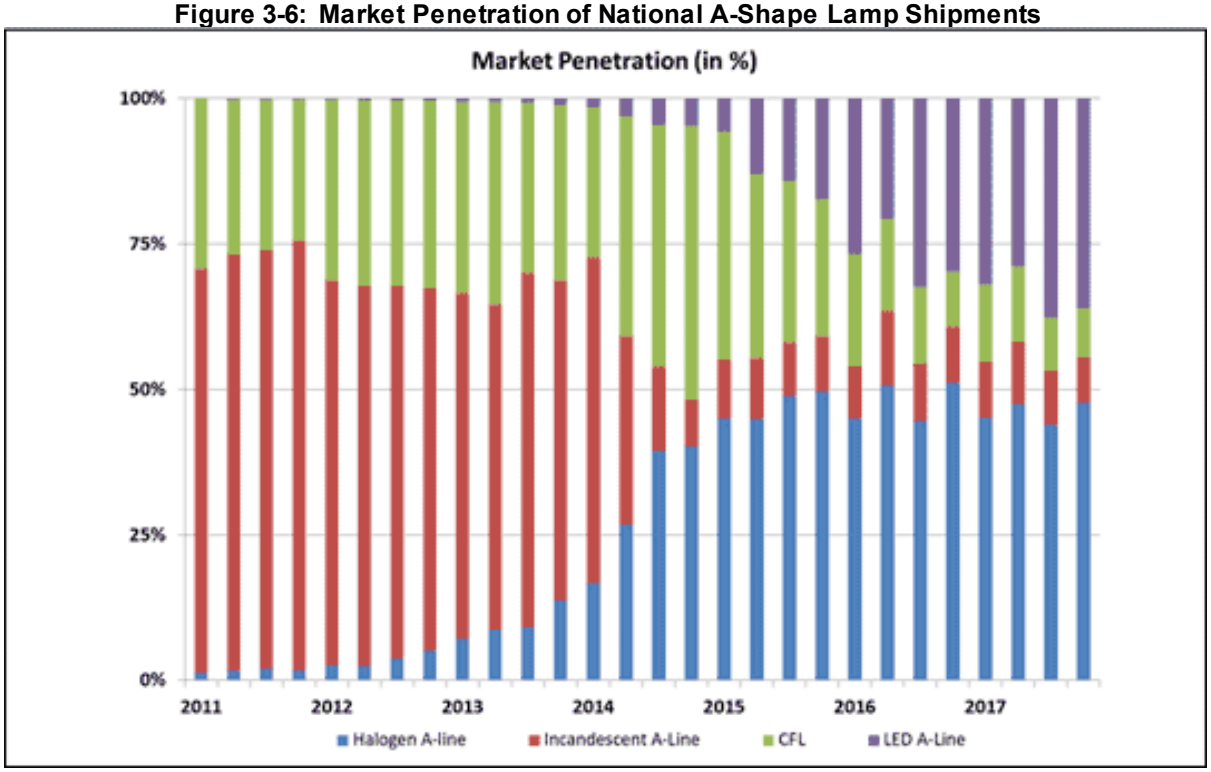
26 Kantner, C., and A. Alstone (2017). Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps, pp.23-24, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN220255_20170718T164013_Impact_of_the_EISA_2007_Energy_Efficiency_Standard_on_General_S.pdf.

27 KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2010-004-ES, available at http://www.energy.ca.gov/appliances/rass/.

28 https://www.nema.org/Intelligence/Indices/Pages/A-line-Lamp-Shipments-Decrease-in-Fourth-Quarter-2017.aspx.

incandescents, including halogen, manufactured on or after January 1, 2018, may no longer be legally offered for sale in California because they are unable to meet the minimum 45 lumens per watt standard for state-regulated GSLs. However, the percentage of shipments for A-shape incandescents, including halogen, is highly likely to be a conservative proxy for a percentage of shipments of other lamp types because A-shape is the most common lamp shape. It is probable that the percentage of shipments for LED lamps that are not A-shaped is lower than that of A-shape lamps because incandescents, including halogen, remain readily available in California.

Figure 3-6: Market Penetration of National A-Shape Lamp Shipments



Source: National Electrical Manufacturers Association

The estimated California existing stock of lamps in 2020 that are addressed in this report is 260 million lamps. (See **Table 3-1**.) Estimates of national market share by light source technology show that shipments of these lamp types continue to be dominated by low-efficacy incandescent lamps.[29] (See **Table 3-2**.) Although LED market share has increased in recent years, California consumers and businesses will achieve significant electricity and monetary savings when replacing these low-efficacy lamps with high-efficacy lamps.

Table 3-1: Estimate of 2020 California Existing Stock of Lamps Addressed in This Report

Lamp Type	2020 Stock Estimate
Large-Diameter Reflector Lamps	67,400,000
Decorative Lamps	125,200,00
Globe Lamps	30,400,000
EISA-Exempt Lamps	35,000,000
Low-Lumen Lamps	2,000,000
Total	260,000,000

Source: Energy Commission staff

Table 3-2: Estimate of 2015 National Market Share by Light Source Technology

Lamp Type	Estimated Stock Share by Technology in 2020		
	Incandescent	CFL	LED
Large-Diameter Reflector Lamps	82%	17%	1%
Decorative Lamps	96%	4%	0%
Globe Lamps	100%	0%	0%
EISA-Exempt Lamps	100%	0%	0%

Source: *Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps*

Distinguishing Characteristics

General service lamps are typically described in terms of the base, shape and diameter, light distribution, operating voltages, and, for CFLs and LEDs, expected lifetime. Within a specific lamp type, the main distinguishing characteristic for consumers is typically the amount of light output, because the purpose of a GSL is to provide overall rather than specific illumination. Historically, incandescent lamps were distinguished by the associated wattage, which stood as a proxy for the lumen output of the lamp. Each of these characteristics are described briefly below:

- **Lumen output**. The lumen output of a lamp is a measure of how much visible light it produces.
- **Base**. The base of a lamp identifies what kind of socket or fixture it can be used with. Common lamp bases include candelabra screw bases (E11 or E12), intermediate screw bases (E17), medium

29 Kantner, C., and A. Alstone (2017). *Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps,* p.4, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN220255_20170718T164013_Impact_of_the_EISA_2007_Energy_Efficiency_Standard_on_General_S.pdf.

screw bases (E26), and bipin bases (for example, G9, GU10, GU24, GX5.3). Less common lamp bases include wedge bases, festoon caps, and quad-pin bases.

- **Shape and diameter**. The shape of a lamp is generally the most familiar characteristic to the consumer, after the base. The pear-shape lamp (called A-shape) is the most common shape of general service lamp. Other shapes can include candle, decorative, or flame shapes (B, C, CA, DC, F, ST), globe or spherical shapes (G, P, PS), directional shapes, typically called "reflector" lamps (R, MR, BR, PAR, ER, MRX), tubular shapes (T or ST), and some specialty or special-purpose shapes. Lamps are also frequently described in terms of diameter, in eighths of an inch. For example, an "MR16" lamp means a multifaceted reflector (MR) lamp with a diameter of 16/8 inch (or 2 inches).
- **Distribution.** The light distribution of a lamp simply describes where the light output is intended to go. An omnidirectional lamp distributes light up, sideways, and down (except for where the lamp attaches at the base). A directional lamp distributes light in a specific direction. A decorative lamp typically distributes most of the light up and out, and not down, similar to a candle.
- **Operating voltages**. Although lamps typically have a range of voltages at which they are capable of operating, most lamps that are used for general illumination (as opposed to some specialty purpose) operate at either 120 volts (line voltage) or 12 volts (low voltage).
- **Lifetime**. The lifetime or "rated life" of a lamp is how long the lamp lasts when on and is typically measured in hours. Incandescent lamps typically have a relatively short-rated life of about 3,000 hours or fewer, whereas LED lamps typically have a longer-rated life ranging from 10,000 to 25,000 hours.

Among directional lamps, additional descriptors often come into play to define the directionality of the associated light distribution and the amount of light to expect from the lamp, including center beam candlepower (CBCP) and beam angle:

- **CBCP**. CBCP is a measure of the luminous intensity of lamp at the center of the beam, in candelas.
- **Beam angle**. Beam angle refers to the directionality of the light and is used to distinguish between a spot light (narrow beam angle) and a flood light (wide beam angle).

Finally, lamps are frequently described by the intended use. As an example, a "mine service lamp" is a lamp "specifically designed for use in mine applications."[30] Describing a lamp by the intended use of it presents a challenge for appliance efficiency regulations because these regulations are enforced at the point of sale, where the intended use of a lamp cannot usually be distinguished. Careful definitions are necessary for these types of lamps so that they do not become loopholes in the standards.

30 California Code of Regulations, Title 20, § 1602(k), definition of "Mine Service Lamp."

EISA-Exempt Lamps

The EISA describes five types of lamps that are explicitly excluded from the definition of "general service incandescent lamp" but that also present a significant risk of a loophole because of the similarity in look and function of these lamp types to a traditional medium screw-base A-shape incandescent lamp. These include rough-service lamps, vibration-service lamps, three-way incandescent lamps, high-lumen (2,601-3,300 lumen) lamps, and shatter-resistant lamps. For many of these lamp types, the distinguishing characteristic of the lamp disappears as you move between lighting technologies. For example, a vibration-service lamp is a lamp that has a sturdier filament to help withstand vibration. A nonfilament lamp, such as a CFL or LED, is an adequate replacement for this application, since these products do not have filaments to jostle loose.

Because these lamps are at high risk for becoming loopholes to the lighting standards, the DOE is required to track and analyze the market share of these lamps each year. If the analysis in any given year shows that one of these types of lamps exceeds a specified threshold of sales, the DOE must either conduct an accelerated rulemaking to establish an energy conservation standard for these products or impose a maximum wattage standard on these lamps (for example, for rough-service, vibration-service, and shatter-resistant lamps the backstop requirement is a maximum 40-watt limitation). For vibration-service and rough-service lamps, the DOE has published final rules confirming the 40-watt backstop requirement is in effect.[31]

The DOE's definition of "general service lamps," effective January 1, 2020, would cover all of these "EISA-exempt lamps" as "general service lamps" and subject them to the 45-lumens-per-watt standard, although there are no standards in effect today for shatter-resistant, three-way, or high-lumen lamps.

Replacement General Service Lamps

GSLs installed in California homes and businesses consume a significant amount of electricity. Replacement GSLs are available in a wide range of efficacies, with the more efficacious lamps enabling significant electricity savings for California consumers. Because general service lamps are distinguished and selected by the associated physical characteristics such as base, shape, distribution, and lumen output, the light source technology is interchangeable by the consumer. The choice of light source technology has little or no effect on the performance of the GSL, which is almost exclusively determined by the physical characteristics of the lamp, but has a dramatic impact on the energy consumption of the lamp. Because the light source technology does not dictate the performance or consumer utility of a GSL, it is appropriate and imperative to maintain a technology-neutral approach to regulating the energy consumption of GSLs.

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31 82 Fed. Reg. 60845 (Dec. 26, 2017).

CHAPTER 4:
Regulatory Approaches

Federal Approaches

There are federal efficiency standards for incandescent reflector lamps, medium-base compact fluorescent lamps, general service incandescent lamps, modified spectrum general service incandescent lamps, intermediate-base incandescent lamps, candelabra-base incandescent lamps, rough-service lamps, and vibration-service lamps. There are no federal standards in effect for general service lamps or general service LED lamps. There are no federal standards for small-diameter directional lamps.

In 2007, the U.S. Congress passed and President George H. W. Bush signed into law the Energy Independence and Security Act (EISA). The EISA included a definition, and certain exclusions from the definition, for general service incandescent lamps (GSILs). The EISA set minimum efficacy standards for GSILs and modified spectrum GSILs and maximum wattage limits for candelabra-base incandescent lamps and intermediate-base incandescent lamps. The EISA included a definition for general service lamps that is the same as the definition for "general service lamp" found in the Code of Federal Regulations (CFR) and the same as the definition for "federally regulated general service lamp" found in the Appliance Efficiency Regulations. This definition for GSL applies primarily to A-shape lamps with a medium screw base and that use either incandescent, including halogen, CFL, or LED light-sources.

The EISA directed the DOE to conduct a rulemaking for GSLs that met four criteria: (1) initiate a rulemaking by January 1, 2014, to determine whether to amend the minimum efficacy standards for GSILs and whether to maintain or discontinue exemptions for incandescent lamps; (2) include in the scope of the rulemaking technologies other than incandescent technologies and a consideration of a minimum 45 lumens-per-watt standard for GSLs; (3) if DOE determines that the GSIL standards should be amended, a final rule by January 1, 2017, with an effective date at least 3 years from the final rule publication date; and (4) consideration of phased-in effective dates.[32] If the DOE did not undertake the required rulemaking or if the final rule did not produce savings greater than or equal to the savings from a minimum efficacy standard of 45-lumens-per-watt, then the EISA establishes a "backstop" standard prohibiting the sale of GSLs that do not meet a minimum efficacy of at least 45 lumens per watt, effective beginning January 1, 2020.[33]

The DOE has an open rulemaking docket for energy conservation standards for general service lamps but has not published a final rule establishing energy conservation standards.[34] Because DOE has not completed a rule meeting the four criteria listed above, the backstop standard established by the EISA has

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32 United States Code, Title 42, § 6295(i)(6)(A)(i)-(iv), available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.pdf.

33 United States Code, Title 42, § 6295(i)(6)(A)(v), available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.pdf.

34 Department of Energy, Energy Conservation Standards for General Service Lamps, Docket EERE-2013-BT-STD-0051, available at https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0051.

been triggered and, in accordance with the statute, "effective beginning January 1, 2020, the Secretary shall prohibit the sale of any general service lamp that does not meet a minimum efficacy standard of 45 lumens per watt."[35]

On January 19, 2017, the DOE published two *Federal Register* notices of final rules adopting an amended definition for general service lamps that is broader than the EISA and the CFR definitions and that discontinues certain exclusions from the definition of general service incandescent lamp.[36,37] A partial summary of the January 1, 2017, definitional rules is:

- Exclusions discontinued for:
    - Reflector lamps.
    - Rough-service lamps.
    - Shatter-resistant lamps.
    - Three-way incandescent lamps.
    - Vibration-service lamps.
    - T-shape lamps of 40 watts or less.
    - Multiple decorative shape lamps of 40 watts or less.
- General service lamp means a lamp that:
    - Has an American National Standards Institute (ANSI) base.
    - Is able to operate at 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or of 277 volts for integrated lamps, or is able to operate at any voltage for nonintegrated lamps.
    - Has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens.
    - Is not a light fixture.
    - Is not an LED downlight retrofit kit.
    - Is used in general lighting applications.
    - Includes, but is not limited to, general service incandescent lamps, compact fluorescent lamps, general service light-emitting diode lamps, and general service organic light-emitting diode lamps.

35 United States Code, Title 42, § 6295(i)(6)(A)(v), available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.pdf.

36 Department of Energy, Energy Conservation Program: Energy Conservation Standards for General Service Lamps; Final rule, 82 Fed. Reg., 7276 (January 1, 2017), available at https://www.regulations.gov/document?D=EERE-2013-BT-STD-0051-0097.

37 Department of Energy, Energy Conservation Program: Energy Conservation Standards for General Service Lamps; Final rule, 82 Fed. Reg., 7322 (January 1, 2017), available at https://www.regulations.gov/document?D=EERE-2013-BT-STD-0051-0098.

The definitional final rules have an effective date of January 1, 2020. Because the effective date is the same as that for the national backstop standard, these lamps will also be subject to the minimum 45-lumens-per-watt efficacy standard. In other words, the two definitional rules effectively expand the scope of products to which the EISA backstop is applicable.

The U.S. Environmental Protection Agency also has a voluntary ENERGY STAR® Lamps Specification Version 2.1, which includes efficacy and performance requirements. The efficacy requirements are set at levels such that on June 28, 2018, the ENERGY STAR qualified product list (QPL) includes 8,633 LED lamps but only 21 CFL lamps.[38] The ENERGY STAR Lamps Specification applies to omnidirectional, directional, and decorative lamps with any base type.

Current California Regulations

On December 3, 2008, the California Energy Commission adopted appliance efficiency standards for state-regulated general service incandescent lamps, modified spectrum general service incandescent lamps, and general service lamps. In that rulemaking, the state adopted the minimum efficacy standards from the EISA with earlier effective dates than took place nationally, as allowed by that law. The standards for general service incandescent lamps (regular and modified spectrum) were phased in between 2011 and 2013, one year earlier than nationally. The minimum 45-lumens-per-watt backstop standard for general service lamps was adopted with an effective date of January 1, 2018, two years earlier than it should take effect nationally. If the DOE completed a timely rulemaking setting a different standard for these lamps, then under EISA's provisions, the Energy Commission could adopt that standard instead of the backstop with an effective date of January 1, 2018. However, as discussed above, the DOE did not complete such a rulemaking. Therefore, the backstop standard took effect in California for state-regulated general service lamps manufactured on or after January 1, 2018. These regulations apply to the EISA-defined general service lamps, primarily A-shape lamps with a medium screw base that use either incandescent, including halogen, CFL, or LED light-sources.

On January 27, 2016, the Energy Commission adopted appliance efficiency regulations for small-diameter directional lamps and general service LED lamps. These regulations are effective for lamps manufactured on or after January 1, 2018, and sold or offered for sale in California. The regulations for small-diameter directional lamps are technology-neutral and apply equally to all technologies, such as halogen and LED. The required minimum efficacy is set at a level that effectively can be met using only an LED light source. The regulations for general service LED lamps apply only to lamps using LED light sources, and the scope is limited to lamps with E12 (candelabra), E17 (intermediate), E26 (medium), or GU24 bases. The regulations for general service LED lamps partially overlap with the types of products that would otherwise be covered as state-regulated GSLs. For example, the general service LED lamps regulations have a lower lumen output threshold (covering 0 lumens to 2,600 lumens) than the state-regulated GSL regulations (310 lumens to 2,600 lumens). These standards took effect on January 1, 2018.

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38 ENERGY STAR Lamps Version 2.1 Qualified Product List, available at https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

The California Building Efficiency Standards require that all lighting in new residential construction be high efficacy and meet the requirements in Joint Appendix 8 (JA8).[39] Lamps covered by the *Appliance Efficiency Regulations* must also meet the JA8 requirements if installed in new residential construction in California. The Appliance Efficiency Regulations and the JA8 requirements are similar but not fully aligned due to the different purposes (sold versus installed).

Other State Approaches

Vermont statute defines general service lamps in a manner identical to the two DOE definitional final rules published in the *Federal Register* on January 19, 2017.[40] Vermont statute directs the Commissioner of the Department of Public Service to adopt a minimum efficacy standard for general service lamps of 45 lumens per watt.[41] This standard would be effective only if the federal backstop for general service lamps is withdrawn, repealed, or otherwise voided.[42]

Stakeholder Proposals Received

The California Statewide IOUs Codes and Standards Enhancement (CASE) Program submitted the only stakeholder proposal in response to the Commission's invitation to submit proposals. The proposal suggests aligning definitions in the Appliance Efficiency Regulations with the two DOE definitional final rules published in the *Federal Register* on January 19, 2017. The proposal additionally suggests including lamps with lumen output of 150 lumens or greater but less than 310 lumens in the definition of general service lamp. The proposal indicates that the DOE definitional final rules excluded certain specialty lamps that can only use incandescent light sources from the definition of GSL and that the DOE found LED replacements for other GSLs to be either available or technologically feasible to manufacture.[43]

39 2016 California Building Energy Efficiency Standards, available at http://energy.ca.gov/title24/2016standards/index.html.
40 Vermont Statutes Annotated, Title 9, § 2793(15), available at https://legislature.vermont.gov/statutes/section/09/074/02793.
41 Vermont Statutes Annotated, Title 9, § 2795(7), available at https://legislature.vermont.gov/statutes/section/09/074/02795.
42 Vermont Statutes Annotated, Title 9, § 2796(f)(2), available at https://legislature.vermont.gov/statutes/section/09/074/02796.
43 California IOUs Response to Invitation to Submit Proposals, pp. 10-14, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN221219_20170918T163557_California_Investor_Owned_Utilities_Comments_Response_to_Invita.pdf.

CHAPTER 5:
Alternative Considerations

Energy Commission staff considered three alternatives for state standards: (1) maintaining the current California Appliance Efficiency Regulations (no change), (2) a more stringent minimum efficacy for GSLs that would eliminate CFLs and require improvement of the average efficacy of LEDs, and (3) expanding the lumen output range and reducing the number of exclusions that partially define GSLs. Energy Commission staff also considered stakeholder proposals submitted to Energy Commission Docket Number 17-AAER-07 in response to the Commission's July 18, 2017, Invitation to Submit Proposals.

Alternative 1: Maintaining Current California Appliance Efficiency Regulations

The current California Appliance Efficiency Regulations for GSLs apply to medium screw base lamps, primarily A-shape, the most common residential lamp. The regulations require GSLs to have a minimum efficacy of 45 lumens per watt. Only CFLs and LEDs can achieve this level of efficacy, so incandescent technologies, including halogens, are effectively eliminated from the market.

Other common directional and decorative lamps that provide general illumination are not required to meet California's 45-lumens-per-watt requirement, and incandescent or halogen versions remain available. Because there are equivalent, cost-effective, higher-efficacy lamps available to replace these low-efficacy versions, this alternative would not meet the Energy Commission's mandate in Public Resources Code section 25402 "to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy."[44]

Alternative 2: More Stringent Minimum Efficacy for GSLs

Alternative 2 would establish a minimum efficacy level higher than 45 lumens per watt for GSLs. Because the average efficacy of LEDs is higher than CFLs, it would be technologically feasible to increase the minimum efficacy to a level where only LED versions of GSLs would be able to meet the standard (for example, 80 lumens per watt). Small-diameter directional lamps and general service LED lamps are already subject to state standards more stringent than 45 lumens per watt. Although this alternative might increase expected electricity savings by removing CFLs from the marketplace, the minimum efficacy standard would be inconsistent with the backstop implemented in California on January 1, 2018, and that should be implemented nationally on January 1, 2020, thereby increasing manufacturer burden and potentially increasing costs associated with preparing to comply with two different standards for the same products.

Alternative 3: Expand Lumen Output Range and Reduce

44 California Public Resources Code § 25402, available at http://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PRC&division=15.&title=&part=&chapter=5.&article.

Exclusions

The existing GSL standard applies to GSLs with a lumen output of at least 310 lumens and not more than 2,600 lumens. Incandescent lamps with a lumen output less than 310 lumens or greater than 2,600 lumens are excluded from the definition of GSILs and are not subject to any federal energy conservation standards. These additional lumen output ranges could be added to the scope of the existing GSL standard, which would subject additional lamp types to a 45-lumen-per-watt minimum efficacy and lead to greater electricity savings.

Certain incandescent lamp types, such as three-way lamps and shatter-resistant lamps, are excluded from the definition of GSILs and are not subject to any federal energy conservation standards. These excluded lamp types could be added to the scope of the existing GSL standard, which would subject additional lamp types to a 45 lumens per watt minimum efficacy and lead to greater electricity savings.

Under this alternative, savings would increase, and the minimum efficacy standard would be consistent with the backstop implemented in California on January 1, 2018, and that should take effect nationally on January 1, 2020. Under this alternative, the vast majority of the lamps subject to the backstop in California would be consistent with the two DOE definitional final rules published in the *Federal Register* on January 19, 2017. Lamps with a lumen output equal to or greater than 150 lumens and less than 310 lumens would be subject only to a 45 lumen per watt backstop in California and would not be covered under the DOE definitional final rules.

CHAPTER 6:
Staff Proposal for General Service Lamps

This chapter presents staff's proposed definitions, test procedures, efficiency standards, and certification and marking requirements for general service lamps. Based on independent analysis of the best available data, staff concludes that the proposed regulations are cost-effective and technically feasible and will save a significant amount of energy statewide, as will be discussed in the following chapters. Staff assumptions and calculation methods are provided in **Appendix A**.

Scope and Definitions

Staff proposes to expand the scope of "general service lamps," which are subject to a minimum 45-lumens-per-watt efficacy standard in California, by aligning the Appliance Efficiency Regulations definition for general service lamps with the two DOE definitional final rules published in the *Federal Register* on January 19, 2017. The effective date for the definitions will occur at the same time in California as nationally, January 1, 2020, resulting in additional lamp types being subject to a 45-lumens-per-watt efficacy standard in California.

Staff proposes to define a low-lumen lamp as one that has a lumen output of 150 lumens or greater and less than 310 lumens and otherwise meets the definition of a general service lamp. Staff proposes an effective date of January 1, 2020, for this definition. The LED versions of these low-lumen lamps with E12, E17, E26, or GU24 bases already fall under the existing state-regulated LED lamps standards, which were effective on January 1, 2018.

Test Procedure

The Energy Commission is undertaking a rulemaking (Docket # 18-AAER-10) that will align the existing lamp test procedures in the California Appliance Efficiency Regulations with the test procedures in Title 10, Code of Federal Regulations, Section 430.23. This alignment reflects new and updated test procedures that have been adopted by the U.S. Department of Energy and are mandatory for manufacturers making representations about the energy use or efficiency of the applicable lamp types.

For low-lumen lamps, staff proposes the same test procedure as is required for a general service lamp of the same light source. For example, a low-lumen lamp that is an integrated LED lamp would be required to use the test procedure in 10 CFR Section 430.23(ee) (Appendix BB to Subpart B of part 430).[45]

45 Code of Federal Regulations, Title 10, § 430.23(gg)(3).

Efficiency Standards

Staff proposes to maintain California's existing efficacy and performance standards for state-regulated LED lamps and small-diameter directional lamps, many of which would also be considered "GSLs." For all other GSLs, staff proposes a minimum efficacy standard of 45 lumens per watt and a minimum rated life of 1,000 hours, aligning with the current state-regulated GSL requirements and the 45-lumens-per-watt standard that has been triggered nationally and takes effect on January 1, 2020. The standards would apply for GSLs *sold* in California on or after January 1, 2020. Although most appliance efficiency standards apply to products based on the date of manufacture, staff proposes a date of sale requirement to be consistent with the implementation of the national backstop when "effective beginning January 1, 2020, the Secretary shall prohibit the **sale** of any general service lamp that does not meet a minimum efficacy standard of 45 lumens per watt."[46] (emphasis added)

Staff proposes a minimum efficacy standard of 45 lumens per watt for low-lumen lamps manufactured on or after January 1, 2020, and sold or offered for sale in California. Low-lumen lamps that meet the definition of state-regulated LED lamp or small-diameter directional lamp will continue to be required to meet the minimum efficacy and performance requirements of state-regulated LED lamps or small-diameter directional lamps.

At this time, staff is not proposing any additional performance requirements for GSLs but is considering the possibility of increasing the minimum rated life requirements and maintaining the minimum color rendering index (CRI) requirements put in place by the EISA.[47]

Certification Requirements

Staff does not propose to require certification of general service lamps or low-lumen lamps as a separate category of appliances. General service lamps that are also a federally regulated medium screw base CFL must continue to certify as a federally regulated CFL but do not need to certify separately as a GSL. Lamps meeting the definition of state-regulated LED lamp or small-diameter directional lamp will continue to be required to certify as a state-regulated LED lamps or small-diameter directional lamps. Lamps such as a low-lumen integrated LED lamp that is not a state-regulated LED lamp or small-diameter directional lamp would not have any certification requirements.

46 United States Code, Title 42, § 6295(i)(6)(A)(v), available at https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap77-subchapIII-partA-sec6295.pdf.

47 80 CRI for nonmodified spectrum lamps or 75 CRI for modified spectrum lamps.

Marking Requirements

Staff is not proposing any new marking requirements for GSLs. The general marking requirements in Section 1607(b) for name, model number, and date of manufacture are applicable to GSLs.[48] The information must be displayed on the lamp itself or on the unit(s) packaging.[49]

Stakeholders have expressed confusion around the two marking requirements for state-regulated LED lamps in Section 1607(d)(13) (B) and (C). When a manufacturer makes a direct comparison between a state-regulated LED lamp and an incandescent lamp, the LED must replicate numerous features of incandescent lamps, including correlated color temperature of 3000 Kelvin (K) or less, dimmability, and a minimum lumen output, or brightness level. When making a claim of incandescent wattage equivalency for an E26 or GU24 base omnidirectional state-regulated LED lamp, only a minimum lumen output is required. Making a claim of wattage equivalency alone does not mean that the lamp is being compared to an incandescent lamp and must meet all the performance requirements expected of an incandescent lamp. These two marking requirements are independent of each other.

48 California Code of Regulations, Title 20, § 1607(b).

49 California Code of Regulations, Title 20, § 1607(c)(2).

CHAPTER 7:
Technical Feasibility

In evaluating the technical feasibility of the proposed standards for newly covered lamp types, Energy Commission staff considered whether there were either (a) high-efficiency replacements for the lamps or (b) lamps without current replacements in the market but for which replacements can be manufactured using existing technologies. If a lamp had neither of these, then standards for the product would not be considered technically feasible at this time. This aligns with a similar assessment prepared by the U.S. Department of Energy when it considered expanding its definition of "general service lamp."[50]

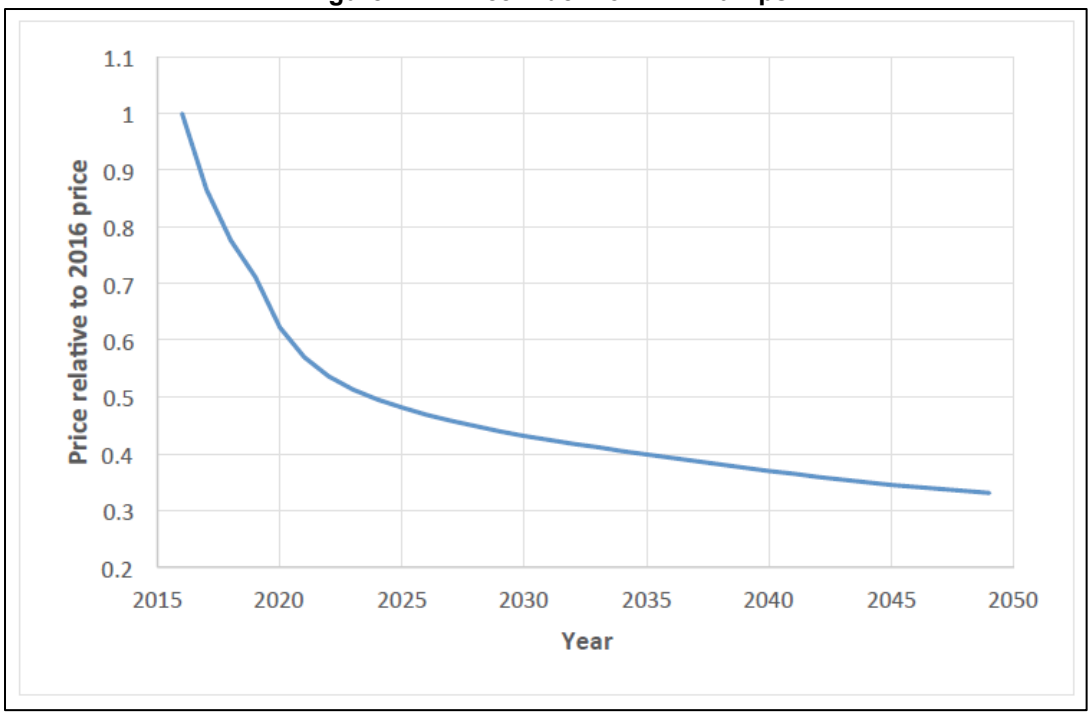
Energy Commission staff conducted this analysis for four lamp categories to determine the technical feasibility of the staff proposal: lamps with an E12, E17, E26, or GU24 base; small-diameter directional lamps; low-lumen lamps; and all other GSLs. The proposed efficacy standard of 45 lumens per watt can be met by either CFL or LED technologies.

LED lamps have become mainstream, and manufacturer cost and retail price continue to fall as sales volumes increase. Although declining at a slower rate after 2020, LED prices are expected to continue this downward trend for the foreseeable future. (**See Figure 7-1**.) Now that LED light sources and drivers have well-established supply chains, manufacturing additional lamp types by connecting a different base, providing a different shape envelope, and perhaps providing different optics, has become a much less complicated and less costly process. There are still technical considerations, such as thermal management and proper light distribution, but these are issues with which lighting manufacturers have abundant experience. The ENERGY STAR QPL, accessed on June 28, 2018, includes more than 8,600 LED lamps, ranging in efficacy from 45.5 to 139 lumens per watt, and are available in more than three dozen lamp shapes.[51]

50 82 Fed. Reg., 7276 at 7301.

51 ENERGY STAR Lamps Version 2.1 Qualified Product List, available at https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

Figure 7-1: Price Index for LED Lamps



Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps

Lamps With an E12, E17, E26, or GU24 Base

Staff's proposal would expand coverage of the 45-lumens-per-watt standard to lamps with an E12, E17, and GU24 base, with any shape, and to lamps with an E26 base and a directional or decorative shape (such as some types of incandescent reflector lamps). In its 2016 rulemaking establishing standards for state-regulated LED lamps, the Energy Commission found that there were either existing LED lamps or that it was technologically feasible to make LED lamps that would meet high-efficacy and performance requirements.[52] Because staff found that LED lamps with an even higher efficacy than the minimum 45-lumens-per-watt standard were technically feasible as part of that rulemaking, it is reasonable to conclude that lamps meeting the minimum 45-lumens-per-watt standard either exist as replacements for this category of lamps or are technologically feasible to produce. Moreover, CFL lamps that exist as replacements for many lamps in this category have an efficacy exceeding 45 lumens per watt and were not considered as part of the 2016 LED rulemaking. The summation of this information makes the proposed 45-lumens-per-watt standard technically feasible.

52 Singh, Harinder, and Ken Rider, 2015. *Analysis of Small-Diameter Directional Lamp and General Service Light-Emitting Diode Lamp Efficiency Opportunities*. California Energy Commission. Publication Number: CEC-400-2015-034, pp. 62-68, available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=206387.

Small-Diameter Directional Lamps

Staff does not believe that its proposal would expand the coverage of the 45-lumens-per-watt standard to any additional small-diameter directional lamps. However, if any additional small-diameter directional lamps were to be covered, the Energy Commission found, in its 2016 rulemaking establishing standards for small-diameter directional lamps, that there were either existing LED lamps or that it was technologically feasible to make LED lamps that would meet high-efficacy requirements.[53] Because staff found that LED lamps with an even higher efficacy than a minimum 45-lumens-per-watt standard were technically feasible as part of that rulemaking, it is reasonable to conclude that lamps meeting the minimum 45-lumens-per-watt standard either exist as replacements for this category of lamps or are technologically feasible to produce. Thus, the proposed 45-lumens-per-watt standard is technically feasible.

Low-Lumen Lamps

On June 28, 2018, the ENERGY STAR QPL included 446 LED lamps with a lumen output equal to or greater than 150 lumens and less than 310 lumens. All of these lamps have an efficacy that exceeds the proposed efficacy standard of 45 lumens per watt.[54]

The distinguishing feature between low-lumen lamps and GSLs is the associated lower lumen output, 150 to 310 lumens. In all other respects, low-lumen lamps are proposed to be defined identically to GSLs. Because low-lumen lamps are technologically identical to GSLs, it follows that when GSLs are technically feasible, low-lumen lamps are also technically feasible. Thus, the proposed 45-lumens-per-watt standard is technically feasible.

All Other GSLs

The primary distinguishing feature of other GSLs is base type (for example, E11 candelabra base, various bi-pin bases). Additional distinguishing features could be items such as form factor. The DOE, in crafting its expanded definitions for GSLs, explicitly excluded lamps where it could not identify efficient, equivalent replacements or where the lamps clearly did not provide general illumination.[55] For the lamps that were included in the definition of GSLs, then, staff infers that the DOE implicitly found that high-efficiency replacements for these lamps were technically feasible, either because they exist in the market today or because there is a clear technological pathway to manufacture such replacement lamps.

Lamps with existing high-efficiency replacements may be either CFL or LED, both of which meet the proposed 45-lumens-per-watt standard. Because CFLs are a mature technology and sales have significantly declined, staff assumes that any technically feasible lamps for which replacement lamps do not yet exist and need to be developed, will use LED light sources. LED lamps can easily be designed to

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53 Ibid, pp. 36-42.
54 ENERGY STAR Lamps Version 2.1 Qualified Product List, available at https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
55 82 Fed. Reg., 7276 at 7301.

exceed 45 lumens per watt, and the amended definition of GSL excludes lamps for which nonincandescent replacements may not be technically feasible (for example, very small form factor and high lumen output). Thus, the proposed 45-lumens-per-watt standard is technically feasible.

CHAPTER 8:
Savings and Cost Analysis

The proposed definitions and broader efficacy standard for general service lamps would significantly reduce energy consumption in the state. Energy Commission staff analyzed the cost-effectiveness of the proposed broader definition for general service lamps and the proposed efficacy standard for low-lumen lamps to ensure that the increased incremental costs to the consumer of a more efficient lamp would be exceeded by the energy-saving benefits over the lifetime of the lamp. In addition, this chapter includes the statewide electricity savings both in the first year the proposed changes are in effect and after all existing noncompliant lamps are replaced with minimally efficient lamps (that is, 45 lumens per watt).

Stock and Sales

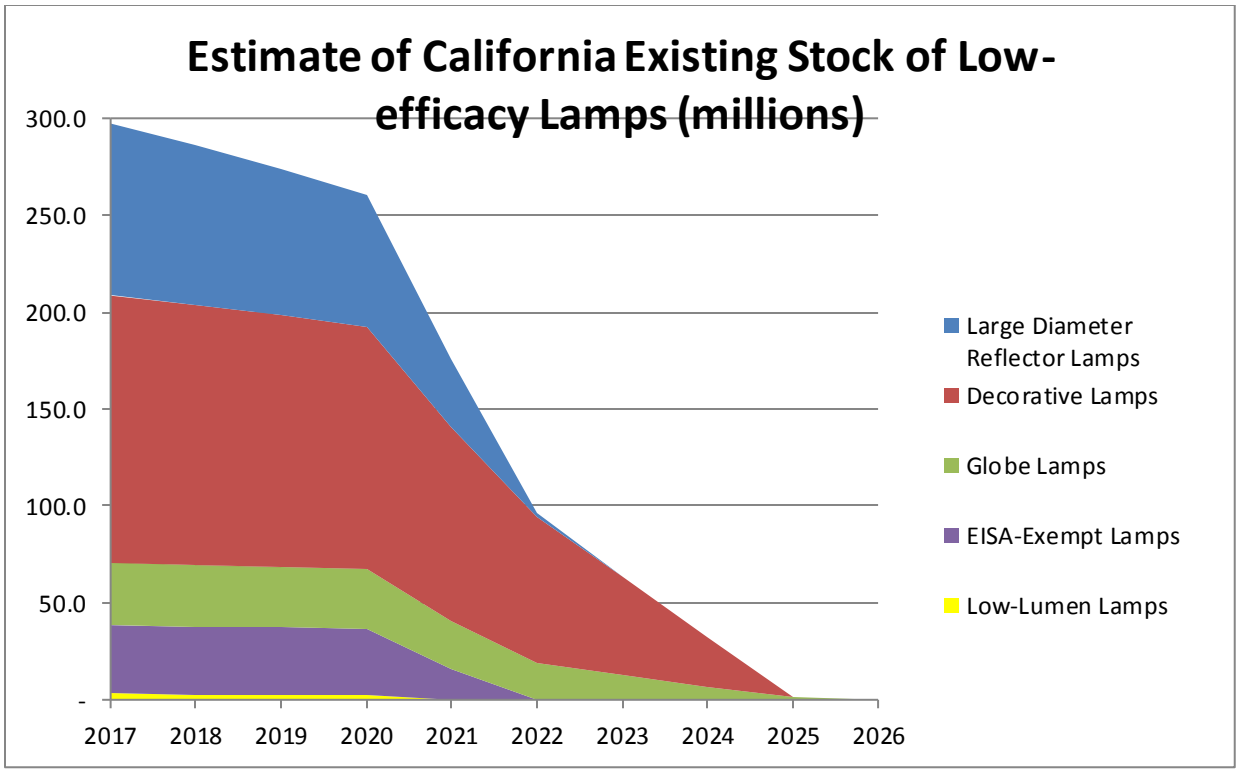
Because the lamp types addressed in this report are not subject to California's existing general service lamp regulations, lower-price incandescent versions of these lamps remain available and directly compete with LED versions of these lamps. The LED versions of these lamps have slightly higher prices but will provide significant electricity and electricity bill savings. LED market share continues to grow, but even in the most common lamp type, the
A-shape, low-efficacy incandescent lamps maintain a market share of shipments that is greater than 50 percent. The lamp types addressed in this report are less common than A-shape lamps and are believed to have substantially lower penetration of LEDs in the existing stock and in shipments. In addition, CFL technology has not been widely used for these lamp types, despite being a technically feasible option for compliance. Existing data show CFL shipments are declining as LED shipments increase.[5 6]

Staff estimated that despite the increasing market share of LED lamps, there will be about 260 million low-efficacy lamps addressed by this report that will still be installed in California homes and businesses in 2020. See **Figure 8-1** for staff's estimate of California existing stock of low-efficacy lamps and **Figure 8-2** for staff's estimate of California shipments of replacement lamps for the standards case. The estimate for shipments of replacement lamps includes only the initial replacement of a low-efficacy lamp and does not include any subsequent replacement of a high-efficacy lamp, shipments for lamps in new construction, or other new lamps. The data used to create these charts can be found in **Tables A-2 and A-3** in Appendix A. In 2020, the year the proposed broader standard would take effect, staff assumes all shipments will be LED. **Figure 8-1** shows the rapid decline in the existing stock of low-efficacy lamps addressed by this report that would result from the rapidly increasing shipments of LED lamps shown in **Figure 8-2**.

These estimates of shipments and existing stock were used in the staff's calculations of statewide electricity savings and statewide monetary savings.

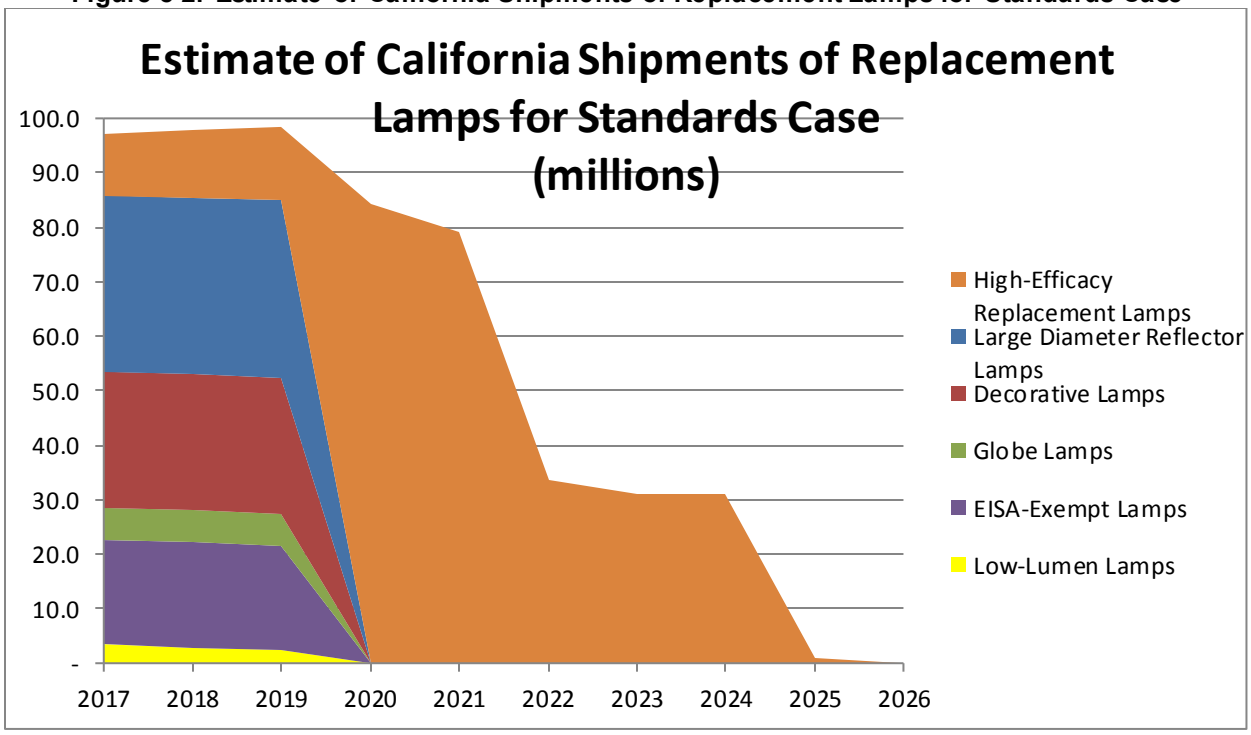
Figure 8-1: Estimate of California Existing Stock of Low-efficacy Lamps

5 6 https://www.nema.org/Intelligence/Indices/Pages/A-line-Lamp-Shipments-Decrease-in-Fourth-Quarter-2017.aspx.



Source: Energy Commission staff

Figure 8-2: Estimate of California Shipments of Replacement Lamps for Standards Case



Source: Energy Commission staff

Incremental Price of Compliant Lamps

As noted previously in this report, the cost to manufacture LED lamps and the retail price consumers pay for LED lamps continue to decline. For most lamp types, the incremental price of an LED lamp is small, especially compared to the monetary savings from reduced electricity consumption. Staff used the highest incremental price for EISA-exempt lamps to provide a conservative analysis. Within the EISA-exempt lamp type, there is significant variability of the incremental price with higher incremental prices for three-way lamps and lamps with a lumen output greater than 2,600 lumens and significantly lower incremental prices for other EISA-exempt lamp types.[57] The incremental prices used by staff in this report are shown in **Table 8-1.**

57 California IOUs Response to Invitation to Submit Proposals, p. 28, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN221219_20170918T163557_California_Investor_Owned_Utilities_Comments_Response_to_Invita.pdf.

Table 8-1: Incremental Price of LED Lamp by Lamp Type

Lamp Type	Incremental Price of LED Lamp
Large-Diameter Reflector Lamps	$1.00
Decorative Lamps (average)	$4.58
Globe Lamps	$4.00
EISA-Exempt Lamps	$14.98
Low-Lumen Lamps*	$1.25

Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps and * Energy Commission staff

Electricity Savings

Appendix A details staff's calculations of electricity savings resulting from the proposed broader standard. Existing, noncompliant lamps have efficacies ranging from 7 to 14 lumens per watt, whereas the proposed broader standard requires a minimum efficacy of 45 lumens per watt. This leads to a significant reduction in annual electricity usage for compliant lamps compared to noncompliant lamps, ranging from 3 to 29 kilowatt-hours (kWh) per year. These values of annual electricity usage for compliant lamps are for a fictitious lamp that exactly meets the standard of 45 lumens per watt. In reality, compliant lamps will be LED lamps with efficacies that are typically 65 lumens per watt or higher.

Table 8-2: Single-Lamp Electricity Usage

Lamp Type	Annual Electricity Usage (kWh)	
	Noncompliant	Compliant
Large-Diameter Reflector Lamps	76.2	16.5
Decorative Lamps (average)	62.2	11.5
Globe Lamps	38.0	6.7
EISA-Exempt Lamps	95.8	29.6
Low-Lumen Lamps	20.4	3.2

Source: Energy Commission staff

Staff assumed compliant lamps will be LED lamps with a rated lifetime of 10,000 hours. Based on the average daily hours of use and the estimated share of lamps in the residential and commercial sectors, staff calculated the sector-weighted rated lifetimes in years, as shown in **Table 8-3**.

Table 8-3: Sector-Weighted Rated Lifetimes

Lamp Type	Daily Hours of Use			Rated Lifetime	
	Residential	Commercial	Sector-Weighted	Hours	Sector-Weighted (years)
Large-Diameter Reflector Lamps	2.9	10.7	3.2	10,000	8.5
Decorative Lamps	2.6	10.7	3.4	10,000	8.0
Globe Lamps	1.7	10.7	2.6	10,000	10.5
EISA-Exempt Lamps	2.3	10.7	3.6	10,000	7.5
Low-Lumen Lamps	8.0	8.0	8.0	10,000	3.4

Source: Energy Commission staff

For the five lamp types analyzed in this report, staff calculated electricity savings per compliant lamp ranging from 17 to 66 kWh per year and ranging from 58 to 508 kWh over the lifetime of the compliant lamp.

Table 8-4: Single Compliant Lamp Electricity Savings

Lamp Type	Electricity Savings (kWh)	
	Annual	Lifecycle
Large-Diameter Reflector Lamps	59.7	508.9
Decorative Lamps (average)	50.7	407.2
Globe Lamps	31.2	328.9
EISA-Exempt Lamps	66.2	497.8
Low-Lumen Lamps	17.2	58.9

Source: Energy Commission staff

Cost-Effectiveness

Appendix A details staff's calculations of monetary savings resulting from the proposed broader standard. Due to the substantial increase in required minimum efficacy and the relatively small incremental price of compliant lamps, four of the five lamp types analyzed in this report have a simple payback period of less than one year, resulting in monetary savings in the first year. The negative first-year monetary savings for the fifth lamp type indicate that incremental price paid for a compliant lamp exceeds the monetary value of the first year of electricity bill savings. However, this lamp type has life-cycle savings of greater than $54 and a simple payback period of less than two years. All five lamp types analyzed in this report result in large life-cycle savings per compliant lamp, ranging from $11 to $90. These values of monetary savings for compliant lamps are for a hypothetical lamp that exactly meets the standard of 45 lumens per watt. In reality, compliant lamps will be LED lamps with efficacies that are typically 65 lumens per watt or higher and lasting about 7 to 10 years.

Table 8-5: Single Compliant Lamp Net Monetary Savings

Lamp Type	Incremental Price	Net Monetary Savings	
		First-year	Lifecycle
Large-Diameter Reflector Lamps	$1.00	$9.96	$90.90
Decorative Lamps (average)	$4.58	$4.60	$61.00
Globe Lamps	$4.00	$1.65	$50.69
EISA-Exempt Lamps	$14.98	-$3.16	$54.64
Low-Lumen Lamps	$1.25	$1.94	$11.77

Source: Energy Commission staff

Therefore, staff finds that the proposed changes are cost-effective for all lamp types.

Statewide Savings

Appendix A details staff's calculations of annual statewide electricity and annual statewide monetary savings resulting from the proposed broader standard. These values are calculated for the first year that the proposed broader standard would be effective and after full stock turnover, when all noncompliant lamps have been replaced by compliant lamps.

Annual statewide electricity savings for the first year and after full stock turnover are calculated by multiplying the single compliant lamp electricity savings by staff's estimates of 2020 lamp shipments and 2020 existing stock, respectively. First-year electricity savings are estimated to exceed 4,600 GWh, and annual electricity savings after full stock turnover are estimated to exceed 13,600 GWh. The first-year electricity savings are equivalent to the yearly electricity generated by one-and-a-half five-hundred megawatt power plants.[58] The annual electricity savings after full stock turnover are equivalent to the yearly electricity generated by four-and-a-half five-hundred megawatt power plants.[59]

Annual statewide monetary savings for the first-year are calculated by multiplying the single compliant lamp first-year monetary savings by staff's estimate of 2020 lamp shipments and then subtracting the total incremental price paid for compliant lamps. For one lamp type, this is a negative value, indicating that the statewide total incremental price paid for compliant lamps exceeds the monetary value of the first year of statewide electricity bill savings. The total first-year savings for California consumers and businesses for the five lamp types analyzed in this report are calculated to exceed $390 million.

Annual statewide monetary savings after full stock turnover are calculated by multiplying the single compliant lamp annual electricity bill savings by staff's estimate of 2020 existing stock. After full stock turnover and replacement of all noncompliant lamps with compliant lamps, staff calculates that the annual statewide savings to California consumers and business will exceed $2.4 billion. If federal definitions take effect and are enforced on

58 About 3,000 GWh per 500 MW power plant. http://newscenter.lbl.gov/2010/03/09/the-rosenfeld-unit-of-energy-efficiency/.
59 Ibid.

January 1, 2020, then most of the savings analyzed in this report are attributable to that federal effort. However, the Energy Commission has proposed to substantially align with the federal definitions to prevent federal backsliding before 2020 and to ensure that the state is prepared to implement and enforce the standards on January 1, 2020.

Table 8-6: Statewide Annual Electricity and Annual Net Monetary Savings

Lamp Type	Annual Electricity Savings (GWh)		Annual Net Monetary Savings ($millions)	
	First-Year	After Full Stock Turnover	First-Year	After Full Stock Turnover
Large-Diameter Reflector Lamps	1,933	4,018	$323	$738
Decorative Lamps (average)	1,267	6,345	$115	$1,149
Globe Lamps	184	950	$10	$172
EISA-Exempt Lamps	1,265	2,317	-$60	$414
Low-Lumen Lamps	35	35	$4	$6
Total	4,684	13,666	$391	$2,480

Source: Energy Commission staff

CHAPTER 9: Environmental Impacts

General service lamps are typically replaced at the end of the useful lives. Replacement with more efficient general service lamps would not present an additional impact to the environment beyond the natural life cycle of the GSL. Both CFL and LED GSLs have longer useful lives than incandescent GSLs and so will result in less waste. Although CFLs present a potential environmental concern due to the presence of mercury in these products, staff does not expect that CFL sales will increase as a result of the proposed standards. Sales of CFLs have significantly declined in the last three years as LED market penetration has increased, with many people choosing LEDs to replace CFLs or instead of CFLs.[60,61,62,63] As a result, this staff proposal would not result in an increase in sales of CFLs, as CFLs are not expected to be the technology used in replacement lamps for the products added to the definition of GSL. Staff has not identified any other potential adverse environmental impacts from the proposed regulations.

The proposed standards will lead to improved environmental quality in California. Saved energy translates to fewer power plants built and less pressure on the limited energy resources, land, and water use associated with electricity generation. In addition, lower electricity consumption results in reduced greenhouse gas and criteria pollutant emissions, primarily from lower generation in hydrocarbon-burning power plants, such as natural gas power plants.

60 https://www.nema.org/Intelligence/Indices/Pages/A-line-Lamp-Shipments-Decrease-in-Fourth-Quarter-2017.aspx.
61 https://news.nationalgeographic.com/energy/2016/02/1602016-cfl-phase-out-light-bulb-leds/.
62 https://talkbusiness.net/2016/02/walmart-to-transition-lighting-products-away-from-compact-fluorescent-to-led/.
63 https://www.nytimes.com/2016/02/02/business/energy-environment/ge-to-phase-out-cfl-light-bulbs.html.

CHAPTER 10:
Proposed Regulatory Language

Proposed new language appears as underline (example) and proposed deletions appear as strikeout (~~example~~). Existing language appears as plain text. Three dots or "…" represents the substance of the regulations that exists between the proposed language and current language.

Section 1602. Definitions.

…[skipping (a)-(j)]

(k) Lamps.

(1) Definitions for General Service Lamps sold before January 1, 2020, and for all other lamps.

…[skipping Appliance Lamp through Voltage Range]

(2) Definitions for General Service Lamps sold on or after January 1, 2020, and Low-Lumen Lamps manufactured on or after January 1, 2020.

"Black light lamp" means a lamp that is designed and marketed as a black light lamp and is an ultraviolet lamp with the highest radiant power peaks in the UV-A band (315 to 400 nm) of the electromagnetic spectrum.

"Bug lamp" means a lamp that is designed and marketed as a bug lamp, has radiant power peaks above 550 nm on the electromagnetic spectrum, and has a visible yellow coating.

"Colored " means a colored fluorescent lamp, a colored incandescent lamp, or a lamp designed and marketed as a colored lamp with either of the following characteristics (if multiple modes of operation are possible [such as variable CCT], either of the below characteristics must be maintained throughout all modes of operation): (1) A CRI less than 40, as determined according to the method set forth in CIE Publication 13.3 (incorporated by reference; see 10 CFR 430.3); or (2) A CCT less than 2,500K or greater than 7,000K.

"Designed and marketed" means exclusively designed to fulfill the indicated application and, when distributed in commerce, designated and marketed solely for that application, with the designation prominently displayed on the packaging and all publicly available documents (e.g., product literature, catalogs, and packaging labels). This definition is applicable to terms related to the following covered lighting products: Fluorescent lamp ballasts; fluorescent lamps; general service fluorescent lamps; general service incandescent lamps; general service lamps; incandescent lamps; incandescent reflector lamps; medium base compact fluorescent lamps; and specialty application mercury vapor lamp ballasts.

"General service incandescent lamp" means a standard incandescent or halogen type lamp that is intended for general service applications; has a medium screw base; has a lumen range of not less

than 310 lumens and not more than 2,600 lumens or, in the case of a modified spectrum lamp, not less than 232 lumens and not more than 1,950 lumens; and is capable of being operated at a voltage range at least partially within 110 and 130 volts; however this definition does not apply to the following incandescent lamps—

(1) An appliance lamp;

(2) A black light lamp;

(3) A bug lamp;

(4) A colored lamp;

(5) A G shape lamp with a diameter of 5 inches or more as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3);

(6) An infrared lamp;

(7) A left-hand thread lamp;

(8) A marine lamp;

(9) A marine signal service lamp;

(10) A mine service lamp;

(11) A plant light lamp;

(12) An R20 short lamp;

(13) A sign service lamp;

(14) A silver bowl lamp;

(15) A showcase lamp; and

(16) A traffic signal lamp.

"General service lamp" means a lamp that has an ANSI base; is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or of 277 volts for integrated lamps (as defined in this section), or is able to operate at any voltage for non-integrated lamps (as defined in this section); has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens; is not a light fixture; is not an LED downlight retrofit kit; and is used in general lighting applications. General service lamps include, but are not limited to, general service incandescent lamps, compact fluorescent lamps, general service light-emitting diode lamps, and general service organic light-emitting diode lamps. General service lamps do not include:

(1) Appliance lamps;

(2) Black light lamps;

(3) Bug lamps;

(4) Colored lamps;

(5) G shape lamps with a diameter of 5 inches or more as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3);

(6) General service fluorescent lamps;

(7) High intensity discharge lamps;

(8) Infrared lamps;

(9) J, JC, JCD, JCS, JCV, JCX, JD, JS, and JT shape lamps that do not have Edison screw bases;

(10) Lamps that have a wedge base or prefocus base;

(11) Left-hand thread lamps;

(12) Marine lamps;

(13) Marine signal service lamps;

(14) Mine service lamps;

(15) MR shape lamps that have a first number symbol equal to 16 (diameter equal to 2 inches) as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3), operate at 12 volts, and have a lumen output greater than or equal to 800;

(16) Other fluorescent lamps;

(17) Plant light lamps;

(18) R20 short lamps;

(19) Reflector lamps (as defined in this section) that have a first number symbol less than 16 (diameter less than 2 inches) as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3) and that do not have E26/E24, E26d, E26/50x39, E26/53x39, E29/28, E29/53x39, E39, E39d, EP39, or EX39 bases;

(20) S shape or G shape lamps that have a first number symbol less than or equal to 12.5 (diameter less than or equal to 1.5625 inches) as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3);

(21) Sign service lamps;

(22) Silver bowl lamps;

(23) Showcase lamps;

(24) Specialty MR lamps;

(25) T shape lamps that have a first number symbol less than or equal to 8 (diameter less than or equal to 1 inch) as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3), nominal overall length less than 12 inches, and that are not compact fluorescent lamps (as defined in this section);

(26) Traffic signal lamps.

"General service light-emitting diode (LED) lamp" means an integrated or non-integrated LED lamp designed for use in general lighting applications (as defined in this section) and that uses light-emitting diodes as the primary source of light.

"General service organic light-emitting diode (OLED) lamp" means an integrated or non-integrated OLED lamp designed for use in general lighting applications (as defined in this section) and that uses organic light-emitting diodes as the primary source of light.

"Infrared lamp" means a lamp that is designed and marketed as an infrared lamp; has its highest radiant power peaks in the infrared region of the electromagnetic spectrum (770 nm to 1 mm); has a rated wattage of 125 watts or greater; and which has a primary purpose of providing heat.

"Integrated lamp" means a lamp that contains all components necessary for the starting and stable operation of the lamp, does not include any replaceable or interchangeable parts, and is connected directly to a branch circuit through an ANSI base and corresponding ANSI standard lamp-holder (socket).

"LED Downlight Retrofit Kit" means a product designed and marketed to install into an existing downlight, replacing the existing light source and related electrical components, typically employing an ANSI standard lamp base, either integrated or connected to the downlight retrofit by wire leads, and is a retrofit kit. LED downlight retrofit kit does not include integrated lamps or non-integrated lamps.

"Left-hand thread lamp" means a lamp with direction of threads on the lamp base oriented in the left-hand direction.

"Light fixture" means a complete lighting unit consisting of light source(s) and ballast(s) or driver(s) (when applicable) together with the parts designed to distribute the light, to position and protect the light source, and to connect the light source(s) to the power supply.

"Low-lumen lamp" means a lamp that has a lumen output of 150 lumens or greater and less than 310 lumens and otherwise meets the definition of a general service lamp.

"Marine lamp" means a lamp that is designed and marketed for use on boats and can operate at or between 12 volts and 13.5 volts.

"Marine signal service lamp" means a lamp that is designed and marketed for marine signal service applications.

"Mine service lamp" means a lamp that is designed and marketed for mine service applications.

"Non-integrated lamp" means a lamp that is not an integrated lamp.

"Other fluorescent lamp" means low pressure mercury electric-discharge sources in which a fluorescing coating transforms some of the ultraviolet energy generated by the mercury discharge into light and include circline lamps and include double-ended lamps with the following characteristics: Lengths from one to eight feet; designed for cold temperature applications; designed for use in reprographic equipment; designed to produce radiation in the ultra-violet region of the spectrum; impact-resistant; reflectorized or aperture; or a CRI of 87 or greater.

"Pin base lamp" means a lamp that uses a base type designated as a single pin base or multiple pin base system.

"Plant light lamp" means a lamp that is designed to promote plant growth by emitting its highest radiant power peaks in the regions of the electromagnetic spectrum that promote photosynthesis: Blue (440 nm to 490 nm) and/or red (620 to 740 nm), and is designed and marketed for plant growing applications.

"Reflector lamp" means a lamp that has an R, PAR, BPAR, BR, ER, MR, or similar bulb shape as defined in ANSI C78.20-2003 (incorporated by reference; see 10 CFR 430.3) and ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3) and is used to provide directional light.

"Showcase lamp" means a lamp that has a T shape as specified in ANSI C78.20-2003 (incorporated by reference; see 10 CFR 430.3) and ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3), is designed and marketed as a showcase lamp, and has a maximum rated wattage of 75 watts.

"Sign service lamp" means a vacuum type or gas-filled lamp that has sufficiently low bulb temperature to permit exposed outdoor use on high-speed flashing circuits, is designed and marketed as a sign service lamp, and has a maximum rated wattage of 15 watts.

"Silver bowl lamp" means a lamp that has an opaque reflective coating applied directly to part of the bulb surface that reflects light toward the lamp base and that is designed and marketed as a silver bowl lamp.

"Specialty MR lamp" means a lamp that has an MR shape as defined in ANSI C79.1-2002 (incorporated by reference; see 10 CFR 430.3), a diameter of less than or equal to 2.25 inches, a lifetime of less than or equal to 300 hours, and that is designed and marketed for a specialty application.

"Traffic signal lamp" means a lamp that is designed and marketed for traffic signal applications and has a lifetime of 8,000 hours or greater.

...[skipping to the end of the section]

Section 1604. Test Methods for Specific Appliances

...[skipping (a)-(j)]

(k) Lamps.[64]

(1) The test method for federally regulated general service fluorescent lamps, ~~federally regulated~~ general service incandescent lamps, and ~~federally regulated~~ incandescent reflector lamps is 10 C.F.R. section 430.23(r) (Appendix R to subpart B of part 430).

~~(2) The test method for state-regulated small diameter directional lamps that use incandescent filament technology is 10 C.F.R. section 430.23(r) (Appendix R to subpart B of part 430).~~

(~~3~~2) The test method for ~~medium base~~ compact fluorescent lamps is 10 C.F.R. section 430.23(y) (Appendix W to subpart B of part 430).

(~~4~~3) The test methods for each basic model of integrated LED lamps, including LED state-regulated small diameter directional lamps and state-regulated LED lamps, are 10 C.F.R. section 430.23(ee) (Appendix BB to subpart B of part 430) (Jan. 1, 2018) and those shown in Table K-1. For certification, compliance, and enforcement purposes, the sampling provisions in 10 C.F.R. section 429.56 (Jan. 1, 2018) shall be used.

Table K-1
Optional Test Methods for State-Regulated LED Lamps and LED State-Regulated Small Diameter Directional Lamps

Measurement	*Test Procedure*	~~*Required or*~~ *Optional**
~~Input power, Lumen output, LPW, Correlated Color Temperature, Duv, Color Rendering Index, Power Factor~~	~~IES LM-79 (2008) with additional requirements provided in 10 C.F.R. section 430.23(ee) (Appendix BB to subpart B of part 430).~~	~~Required~~
~~Lumen Maintenance and Time to Failure~~	~~IES LM-84 (2014) and TM-28 (2014) with additional requirements provided in 10 C.F.R. section 430.23(ee) (Appendix BB to subpart B of part 430).~~	~~Required~~
~~Standby Power~~	~~10 C.F.R. section 430.23(ee) (Appendix BB to subpart B of part 430).~~	~~Required~~
Flicker	Title 24, part 6, Joint Appendix 10 (2015), tested at both 100% ~~percent~~ and 20% ~~percent~~ output. Lamps with a percent amplitude modulation (percent flicker) less than 30 percent at frequencies less than 200 Hz shall report "yes" for "reduced flicker operation" described in section 1606 of this Article, otherwise report "no".	Optional
Lumen Maintenance, Rated Life, and Survival Rate for Compliance with Title 24 Joint Appendix 8 and minimum dimming level	Title 24, part 6, Joint Appendix 8 (2015).	Optional

64 The proposed regulatory language in section 1605.3(k) reflects language adopted by the Energy Commission on July 11, 2018, and expected to become effective on October 1, 2018, pending approval by the Office of Administrative Law. See rulemaking docket number 18-AAER-10.

Audible Noise	ENERGY STAR Recommended Practice – Noise (2013) with the following modification: measurements shall be taken at 100 percent output as well as at 20 percent output if dimmable.	Optional

* ~~Required test procedures must be conducted per section 1603(a) of this Article for each basic model of lamp.~~ Optional test procedures are conditionally required depending on manufacturer claims of performance as described in sections 1607(d)(12) of this Article and 1606 Table X of this Article.

(5~~4~~) ~~There are no federally prescribed test methods for federally regulated organic light-emitting diode (OLED) lamps; federally regulated candelabra base incandescent lamps, or federally regulated intermediate base incandescent lamps.~~ The test methods for low-lumen lamps are:

(A) for compact fluorescent low-lumen lamps, 10 C.F.R. section 430.23(y) (Appendix W to Subpart B of part 430) (Jan. 1, 2018).

(B) for integrated LED low-lumen lamps, 10 C.F.R. section 430.23(ee) (Appendix BB to Subpart B of part 430) (Jan. 1, 2018).

(C) for all other low-lumen lamps, 10 C.F.R. section 430.23(gg) (Appendix DD to Subpart B of part 430) (Jan. 1, 2018).

(5) The test method for general service lamps that are other than lamp types described in sections 1604(k)(1) through 1604(k)(4) of this Article is 10 C.F.R. section 430.23(gg) (Appendix DD to Subpart B of part 430).

...[skipping to the end of the section]

Section 1605.3. State Standards for Non-Federally-Regulated Appliances.

...[skipping (a)-(j)]

(k) Lamps.[65]

...[skipping (1) Incandescent Reflector Lamps]

(2) Standards for State-Regulated LED Lamps, ~~and~~ General Service Lamps, and Low-Lumen Lamps. General service lamps shall meet the standards shown in Table K-8. Low-lumen lamps shall meet the standards shown in Table K-9. The energy consumption rate of state-regulated LED lamps with a lumen output of 150 lumens or greater for ~~candelabra~~E12 bases, or 200 lumens or greater for ~~other~~E17, E26, or GU24 bases, manufactured on or after the effective dates shown in Table K-~~9~~10 shall meet the standards shown in that table.

Table K-8
Standards for State-Regulated General Service Lamps - Tier II

Lumen Ranges	*Minimum Lamp Efficacy*	*Minimum Rated Lifetime*	*Effective Date*
310-2600	45 lumens per watt	1,000 Hours	Jan 1, 2018
310-3300	45 lumens per watt	1,000 Hours	Sold on or after Jan 1, 2020

Table K-9
Standards for Low-Lumen Lamps

Lumen Ranges	*Minimum Lamp Efficacy*	*Minimum Rated Lifetime*	*Effective Date*
150≤Lumens<310	45 lumens per watt	1,000 Hours	Manufactured on or after Jan 1, 2020

(A) State-regulated LED lamps with lumen output of 150 lumens or greater for ~~candelabra~~E12 bases, or 200 lumens or greater for ~~other~~E17, E26, or GU24 bases, and manufactured on or after January 1, 2018 shall have:

(i) A color point that meets the requirements in Table B1 of Annex B of ANSI C7 8.377-2015 for color targets and color consistency.

(ii) A CRI (Ra) of 82 or greater.

(iii) Individual color scores of R1, R2, R3, R4, R5, R6, R7, and R8 of 72 or greater.

(iv) A power factor of 0.7 or greater.

(v) A rated life of 10,000 hours or greater as determined by the lumen maintenance and time to failure test procedure.

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65 The proposed regulatory language in section 1605.3(k) reflects language adopted by the Energy Commission on July 11, 2018, and expected to become effective on October 1, 2018, pending approval by the Office of Administrative Law. See rulemaking docket number 18-AAER-10.

(vi) State-regulated LED lamps that have an ANSI standard lamp shape of A shall meet the omnidirectional light distribution requirements of ENERGY STAR's Product Specification for Lamps Version 2.0 (December 2015).

(vii) State-regulated LED lamps that have an ANSI standard lamp shape of B, BA, C, CA, F, or G shall meet the decorative light distribution requirements of ENERGY STAR's Product Specification for Lamps Version 1.1 (August 2014).

(B) In addition to the requirements in section 1605.3(k)(2)(A) of the Article, state-regulated LED lamps manufactured on or after July 1, 2019 shall have a standby mode power of 0.2 watts or less.

Table K-~~9~~10
Standards for State-Regulated LED Lamps

Effective Date	*Minimum Compliance Score*	*Minimum Efficacy Lumens Per Watt*
January 1, 2018	282	68
July 1, 2019	297	80
This compliance score shall be calculated as the sum of the efficacy and 2.3 times the CRI of a lamp.		

...[skipping to the end of the section]

Section 1606. Filing by Manufacturers; Listing of Appliances in the MAEDbS.[66]

(a) Filing of Statements.

Each manufacturer shall electronically file with the Executive Director through the MAEDbS a statement for each appliance that is sold or offered for sale in California. The statement shall contain all of the information described in paragraphs (2) through (4) of this subsection and shall meet all of the requirements of paragraph (1) of this subsection and all other applicable requirements in this Article.

The effective dates of this section shall be the same as the effective dates shown in section 1605.1, 1605.2 or 1605.3 of this Article for appliances for which there is an energy efficiency, energy consumption, energy design, water efficiency, water consumption, or water design standard in section 1605.1, 1605.2, or 1605.3 of this Article. For appliances with no energy efficiency, energy consumption, energy design, water efficiency, water consumption, or water design standard in section 1605.1, 1605.2, or 1605.3 of this Article, the effective date of this section shall be one year after they are added to section 1601 of this Article, unless a different effective date is specified.

Exceptions to Section 1606(a) of this Article: Section 1606(a) of this Article is not applicable to:

1. external power supplies,

2. compressors,

3. portable air conditioners (except for spot air conditioners),

4. small electric motors, ~~or~~

5. à la carte chargers meeting the Exception noted in section 1605.3(w)(2) of this Article ., or

6. general service lamps.

...[skipping to the end of the section]

66 The proposed regulatory language in section 1605.3(k) reflects language adopted by the Energy Commission on July 11, 2018, and expected to become effective on October 1, 2018, pending approval by the Office of Administrative Law. See rulemaking docket number 18-AAER-10.

Section 1607. Marking of Appliances.[67]

(a) Scope of Section 1607.

Every unit of every appliance within the scope of section 1601 of this Article shall comply with the applicable provisions of this section. The effective dates of this section shall be the same as the effective dates shown in section 1605.1, 1605.2 or 1605.3 of this Article for appliances for which there is an energy efficiency, energy consumption, energy design, water efficiency, water consumption, or water design standard in section 1605.1, 1605.2, or 1605.3 of this Article. For appliances with no energy efficiency, energy consumption, energy design, water efficiency, water consumption, or water design standard in section 1605.1, 1605.2, or 1605.3 of this Article, the effective date of this section shall be January 1, 2006.

(b) Name, Model Number, and Date.

Except as provided in section 1607(c) of this Article, the following information shall be permanently, legibly, and conspicuously displayed on an accessible place on each unit;

(1) manufacturer's name or brand name or trademark (which shall be either the name, brand, or trademark of the listed manufacturer specified pursuant to section 1606(a)(2)(A) of this Article;

(2) model number; and

(3) date of manufacture, indicating (i) year and (ii) month or smaller (e. g. week) increment. If the date is in a code that is not readily understandable to the lay person, the manufacturer shall immediately, on request, provide the code to the Energy Commission.

(c) Exceptions to Section 1607(b).

(1) For plumbing fixtures and plumbing fittings, the information required by section 1607(b) of this Article shall be permanently, legibly, and conspicuously displayed on an accessible place on each unit or on the unit's packaging.

(2) For lamps, the information required by section 1607(b) of this Article shall be permanently, legibly, and conspicuously displayed on an accessible place on each unit, on the unit's packaging, or, where the unit is contained in a group of several units in a single package, on the packaging of the group.

(3) For fluorescent lamp ballasts, the date of manufacture information required by section 1607(b)(3) of this Article shall indicate (i) year and (ii) three-month or smaller increment. If the date is in a code that is not readily understandable to the layperson, the manufacturer shall immediately, on request, provide the code to the Energy Commission.

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67 The proposed regulatory language in section 1605.3(k) reflects language adopted by the Energy Commission on July 11, 2018, and expected to become effective on October 1, 2018, pending approval by the Office of Administrative Law. See rulemaking docket number 18-AAER-10.

Section 1608. Compliance, Enforcement, and General Administrative Matters.[68]

(a) General Requirements for the Sale or Installation of All Appliances.

Any unit of any appliance within the scope of section 1601 of this Article may be sold or offered for sale in California only if:

(1) the appliance appears in the most recent MAEDbS established pursuant to section 1606(c) of this Article, unless the only reason for the appliance's absence from the MAEDbS is its failure to comply with an applicable standard in section 1605.1 of this Article;

(2) the manufacturer has:

(A) tested the appliance as required by sections 1603 and 1604 of this Article;

(B) marked the unit as required by section 1607 of this Article;

(C) for any appliance for which there is an applicable standard in section 1605.2 or 1605.3 of this Article, certified under section 1606(a) of this Article that the appliance complies with the standard;

(3) the unit has the same components, design characteristics, and all other features that affect energy or water consumption or energy or water efficiency, as applicable, as the units that were tested under sections 1603 and 1604 of this Article and for which information was submitted under section 1606(a) of this Article; and

(4) for any appliance for which there is an applicable standard in section 1605.2 or 1605.3 of this Article, the unit complies with the standard.

Exceptions: to Sections 1608(a)(1) and 1608(a)(2)(C) of this Article. Sections 1608(a)(1) and 1608(a)(2)(C) of this Article are not applicable to:

1. external power supplies,

2. compressors,

3. portable air conditioners (except for spot air conditioners),

4. small electric motors, ~~or~~

5. à la carte chargers meeting the EXCEPTION noted in section 1605.3(w)(2) of this Article., or

6. general service lamps.

...[skipping to the end of the section]

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68 The proposed regulatory language in section 1605.3(k) reflects language adopted by the Energy Commission on July 11, 2018, and expected to become effective on October 1, 2018, pending approval by the Office of Administrative Law. See rulemaking docket number 18-AAER-10.

APPENDIX A:
Staff Assumptions and Calculation Methods

Appendix A discusses the information and calculations used to estimate the current electricity consumption and the estimated electricity savings for a subset of the lamps that would be covered by the proposed regulations. This subset is composed of the products for which the most information is available and is generally representative for all of the lamps that would be covered by the proposed regulations. Values in tables are the rounded results of calculations, but unrounded results are used for subsequent calculations.

Assumptions and Estimates Used in Calculations

Table A-1 summarizes the estimated share of California shipments by technology and by lamp type for the subset of lamps addressed in this report. Staff began with the estimate of 2015 national market share by technology from the "Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps" and adjusted the percentage of LEDs upward to reflect increasing market share.

Table A-1: Estimate of Shipments Share by Light Source Technology in 2017

Lamp Type	Incandescent	LED
Large-Diameter Reflector Lamps	80%	20%
Decorative Lamps	85%	15%
Globe Lamps	90%	10%
EISA-Exempt Lamps	100%	0%
Low-Lumen Lamps	85%	15%

Source: Energy Commission staff

Tables A-2 and A-3 summarize the estimated California shipments and existing stock for the subset of lamps addressed in this report, by lamp type. Staff estimates globe lamps to make up 19 percent of decorative lamps shipments and stock.[69] For low-lumen lamps, staff estimates that one-quarter of California homes have one low-lumen lamp (for example, night light).

Staff began with the estimate of 2017 existing stock and shipment estimates from the "General Service Lamps (Expanded Scope) CASE Initiative" and reduced existing stock in subsequent years by the percentage of LED shipments. Staff applied a 10 percent multiplier to the estimate of LED shipments in 2018 and 2019 (for example, large-diameter reflector lamps have shipment shares of 22 percent in 2018 and 24.2 percent in 2019) to reflect additional increases in LED market share. Beginning in 2020, the year the proposed broader standard would become effective, shipments are assumed to be entirely composed of LEDs, and the stock of incandescent lamps addressed in this report begins to decline rapidly.

69 Kantner, C., and A. Alstone (2017). *Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps*, p.4, available at http://docketpublic.energy.ca.gov/PublicDocuments/17-AAER-07/TN220255_20170718T164013_Impact_of_the_EISA_2007_Energy_Efficiency_Standard_on_General_S.pdf.

Shipments also decline year over year because of the longer lifetime of LEDs, resulting in fewer purchases of lamps over time.

Table A-2: Estimate of California Existing Stock of Low-efficacy Lamps (millions)

Lamp Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Large-Diameter Reflector Lamps	88.8*	82.3	75.2	67.4	35.0	2.6	-	-	-	-
Decorative Lamps	137.6*	133.9	129.7	125.2	100.2	75.2	50.2	25.2	0.2	-
Globe Lamps	32.4*	31.8	31.2	30.4	24.5	18.6	12.7	6.8	0.9	-
EISA-Exempt Lamps	35.0*	35.0	35.0	35.0	15.9	-	-	-	-	-
Low-Lumen Lamps	3.5	3.0	2.5	2.0	-	-	-	-	-	-

Source: Energy Commission staff and General Service Lamps (Expanded Scope) CASE Initiative*

Table A-3: Estimate of California Shipments of Replacement Lamps for Standards Case (millions)

Lamp Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Large-Diameter Reflector Lamps	32.4*	32.4	32.4	-	-	-	-	-	-	-
Decorative Lamps	25.0*	25.0	25.0	-	-	-	-	-	-	-
Globe Lamps	5.9*	5.9	5.9	-	-	-	-	-	-	-
EISA-Exempt Lamps	19.1*	19.1	19.1	-	-	-	-	-	-	-
Low-Lumen Lamps	3.5	3.0	2.5	-	-	-	-	-	-	-
High-Efficacy Replacement Lamps	11.3	12.4	13.5	84.4	79.2	33.5	30.9	30.9	1.1	-

Source: Energy Commission staff and General Service Lamps (Expanded Scope) CASE Initiative*

Table A-4 summarizes the estimated sector share for a subset of lamps addressed in this report, by lamp type.

Table A-4: Estimate of Sector Share by Lamp Type

Lamp Type	Sector Share	
	Residential	Commercial
Large-Diameter Reflector Lamps*	96%	4%
Decorative Lamps	90%	10%
Globe Lamps	90%	10%
EISA-Exempt Lamps*	84%	16%
Low-Lumen Lamps	100%	0%

Source: Energy Commission staff and General Service Lamps (Expanded Scope) CASE Initiative*

Table A-5 summarizes the estimated average daily hours of use for a subset of lamps addressed in this report, by lamp type. Staff applied the estimates of sector share (**Table A-4**) to determine the sector-weighted daily hours of use. The sector-weighted annual hours of use are determined by multiplying the sector-weighted daily hours of use by the number of days in a year in use (assumed to be every day – 365.25).

$$\begin{aligned} &Sector\ Weighted\ Daily\ Hours\ of\ Use \\ &\quad = (Residential\ Sector\ Share * Residential\ Daily\ Hours\ of\ Use) \\ &\quad + (Commercial\ Sector\ Share * Commercial\ Daily\ Hours\ of\ Use) \end{aligned}$$

Table A-5: Estimate of Average Hours of Use by Lamp Type

Lamp Type	Daily Hours of Use			Annual Hours of Use
	Residential	Commercial	Sector-Weighted	Sector-Weighted
Large-Diameter Reflector Lamps	2.9	10.7	3.2	1,172.4
Decorative Lamps	2.6	10.7	3.4	1,244.7
Globe Lamps	1.7	10.7	2.6	949.0
EISA-Exempt Lamps	2.3	10.7	3.6	1,330.1
Low-Lumen Lamps*	8.0	8.0	8.0	2,920.0

Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps and Energy Commission staff*

Table A-6 summarizes the properties of a representative noncompliant incandescent lamp for a subset of lamps addressed in this report, by lamp type. The efficacy is determined by dividing the initial lumens by the wattage. The sector-weighted rated lifetime in years is determined by dividing the rated lifetime in hours by the sector-weighted annual hours of use (**Table A-5**).

Table A-6: Properties of Representative Noncompliant Incandescent Lamp

Lamp Type	Wattage	Initial Lumens	Efficacy (lumens per watt)	Rated Lifetime	
				Hours	Sector-Weighted (years)
Large-Diameter Reflector Lamps	65	635	9.8[70]	2,000	1.7
Decorative Lamps (average)	50	417.5	8.4	3,000	2.4
Globe Lamps	40	320	8.0	3,000	3.2
EISA-Exempt Lamps	72	1000	13.9	3,500*	2.6
Low-Lumen Lamps*	7	50	7.1	3,000	1.0

Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps and Energy Commission staff*

Table A-7 summarizes the properties of a representative compliant lamp for a subset of lamps addressed in this report, by lamp type. The compliant lamp is assumed to have identical initial lumens to the noncompliant lamp (**Table A-6**) and an efficacy equal to the proposed standard (that is, 45 lumens per watt). The compliant lamp is assumed to be an LED with a rated lifetime of 10,000 hours.

To calculate the wattage, the initial lumens are divided by the efficacy. The sector-weighted rated lifetime in years is determined by dividing the rated lifetime in hours by the sector-weighted annual hours of use (**Table A-5**).

Table A-7: Properties of Representative Compliant Lamp

Lamp Type	Wattage	Initial Lumens	Efficacy	Rated Lifetime

70 Although this lamp does not comply with the federal energy conservation standards in Code of Federal Regulations, Title 10, § 430.23(n)(6), it appears to remain broadly available because of riders in previous federal appropriations acts (see, e.g., H.R. 2029 – Consolidated Appropriations Act, 2016, section 312 (114th Congress), which prohibited the DOE from implementing or enforcing these standards.

			(lumens per watt)	Hours	Sector-Weighted (years)
Large-Diameter Reflector Lamps	14.1	635	45	10,000	8.5
Decorative Lamps	9.3	417.5	45	10,000	8.0
Globe Lamps	7.1	320	45	10,000	10.5
EISA-Exempt Lamps	22.2	1000	45	10,000	7.5
Low-Lumen Lamps	1.1	50	45	10,000	3.4

Source: Energy Commission staff

Table A-8 summarizes the estimated price for noncompliant and compliant lamps and the calculated incremental price for a subset of lamps addressed in this report, by lamp type. To calculate the incremental price, the noncompliant lamp price was subtracted from the compliant lamp price.

Table A-8: Estimate of Prices for Noncompliant and Compliant Lamps

Lamp Type	Noncompliant Lamp Price	Compliant Lamp Price	Incremental Price
Large-Diameter Reflector Lamps	$2.33	$3.33	$1.00
Decorative Lamps (average)	$1.24	$5.82	$4.58
Globe Lamps	$2.32	$6.32	$4.00
EISA-Exempt Lamps	$1.99	$16.97	$14.98
Low-Lumen Lamps*	$1.25	$2.50	$1.25

Source: Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps and Energy Commission staff*

Table A-9 summarizes the average retail price of electricity in California as reported by the U.S. Energy Information Administration for February 2017.

Table A-9: Average Retail Price of Electricity in California

Sector	Price ($ per kWh)
Residential	$0.1855
Commercial	$0.1421

Source: U.S. Energy Information Administration Electric Power Monthly with Date for February 2017, published April 2017

Table A-10 summarizes the sector-weighted retail price of electricity by lamp type. Staff determined these values by applying the estimates of sector share (see Table A-4) to the average retail price of electricity in California (Table A-9).

$$\begin{aligned} &Sector\ Weighted\ Price\ per\ kWh\ by\ Lamp\ Type \\ &= (Residential\ Sector\ Share\ by\ Lamp\ Type * Residential\ Average\ Retail\ Price) \\ &+ (Commercial\ Sector\ Share\ by\ Lamp\ Type * Commercial\ Average\ Retail\ Price) \end{aligned}$$

Table A-10: Sector-Weighted Retail Price of Electricity by Lamp Type

Lamp Type	Sector-Weighted Price ($ per kWh)
Large-Diameter Reflector Lamps	$0.1838
Decorative Lamps (average)	$0.1812
Globe Lamps	$0.1812
EISA-Exempt Lamps	$0.1786
Low-Lumen Lamps	$0.1855

Source: Energy Commission staff

Calculations of Electricity Usage and Savings

Table A-11 summarizes the calculated annual electricity usage for a noncompliant lamp and compliant lamp of each type addressed in this report. **Table A-11** also summarizes the annual and life-cycle electricity savings for a compliant lamp.

The annual electricity usage is calculated by multiplying the wattage of the representative lamp (**Table A-6** or **A-7**) by the sector-weighted annual hours of use (**Table A-5**) and dividing by 1,000 to convert from watt-hours to kilowatt-hours.

$$Annual\ Electricty\ Usage\ (kWh) = \frac{Wattage * Sector\ Weighted\ Annual\ Hours\ of\ Use}{1{,}000\ \text{watt\_hours per kilowatt\_hour}}$$

The annual electricity savings are determined by subtracting the annual electricity usage of a compliant lamp from the annual electricity usage of a noncompliant lamp. The life-cycle electricity savings are determined by multiplying the annual electricity savings by the compliant lamp sector-weighted rated lifetime in years (**Table A-7**).

Table A-11: Single Lamp Electricity Usage and Single Compliant Lamp Electricity Savings

Lamp Type	Annual Electricity Usage (kWh)		Electricity Savings (kWh)	
	Noncompliant Lamp	Compliant Lamp	Annual	Lifecycle
Large-Diameter Reflector Lamps	76.2	16.5	59.7	508.9
Decorative Lamps (average)	62.2	11.5	50.7	407.2
Globe Lamps	38.0	6.7	31.2	328.9
EISA-Exempt Lamps	95.8	29.6	66.2	497.8
Low-Lumen Lamps	20.4	3.2	17.2	58.9

Source: Energy Commission staff

Table A-12 summarizes the number of compliant and noncompliant lamps necessary to equate to the rated lifetime of a compliant lamp. **Table A-12** also summarizes the total purchase price paid for the number of compliant and noncompliant lamps that equate to the rated lifetime of a compliant lamp.

The number of noncompliant lamps is determined by dividing the rated lifetime in hours of a compliant lamp (that is, 10,000 hours) (**Table A-7**) by the rated lifetime in hours of a noncompliant lamp (**Table A-8**) and rounding up to the next whole number because a partial lamp cannot be purchased. Total purchase price paid is determined by multiplying the number of lamps by the corresponding estimated lamp price (**Table A-8**).

$$Number\ of\ Noncompliant\ Lamps\ =\ Roundup\left(\frac{10{,}000}{Rated\ Lifetime\ in\ Hours\ of\ Noncompliant\ Lamp}\right)$$

Table A-12: Number of Noncompliant Lamps to Achieve Equivalent Life of Compliant Lamp

Lamp Type	Number of Compliant Lamps	Number of Noncompliant Lamps	Total Purchase Price Paid, Compliant	Total Purchase Price Paid, Noncompliant
Large-Diameter Reflector Lamps	1	5	$3.33	$11.65
Decorative Lamps (average)	1	4	$5.82	$4.96
Globe Lamps	1	4	$6.32	$9.28
EISA-Exempt Lamps	1	3	$16.97	$5.97
Low-Lumen Lamps	1	4	$2.50	$5.00

Source: Energy Commission staff

Table A-13 summarizes the first-year and life-cycle monetary savings for a compliant lamp.

The monetary savings from avoided replacement lamps is determined by subtracting the total purchase price paid for a compliant lamp from the total purchase price paid for an equivalent number of noncompliant lamps (based on equating rated lifetimes) (**Table A-12**). For two lamp types, this is a negative value, indicating that the purchase price paid for a compliant lamp exceeds the cumulative purchase price paid for an equivalent number of noncompliant lamps (based on equating rated lifetimes).

$$Monetary\ Savings\ from\ Avoided\ Noncompliant\ Replacement\ Lamps$$
$$=\ Total\ Purchase\ Price, Noncompliant - Total\ Purchase\ Price, Compliant$$

The first-year monetary savings are calculated by subtracting the incremental price of a compliant lamp (**Table A-8**) from the annual electricity bill savings. (see **Tables A-15 to A-19.**) For one lamp type, this is a negative value, indicating that the incremental price of a compliant lamp exceeds the monetary value of the first year of electricity bill savings. In the second year, the value of the cumulative electricity bill savings will exceed the incremental price of a compliant lamp, indicating a simple payback period of less than two years. For the other four lamp types, this is a positive value, indicating that the monetary value of the first year of electricity bill savings exceeds the incremental price of a compliant lamp. In other words, the simple payback period for these four lamp types is less than one year.

$$First\_year\ Monetary\ Savings = Annual\ Electricity\ Bill\ Savings - Incremental\ Price$$

The life-cycle monetary savings per lamp are determined by adding the life-cycle electricity bill savings (**Tables A-15 to A-19**) to the monetary savings from avoided noncompliant replacement lamps and subtracting the incremental price of a compliant lamp (**Table A-8**). The life-cycle electricity bill savings reflect a 3 percent annual discount, as discussed in the next section of this appendix. The life-cycle monetary savings are positive for all five lamp types, indicating that the proposed standard is cost-effective for all five lamp types.

$$Lifecycle\ Monetary\ Savings = Lifecycle\ Electricity\ Bill\ Savings + Monetary\ Savings\ from\ Avoided\ Noncompliant\ Replacement\ Lamps - Incremental\ Price$$

Table A-13: Single Lamp First-Year and Life-Cycle Net Monetary Savings

Lamp Type	Incremental Price	Electricity Bill Savings ($)		Monetary Savings From Avoided Noncompliant Replacement Lamps	Net Monetary Savings	
		Annual	Lifecycle (3% annual discount)		First-year	Lifecycle
Large-Diameter Reflector Lamps	$1.00	$10.96	$83.58	$8.32	$9.96	$90.90
Decorative Lamps (average)	$4.58	$9.18	$66.44	-$0.86	$4.60	$61.00
Globe Lamps	$4.00	$5.65	$51.73	$2.96	$1.65	$50.69
EISA-Exempt Lamps	$14.98	$11.82	$80.62	-$11.00	-$3.16	$54.64
Low-Lumen Lamps	$1.25	$3.19	$10.52	$2.50	$1.94	$11.77

Source: Energy Commission staff

Table A-14 summarizes the statewide annual electricity savings and statewide annual monetary savings for the first year the proposed broader standard would be effective and after full stock turnover. (For example, all lamps addressed in this report have been replaced by compliant lamps.)

Statewide annual electricity savings for the first year that the proposed broader standard is effective are determined by multiplying the annual electricity savings for a compliant lamp (**Table A-11**) by the estimated California shipments in 2020 (**Table A-3**).

$$Statewide\ Annual\ Electricity\ Savings, First\_Year = Annual\ Electricity\ Savings, Single\ Lamp * Estimated\ 2020\ Shipments$$

Statewide annual electricity savings after full stock turnover are determined by multiplying the annual electricity savings for a compliant lamp (**Table A-11**) by the estimated California existing stock in 2020 (**Table A-2**).

$$Statewide\ Annual\ Electricity\ Savings, After\ Full\ Stock\ Turnover = Annual\ Electricity\ Savings, Single\ Lamp * Estimated\ 2020\ Existing\ Stock$$

Statewide annual monetary savings for the first year that the broader standard is effective are determined by multiplying the first-year monetary savings for a single lamp (**Table A-13**) by the estimated California shipments in 2020 (**Table A-3**). For one lamp type, this is a negative value, indicating that the statewide total incremental price paid for compliant lamps exceeds the monetary value of the first year of statewide electricity bill savings. After full stock turnover for this lamp type, statewide annual savings are more than $400 million.

$$Statewide\ Annual\ Monetary\ Savings, First\_Year = First\_Year\ Monetary\ Savings, Single\ Lamp * Estimated\ 2020\ Shipments$$

Statewide annual monetary savings after full stock turnover are determined by multiplying the annual electricity bill savings for a single lamp (**Table A-13**) by the estimated California existing stock in 2020 (**Table A-2**).

$$Statewide\ Annual\ Monetary\ Savings, After\ Full\ Stock\ Turnover = Annual\ Electricity\ Bill\ Savings, Single\ Lamp * Estimated\ 2020\ Existing\ Stock$$

Table A-14: Statewide Annual Electricity and Annual Net Monetary Savings

Lamp Type	Annual Electricity Savings (GWh)		Annual Net Monetary Savings ($millions)	
	First-Year	After Full Stock Turnover	First-Year	After Full Stock Turnover
Large-Diameter Reflector Lamps	1,933	4,018	$323	$738
Decorative Lamps (average)	1,267	6,345	$115	$1,149
Globe Lamps	184	950	$10	$172
EISA-Exempt Lamps	1,265	2,317	-$60	$414
Low-Lumen Lamps	35	35	$4	$6
Total	4,684	13,666	$391	$2,480

Source: Energy Commission staff

Calculations of Single Lamp Electricity Bill Savings

The monetary values in **Tables A-15** through **A-19** for single lamp electricity bill savings reflect a 3 percent annual discount to the value of a kilowatt-hour. (In other words, the value in year two is 97 percent of the value in year one, and the value in year three is 97 percent of the value in year two.)

See **Table A-11** for the annual electricity savings by lamp type. See **Table A-10** for the first-year sector-weighted retail price of a kilowatt-hour. In each subsequent year, the value of a kilowatt-hour is 97 percent of the previous year, as discussed above. Annual electricity bill savings are determined by multiplying the electricity savings in kilowatt-hours by the price of a kilowatt-hour.

Lifetime electricity bill savings are determined by adding the yearly values for annual electricity bill savings.

Table A-15: Single-Lamp Electricity Bill Savings, Large-Diameter Reflector Lamp

Year	Annual Electricity Savings (kWh)	Price of kWh	Annual Savings	Lifetime Savings
2020	59.7	$0.1838	$10.96	$10.96
2021	59.7	$0.1783	$10.63	$21.60
2022	59.7	$0.1729	$10.32	$31.91
2023	59.7	$0.1677	$10.01	$41.92
2024	59.7	$0.1627	$9.71	$51.63
2025	59.7	$0.1578	$9.41	$61.04
2026	59.7	$0.1531	$9.13	$70.17
2027	59.7	$0.1485	$8.86	$79.03
2028 (partial)	31.6	$0.1440	$4.55	$83.58

Source: Energy Commission staff

Table A-16: Single-Lamp Electricity Bill Savings, Decorative Lamp (Average)

Year	Annual Electricity Savings (kWh)	Price of kWh	Annual Savings	Lifetime Savings
2020	50.7	$0.1812	$9.18	$9.18
2021	50.7	$0.1757	$8.91	$18.09
2022	50.7	$0.1705	$8.64	$26.73
2023	50.7	$0.1653	$8.38	$35.11
2024	50.7	$0.1604	$8.13	$43.24
2025	50.7	$0.1556	$7.88	$51.12
2026	50.7	$0.1509	$7.65	$58.77
2027	50.7	$0.1464	$7.42	$66.19
2028 (partial)	1.7	$0.1420	$0.25	$66.44

Source: Energy Commission staff

Table A-17: Single-Lamp Electricity Bill Savings, Globe Lamp

Year	Annual Electricity Savings (kWh)	Price of kWh	Annual Savings	Lifetime Savings
2020	31.2	$0.1812	$5.65	$5.65
2021	31.2	$0.1757	$5.48	$11.14
2022	31.2	$0.1705	$5.32	$16.46
2023	31.2	$0.1653	$5.16	$21.62
2024	31.2	$0.1604	$5.01	$26.63
2025	31.2	$0.1556	$4.86	$31.48
2026	31.2	$0.1509	$4.71	$36.19
2027	31.2	$0.1464	$4.57	$40.76
2028	31.2	$0.1420	$4.43	$45.19
2029	31.2	$0.1377	$4.30	$49.49
2030 (partial)	16.8	$0.1336	$2.24	$51.73

Source: Energy Commission staff

Table A-18: Single-Lamp Electricity Bill Savings, EISA-Exempt Lamp

Year	Annual Electricity Savings (kWh)	Price of kWh	Annual Savings	Lifetime Savings
2020	66.2	$0.1786	$11.82	$11.82
2021	66.2	$0.1732	$11.47	$23.29
2022	66.2	$0.1680	$11.12	$34.41
2023	66.2	$0.1630	$10.79	$45.20
2024	66.2	$0.1581	$10.47	$55.67
2025	66.2	$0.1533	$10.15	$65.82
2026	66.2	$0.1487	$9.85	$75.67
2027 (partial)	34.3	$0.1443	$4.95	$80.62

Source: Energy Commission staff

Table A-19: Single-Lamp Electricity Bill Savings, Low-Lumen Lamp

Year	Annual Electricity Savings (kWh)	Price of kWh	Annual Savings	Lifetime Savings
2020	17.2	$0.1855	$3.19	$3.19
2021	17.2	$0.1799	$3.09	$6.28
2022	17.2	$0.1745	$3.00	$9.29
2023 (partial)	7.3	$0.1693	$1.24	$10.52

Source: Energy Commission Staff

APPENDIX B: Acronyms

Acronym	Description
AB	Assembly Bill
ANSI	American National Standards Institute
CASE	Codes and Standards Enhancement
CFL	Compact fluorescent lamp
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
CRI	Color rendering index
DOE	United States Department of Energy
EISA	Energy Independence and Security Act of 2007
GHG	Greenhouse gas
GSIL	General service incandescent lamp
GSL	General service lamp
GWh	Gigawatt-hour
IEPR	*Integrated Energy Policy Report*
IOU	Investor-owned utility
JA8	Joint Appendix 8
kWh	Kilowatt-hour
LED	Light-emitting diode
MW	Megawatt
OLED	Organic light-emitting diode
QPL	Qualified Product List
RASS	Residential Appliance Saturation Study
SB	Senate Bill
UV	Ultraviolet