California Energy Commission

STAFF REPORT

STANDARDIZED REGULATORY IMPACT ASSESSMENT OF 2015 PROPOSED APPLIANCE EFFICIENCY REGULATIONS

Regulations for Small-Diameter Directional Lamps and Light-Emitting Diode (LED) Lamps

California Energy Commission

Docket number: 15-AAER-6

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

AUGUST 2015

CEC-400-2015-028

CALIFORNIA ENERGY COMMISSION

Harinder Singh
Ken Rider
Jared Babula
Michael Murza
Pierre duVair, Ph.D.
Primary Authors

Pierre duVair, Ph.D.
Senior Economist

Ken Rider
Project Manager

Consuelo Martinez
Office Manager
APPLIANCES AND EXISTING BUILDINGS OFFICE

Dave Ashuckian
Deputy Director
EFFICIENCY DIVISION

Robert P. Oglesby
EXECUTIVE DIRECTOR

PREFACE

On March 14, 2012, the California Energy Commission issued an Order Instituting Rulemaking (OIR) 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 1609). In this OIR, the Energy Commission identified appliances with the potential to save energy and/or water. The Energy Commission undertook pre-rulemaking efforts to develop the proposed appliance efficiency standards and measures to take advantage of these energy-saving opportunities.

On March 25, 2013, the Energy Commission released an "Invitation to Participate" to provide interested parties the opportunity to inform the Energy Commission about the product, market, and industry characteristics of the appliances identified in the OIR. Energy Commission staff reviewed the information and data received in the docket and hosted staff workshops on May 28 through May 31, 2013, to vet this information publicly.

On June 13, 2013, Energy Commission staff released an "Invitation to Submit Proposals" to seek submissions for standards, test procedures, labeling requirements, and other measures to improve the efficiency and reduce the energy or water consumption of the appliances identified in the OIR.

Energy Commission staff reviewed all information received to determine which appliances were strong candidates for the development of efficiency standards and measures. Based on the analysis of the information received from stakeholders through webinars and workshops, the Energy Commission staff prepared a draft staff report containing draft efficiency regulations for small-diameter directional and general service light-emitting diode (LED) lamps. On September 19, 2014, the Energy Commission released a notice of a staff workshop accompanied by the draft staff report. The Energy Commission took public comment at the September 29, 2014, workshop, and additional written comments were submitted by stakeholders by November 14, 2014.

The pre-rulemaking efforts indicated that the proposed regulations could have potential energy savings that would exceed the $50 million per year threshold for conducting standardized regulatory impact assessments under Senate Bill 617 (Calderon, Chapter 496, Statutes of 2011). Therefore, the Energy Commission provides this standardized regulatory impact assessment for small-diameter directional lamps and general service LED lamps to assess the economic impact of the proposed and alternative regulations.

ABSTRACT

This standardized regulatory impact assessment prepared by the California Energy Commission analyzes the potential economic impacts of the 2015 proposed and alternative appliance efficiency regulations for small-diameter directional lamps and general purpose light-emitting-diode (LED) lamps. The analysis considers impacts to California jobs, businesses, competitive advantages and disadvantages, state investment, incentives for innovation, and benefits and costs to Californians.

The proposed standards are designed such that appliances sold in California will use less energy and consumers will benefit from the purchase of more efficient appliances. The standards also strive to minimize any negative impact to efficacy of the appliances. The proposed standards will reduce electricity consumption. Reduced consumption results in conservation of electricity and makes electricity available for other purposes. Regulations will transform the market toward more cost-effective and energy-efficient appliances.

The proposed standards will provide electricity savings of 32,792 gigawatt-hours (GWh) over the first 13 years of implementation and monetary savings of $4.27 billion to California consumers over that period. Energy Commission staff used a macroeconomic model to estimate the effects of proposed and alternative regulations within the California economy. Estimated job-years will increase by an average of 4,161 under the proposed regulations. In addition, the proposed standards yield an estimated $5.65 billion increase in real disposable personal income between 2017 through 2029, which is beneficial for the California economy.

Keywords: Appliance efficiency regulations, energy efficiency, economic impact, small-diameter-directional lamp, halogen, incandescent, HIR, and LED lamps, general services LED lamps.

Rider, Ken, Pierre duVair, Harinder Singh, Jared Babula, Michael Murza. 2015. *Standardized Regulatory Impact Assessment of 2015 Proposed Appliance Efficiency Regulations*. California Energy Commission. CEC-400-2015-028.

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY

California Energy Commission staff prepared this report to comply with the rulemaking requirements for major regulations contained within Senate Bill 617 (Calderon/Pavley, Chapter 496, Statutes of 2011) and the standardized regulatory impact assessment described in the California Department of Finance regulations. The report analyzes the economic impact to California of adopting new minimum efficiency standards for several types of lamps. Specifically, the Energy Commission is considering standards for small-diameter directional lamps that would apply to all technologies of that lamp type (including halogen and light-emitting diode [LED]). In addition, the Commission is considering standards for medium- and candelabra-base LED lamps that would affect only LED technologies and would not cover competing technologies such as incandescent and compact fluorescent lamps.

The regulations would set minimum reporting and performance levels that are required to lawfully sell or offer to sell a lamp in California. The effect achieved is a market transformation toward more efficient products being offered for sale within the state. This change in product offering can lead to an increased first cost as the products that meet the standard are more expensive to manufacture. However, statutory requirements for the Energy Commission require that the standard be set at a level at which a consumer is left with a net financial benefit over the life of the product.

These regulations are the result of a public request for proposals to improve the efficiency of appliances sold in California cost-effectively. The Energy Commission held several public workshops to scope, collect data and proposals on, and evaluate proposed appliance standards. On March 25, 2013, the Energy Commission released an invitation to participate to more than 1,000 potential stakeholders. The invitation encouraged stakeholder participation and included initial requests for detailed data regarding the appliances included in the proceeding.

On June 13, 2013, the Energy Commission issued a request for proposals from interested parties that would outline ways for the Energy Commission to attain identified potential efficiency gains. Energy Commission staff provided a template that specifically requested information within proposals necessary to prepare a comprehensive standardized regulatory impact assessment. Staff used these proposals, data, and its own research to draft proposed regulations to further solicit feedback before beginning the formal rulemaking.

The Energy Commission issued a staff report and held a workshop in September 2014 to solicit feedback on proposed standards for small-diameter directional lamps and general service LED lamps. Both written and oral comments from the public were encouraged and received, but little specific economic impact information was received from manufacturers. Therefore, Energy Commission staff used its own research and professional judgment in conjunction with comments received to reasonably assess the economic impacts necessary for a complete assessment. In addition to impacts of the proposed regulations, staff analyzed two alternatives: (1) a regulations package with more stringent energy efficiency standards and (2) a regulations package with less stringent standards.

Energy Commission staff used a macroeconomic model to estimate the effects of proposed and alternative regulations within the California economy. Three scenarios were modeled and evaluated (more stringent, proposed, and less stringent). The proposed scenario uses the stringency level that the Energy Commission plans to introduce at the outset of the rulemaking. The less stringent level was selected from input provided by interested stakeholders in the pre-rulemaking process. The more stringent level incorporated stakeholder feedback and was chosen at the maximum stringency level that Energy Commission staff could propose and still meet the time frame and statutory limitations regarding technical feasibility and cost-effectiveness. Information provided in Table ES-1 summarizes the estimated economic impacts from 2017 to 2029 following implementation of the proposed regulations.

Table ES-1:
Estimated Economic Impacts of Proposed and Alternative Standards

Alternative Level of Efficiency Standards	**Cumulative Electricity Savings (GWh)**	**Savings to Consumers ($ billion)**	**Jobs Impacts (job-years)**	**Income Resulting From Jobs ($ billion)**	**Gross Domestic Product Impacts ($ billion)**	**Gross Private Investment ($Million)**
Proposed	32,792	$4.02	54,098	$5.65	$3.20	$128
More Stringent	35,342	$4.29	56,157	$5.82	$3.28	$104
Less Stringent	24,178	$3.12	48,089	$5.21	$3.09	$258

Source: Energy Commission Staff – Appliances and Existing Buildings Office

All monetary figures are 2015 dollars in net present value using a 3 percent annual discount rate.

The proposed lamp efficiency standards are estimated to avoid between $33 million and $222 million in public health losses over a ten-year period through avoided criteria pollutant emissions. In addition, the proposed standards are estimated to avoid $373 million in damages as a result of lowering greenhouse gas emissions by 10.3 million metric tons from 2017 through 2029.

CHAPTER 1: Introduction

The California Energy Commission is the state's primary energy policy and planning agency. Established in 1975 under the Warren-Alquist Act,[1] the Energy Commission must reduce the wasteful and inefficient consumption of energy and water in the state by prescribing energy and water efficiency standards. These standards must be technologically feasible to implement and result in no added costs to the consumer over the lifetime of the product.[2] The Energy Commission must also consider other relevant factors, including the impact on housing costs, the total statewide costs and benefits of the standard over the product lifetime, the economic impact on California businesses, and alternative approaches and their associated costs.[3]

This standardized regulatory impact assessment analyzes the economic impact of adopting new minimum efficiency standards for certain light bulbs (referred to as "lamps") – small-diameter directional lamps and general service LED lamps. Small-diameter directional lamps are light bulbs with a diameter of 2.25 inches or less that provide more light on a particular object than the surrounding area. There are two main types of small-diameter directional lamps: multifaceted reflector (MR) lamps (more common) and parabolic aluminized reflector (PAR) lamps (less common). These lamps are typically found in residential track lighting or pointed at an object in a store. They can be made with incandescent, halogen, halogen infrared (HIR, meaning that it has an infrared coating to reduce wasted heat), or LED technologies.

Figure 1: Examples of Small-Diameter Directional Lamps

A	B	C
Halogen MR-16 lamp	LED MR-16 lamp	Halogen PAR-16 lamp.

1 Warren-Alquist State Energy Resources Conservation and Development Act, Division 15 of the Public Resources Code, § 25000 et seq.

2 Pub. Resources Code, § 25402(c)(1).

3 *Ibid.*

General service LED lamps are replacements for historically incandescent screw-in light bulbs. They can be omnidirectional (spreading light in all directions) or directional (lighting a particular specific direction and area). Candelabra-based general service LED lamps are typically used in night lights or chandeliers. Here are examples of general service LED lamps:

Figure 2: Examples of LED Lamp Types

A B C

A: medium screw base omnidirectional LED B: medium screw base directional LED C: candelabra LED

The energy efficiency of lighting products is expressed in lumens per watt (LPW), which is the amount of light output per unit of power. Higher lumens-per-watt ratings indicate a more efficient lamp. Correlatively, the higher the wattage, the more energy the lamp consumes.

Chapter 2 explains the baseline and three scenarios developed – proposed standards, a less-efficient standard, and a more-efficient standard – for each lamp type. Chapters 3 through 8 summarize and explain the macroeconomic impacts to California from those scenarios in terms of jobs, businesses, competitive advantages and disadvantages, state investment, incentives for innovation, and benefits and costs to Californians. The macroeconomic impacts are presented together to provide overall impacts to the economy of the entire regulation package, thereby including any interrelated economic effects. Additional information about the method for the macroeconomic impact analysis is available in Appendix A.

CHAPTER 2: Baseline and Scenarios Analyzed

Baseline

Energy Commission staff obtained information to establish baseline conditions within California's existing lighting stock and market for lighting fixtures and lamps. The baseline characterizes how the relevant lighting market operates today or would operate in the absence of any additional energy efficiency regulation.

The baseline characteristics were established using existing studies, stakeholder comments, and staff research. The incremental cost of baseline products is considered to be $0, and costs associated with improved products consist solely of the incremental costs relative to baseline products.

The macroeconomic model used was REMI PI+ (Version 1.7.2) for California as a single statewide region. Staff prepared inputs to the model including reduced sales of electricity and expected costs of implementing new standards.

The LED market is undergoing rapid change in almost all important aspects to statewide economic evaluation. The numbers of shipments, the baseline cost, and the performance of the lamps have fairly dramatic year-over-year changes in recent history. In addition, several existing efficiency laws and policies will further accelerate the uptake of general service LED lighting over the next decade.

Small-Diameter Directional Lamps

The small-diameter directional lamp baseline consists of a market split of 10 percent LED and 90 percent incandescent-halogen lamps.[4] The baseline model is based on a "snapshot" of the market with the efficiency and market share of LED and non-LED lamps held static over the analysis period.[5] The halogen lamp technology that makes up the majority of the market today is very mature, and no changes are expected regarding the energy efficiency of the product or useful lifetime. In fact, there have not been major advances in some halogen technologies for

4 Available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2B_Lighting/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Small_Diameter_Directional_Lamps_2013-07-29_TN-71763.pdf. Page 6 provides the existing LED market share for 2013. Page 23 provides steady 1.3 percent increase in shipments of lamps. LED stock is about 10 percent.

5 Current ENERGY STAR® and Lighting Facts data show average efficacy of LED small-diameter directional lamps is about 65 LPW or greater. A baseline 40 LPW lamp is used because the current installed stock and significant retail stock remains at 40 LPW.

decades. These lamps operate at an efficacy of about 8 LPW when factoring in transformer losses[6] and cost about $6 each.

LED technology, in contrast, has advanced significantly and is expected to continue advancing. However, in the small-diameter directional lamp market, the technology has evolved at a much slower pace than the large-diameter directional lamp or omnidirectional LEDs lamp markets. For this reason the baseline efficacy is lower than general service LEDs in the analysis, at 40 LPW. Staff assumed a 40 LPW baseline for small-diameter directional LED lamp stock because the current installed stock and a significant amount of retail stock are averaging 40 LPW. Although there will be efficacy improvements in LED lamps in the next 10 years, without efficiency standards, low-efficacy lamps will continue to dominate the market because it is a smaller, primarily commercial, market.

Manufacturers are producing high color rendering index (CRI) and narrow beam angle LED lamps with less emphasis on improving efficacy. This efficacy number is therefore held static throughout the analysis period.[7] The price of a small-diameter directional LED lamp is expected to be $10 per lamp over the analysis period.[8] Because there are no existing or anticipated efficiency regulations for small-diameter directional lamps, no other changes in the market are included in the baseline.

The small-diameter directional lamp baseline is composed of statewide stock and sales of residential and commercial lamps of various wattage ranges and of line voltage (110 volts) and low voltage (12-24 volt) lamps and current performance. Stock numbers are adjusted each year by an estimated cumulative annual growth rate based on stakeholder input, assumed population growth, and other factors.

---

6 Available at http://cltc.ucdavis.edu/sites/default/files/files/publication/201505-electrical-compatibility-mr16-led-replacements.pdf, page 22 of the final task report on MR-16 LED replacement lamps electrical compatibility and performance.

7 Available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2B_Lighting/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Small_Diameter_Directional_Lamps_2013-07-29_TN-71763.pdf , page 10 section 4.3.4 paragraph 2, "efficacy ranging between 35 to 45 lumens per watt." Staff used average number of 40 LPW.

8 See, for example, http://www.maxximastyle.com/mr16-led-light-bulbs/mr16-led-flood-light-bulb-400-lumens-5-watts-neutral-white-35-watt-equivalent.

Table 1: Existing Residential and Commercial Stock of Small-Diameter Directional Lamps

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Residential (millions of lamp units)	5.5	5.6	5.7	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.4
Commercial (millions of lamp units)	10.3	10.4	10.5	10.7	10.8	10.9	11.1	11.2	11.4	11.5	11.7	11.8
Total (millions of lamp units)	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.3	17.5	17.7	18.0	18.2

Ninety percent of future unit sales of small-diameter directional lamps will likely be replacement; 10 percent will be for new construction.[9] Future shipments are based on lamp replacement as well as growth in the stock of lighting applications. Taking into account the shorter average lifetime for the current installed base of halogen lamps (one to two years), staff projects average annual shipments around 10 million lamps per year. As the installed base transitions to more energy-efficient, longer-life products, staff expects annual sales of replacement lamps to drop.[10]

LED Lamps

The general service LED lamp baseline is more dynamic than the small-diameter directional lamp baseline. When the pre-rulemaking process began, LED lamps had about 1 percent market share of the general service lamp market. That market share is expected to increase significantly. Analysis was conducted by segregating the market into three core lamp types: medium screw base omnidirectional lamps, medium screw base directional lamps, and candelabra base lamps.

Medium Screw Base Omnidirectional LED Lamp Baseline

The medium screw base omnidirectional LED lamp baseline includes regulatory impacts from an existing regulation that will take effect on January 1, 2018.[11] The regulation requires that most general service lamps, including non-LED lamps, meet a standard of 45 LPW to be sold or offered for sale in California. There are no halogen or incandescent lamps that meet this level of

9 Available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2B_Lighting/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Small_Diameter_Directional_Lamps_2013-07-29_TN-71763.pdf, page 23, “future shipments.”

10 Available at:http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2B_Lighting/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Small_Diameter_Directional_Lamps_2013-07-29_TN-71763.pdf, page 23, Section 5.3.2.

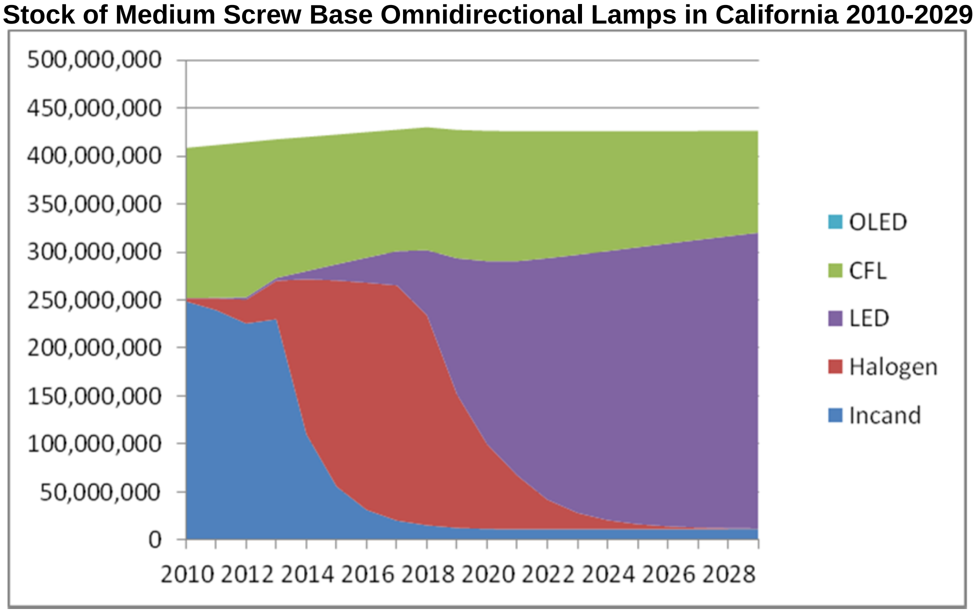
11 California Code of Regulations, Title 20: Division 2, Chapter 4, Article 4,1605.3(k)(2) Table K-11.

efficiency. Therefore, the standard is expected to cause a large market shift from the incumbent technology to LEDs and compact fluorescent lamps (CFLs). In addition, it is expected that the majority of this shift will be toward LEDs, which seem to have better consumer acceptance than CFLs.

The market model is complex and incorporates earlier efficiency standards[12] that moved the existing stock from incandescent to halogen lamps. Although most incandescent lamps were not available after 2013 in California, an assumed "hoarding" factor was used to account for consumer stockpiles of incandescent lamps in garages, and retailer stockpiling in warehouses and on the shelf. The model incorporates trends of LED taking market share from CFL, halogen, and incandescent technologies. Some lamp types, such as three-way lamps and rough service lamps, are exempt from existing efficiency regulations,[13] allowing incandescent lamps to continue in the market, which is why some number of incandescent lamps are assumed to persist throughout the analysis period. These complexities and associated results are shown in Figure 3.

The number of shipments by year is on a strong downward trend as a result of the longer lifetime of LED replacement lamps, relative to incumbent CFL and incandescent lamps, and decrease in the rate of lamp breakage and replacement each year. Organic LED (OLED) was included in the market model in case the technology was released during analysis. However, there are no OLED lamps available and no predictions of market share and efficiency over time. This baseline market transformation was assumed to be the same regardless of the standard level. Baseline shipments are shown in Figure 4.

Figure 3:
Stock of Medium Screw Base Omnidirectional Lamps in California 2010-2029

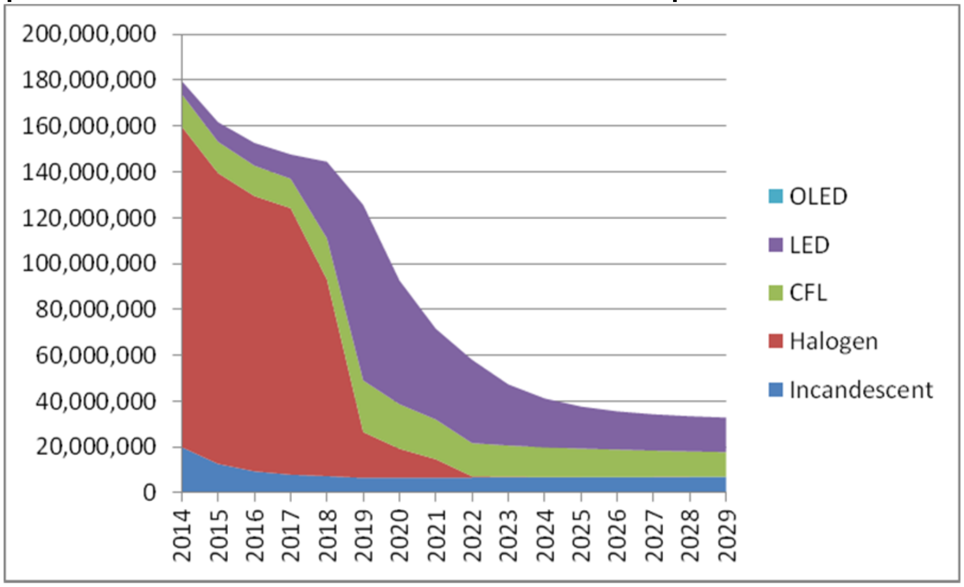


12 California Code of Regulations, Title 20: Division 2, Chapter 4, Article 4,1605.3(k)(2) Table K-10.

13 California Code of Regulations, Title 20: Division 2, Chapter 4, Article 4,1602(k), see definition of "Federally-regulated general service incandescent lamp."

Source: Energy Commission Staff – Appliances and Existing Buildings Office

Figure 4:
Shipments of Medium Screw Base Omnidirectional Lamps in California 2014-2029

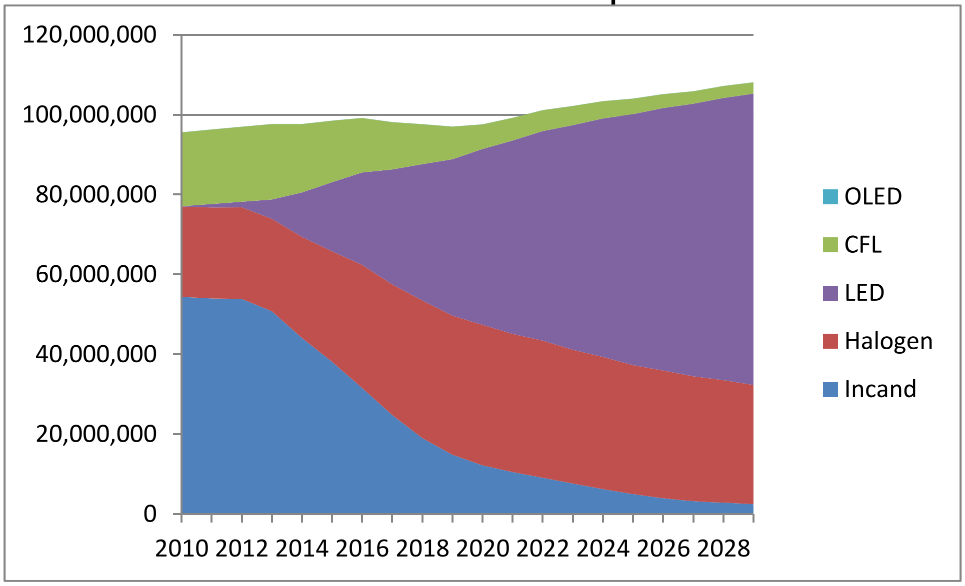


Source: Energy Commission Staff – Appliances and Existing Buildings Office

Medium Screw Base Directional Lamps Baseline

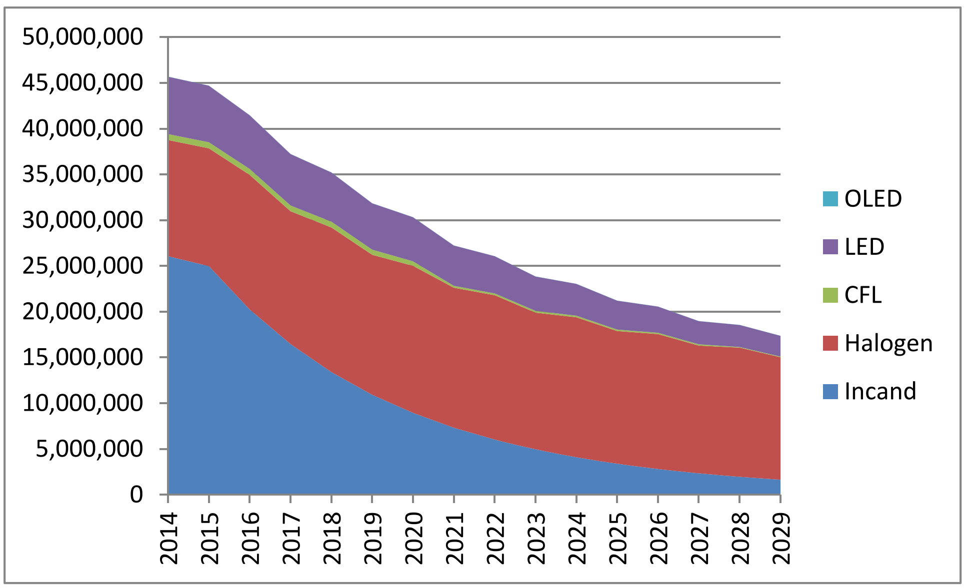
Medium screw base directional lamps do not have existing regulations that are driving a rapid transformation of the marketplace from incandescent and halogen technologies toward LEDs. However, increasing performance, decreasing price, U.S. Department of Energy (DOE) forecasts, and historical shipments show a fairly rapid uptake of LED sales to replace incumbent technologies. As with the medium screw base omnidirectional LEDs, the number of shipments decreases over time as short-life incandescent lamps are replaced with longer-life LEDs. This effect and the overall baseline stock and shipments used in economic modeling are shown in Figures 5 and 6.

Figure 5:
Stock of Medium Screw Base Directional Lamps in California 2010-2029



Source: Energy Commission Staff – Appliances and Existing Buildings Office

Figure 6:
Shipments of Medium Screw Base Directional Lamps in California 2014-2029

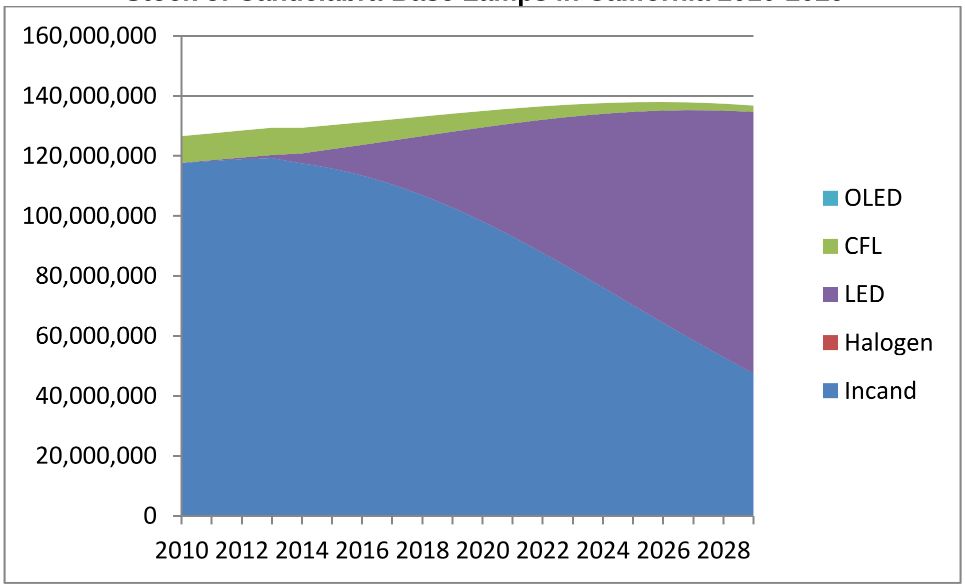


Source: Energy Commission Staff – Appliances and Existing Buildings Office

Candelabra-Base Lamps Baseline

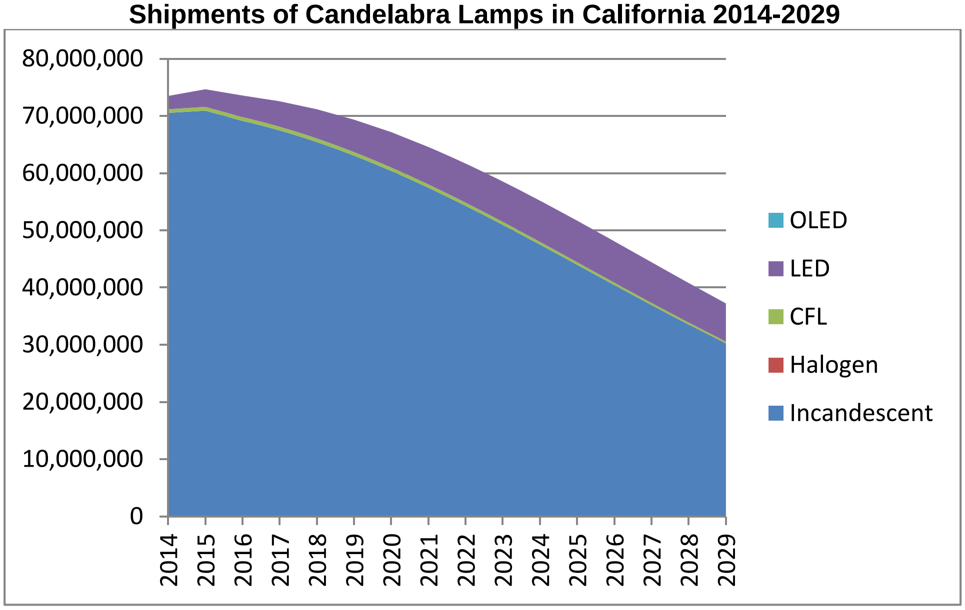
Like medium-based directional lamps, candelabra-base lamps do not have existing regulations that are driving a rapid transformation of the marketplace from incandescent technologies toward LEDs. However, increasing performance, decreasing price, DOE forecasts, and historical shipments show a fairly rapid uptake of LED sales to replace incumbent technologies. As with the medium screw base omnidirectional LEDs, the number of shipments decreases over time as short-life incandescent lamps are replaced with longer-life LEDs. The baseline stock and shipments used for economic modeling are shown in Figures 7 and 8.

Figure 7:
Stock of Candelabra-Base Lamps in California 2010-2029



Source: Energy Commission Staff – Appliances and Existing Buildings Office

Figure 8:
Shipments of Candelabra Lamps in California 2014-2029



Source: Energy Commission Staff – Appliances and Existing Buildings Office

To calculate energy savings, the baseline LED has a static efficacy developed from the average of all available efficacy data for LED products, applying equal weightings to each LED model.[14] The baseline efficacy for medium screw base omnidirectional LED lamps is 81.3 LPW, for medium screw base directional LED lamps is 69 LPW, and for candelabra-base LED lamps is 72.3 LPW. Because this portion of the proposed standard only deals with LED-to-LED replacements and does not extend the expected lifetime of products, no baseline price was established. Instead, costs are considered relative to the baseline, where the baseline incremental cost of not setting a standard is $0 with $0 of electricity savings. The static life of the LED lamps was assumed to be 25,000 hours, which is the most common lamp life rating in the market today. This translates to about a 25-year life in a home.

Proposed Standard

Small-Diameter Directional Lamp Proposal

Energy Commission staff currently proposes a standard of ≥ 80 lumens per watt or a CRI +*Efficiency* ≥ 165 and a minimum required *Efficiency* ≥ 70 LPW for small-diameter directional lamps, effective January 1, 2018. This standard will effectively eliminate halogen and HIR technologies from the small-diameter directional lamp market, as there are no products that can meet this standard. LED lamps that meet or exceed this standard are readily available.

LED Lamp Proposal

Energy Commission staff proposes to provide a tradeoff between color rendering (measured as color rendering index or CRI) and efficacy that will set a Tier 1 standard effective January 1, 2017, and a Tier 2 standard effective January 1, 2019.[15] Many lamps today meet the Tier 1 standard, and several also meet the Tier 2 standard. Energy Commission staff expects that additional improvements in lamp efficiency will further decrease energy consumption of these lamps while maintaining high-quality aspects.

Staff also proposes certain requirements for lamps that claim to be dimmable, incandescent-equivalent, or meeting the Voluntary California Quality LED Lamp Specification.[16] These requirements include meeting tests for flicker and noise, having a certain color temperature and lumen output, or meeting the requirements in the voluntary specification. Because these tests are not mandatory for lamps to enter the California market, the costs or potential savings are not included in the economic impact analysis.

---

14 LED model data were pulled from the ENERGY STAR and Lighting Facts programs refreshed to June 15, 2015. These sources of data are publicly available at each program website. ENERGY STAR data are available at http://www.energystar.gov/productfinder/product/certified-light-bulbs/results; Lighting Facts data are available at http://www.lightingfacts.com/products.

15 See Figure 9 for representations of the levels.

16 The Voluntary California Quality LED Lamp Specification is available on the Energy Commission's website here: http://www.energy.ca.gov/2015publications/CEC-400-2015-001/CEC-400-2015-001.pdf.

Alternatives

To develop alternative scenarios, Energy Commission staff looked to the proposals made by stakeholders in response to the September 2014 draft staff report and at the public workshop. The alternatives identified are based on changes to the efficacy levels (LPW), as efficacy levels are the primary driver of energy savings from the proposed regulations and, therefore, the most relevant to the economic impact of the proposed regulations on the state.

Small-Diameter Directional Lamp Alternatives

The alternatives for small-diameter directional lamps include a more stringent standard and a less stringent standard. A less stringent level of 60 LPW was proposed by National Electrical Manufacturers Association (NEMA) and Philips Lighting. No stakeholder proposed a more stringent standard than the Energy Commission proposal, so staff selected a 90 LPW standard for this standardized regulatory impact assessment. These standards are converted into wattage in Table 2 to allow for an easy comparison of energy consumption.

Table 2: Small-Diameter Directional Lamp Wattages, Including Transformer Losses

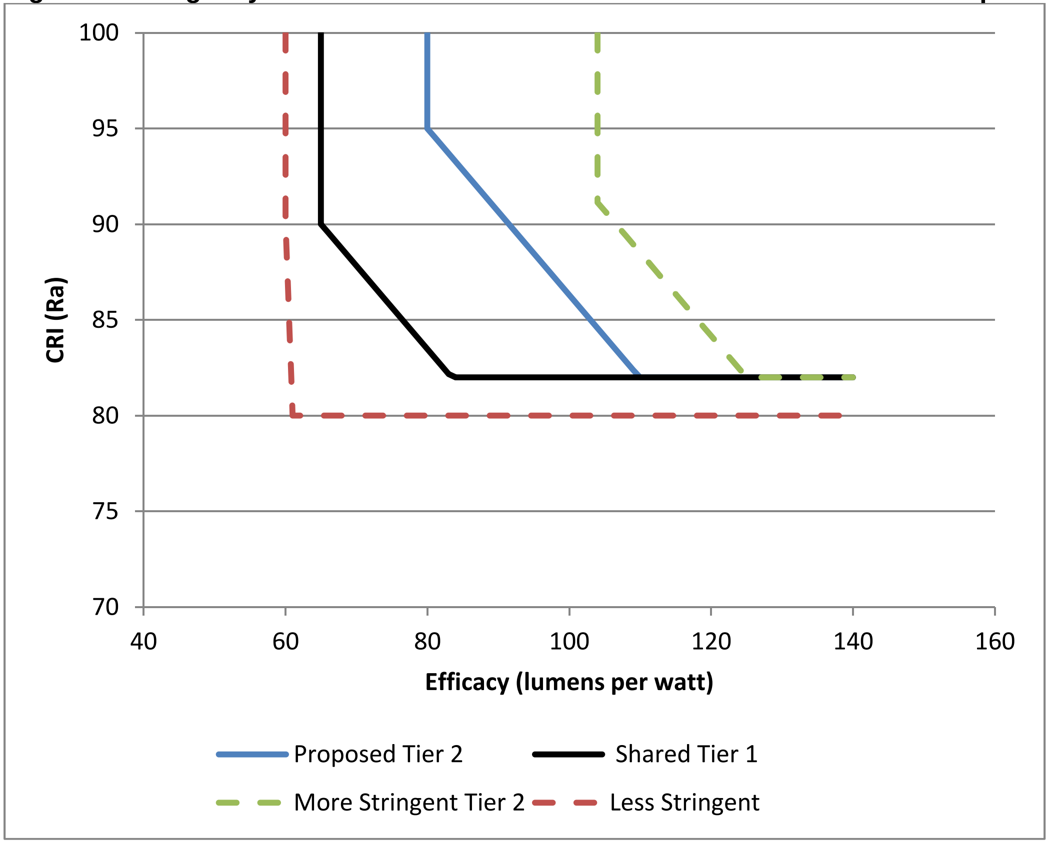
Halogen baseline (watts)	LED baseline (watts)	Less Stringent Scenario Compliant LED (watts)	Proposed Scenario Compliant LED (watts)	More Stringent Scenario Compliant LED (watts)
50	21	14	11	10
35	14	9	7	6
20	7	5	4	3

All three levels considered for small-diameter directional lamps in Table 2 include a standard level that exceeds the current incandescent, halogen, and HIR lamp technology. The effect of the regulations for small-diameter directional lamps was evaluated relative to the existing stock and incremental energy savings as compared to the products available in the market today and product life cycle. This approach sought to evaluate the effect of energy savings on the levels of electricity consumption today.

LED Lamp Alternatives

The alternative scenarios for LED lamps include a less stringent and a more stringent standard. The less stringent scenario would set a standard at the same level as small-diameter directional lamps, at a single tier of 60 LPW effective January 1, 2017, as recommended by NEMA. The proposed levels are comparable to a 100 LPW standard. Although no stakeholder proposed a more stringent level than staff's proposal, staff evaluated a more stringent level at which only a handful of the very best LEDs in the market would comply. This would lead to a standard roughly equivalent to 120 LPW, or twice as efficient as the low scenario. The proposed standards and more stringent standards both share the same first tier standard in January 1, 2017, but transition to different stringency second tier standards on January 1, 2019. An example is provided in Figure 9, in which the higher the CRI and efficacy numbers are, the more efficient the lamp. Lamps that score to the upper right of the lines would be able to be sold or offered for sale in California.

Figure 9: Stringency Scenarios for Medium Screw-Base Omnidirectional Lamps



Source: Energy Commission Staff – Appliances and Existing Buildings Office

Differences in LPW stringencies lead to different energy savings, as well as different incremental costs.

Costs and Savings from Scenarios

The core analysis that supports this economic assessment is taken from a consumer perspective and then expanded to the statewide economy. The consumer perspective is calculated at the per-unit level of a lamp purchase. The costs of the proposed and alternative standards stem from the incremental cost of an enhanced efficiency lamp compared with a lamp available today. These incremental costs are derived either from a comparison of the retail price of an efficient lamp compared with a baseline lamp, or from the estimated manufacturer cost to make an inefficient lamp as efficient as necessary to meet the proposed standard. The cost approach depends on the correlation between the price and the efficiency level.

The financial savings are from reduced operating costs, which lead to lower utility bills, and reduced capital costs (if applicable) either from a lower purchase price or from a reduced number of purchases due to longer life.

Because all of the scenarios anticipate full implementation to begin in 2019 (for Tier 2 standards), the analysis looks at the economic impact through 2029, thereby characterizing 10 years of economic impacts of the combined standards.

Small-Diameter Directional Lamps

Costs

Halogen and HIR small-diameter directional lamps have a retail cost of about $6 per lamp.[17] LED lamps that would meet the proposed standard are expected to be more expensive, at $10 per lamp.[18] The $4 difference in retail price is the estimated incremental cost of a more efficient lamp. This incremental cost does not change between the proposed standard and the alternative scenarios. Low-volume sales and unique features such as narrow beam angle, higher CRI, and dimmable features will keep the price of small-diameter directional lamps unchanged throughout the analysis period.

Savings

Small-diameter directional lamp standards will cause two types of monetary savings: capital cost savings due to buying fewer replacement lamps, where the LED lamps are replacing halogen lamps, and operating cost savings due to reduced utility bills.

The small-diameter directional lamp proposed standards and alternatives will cause the replacement of incandescent, halogen, and HIR lamps with LED lamps as these technologies do not meet the proposed or alternative standards. The proposed standards will also cause the replacement of less efficient LEDs that do not meet the standard but are available in the market. To translate these wattages into annual energy consumption, an assumption of 3,720 hours of use per year for commercial lamps and 840 hours of use per year for residential lamps was used. About 65 percent of small-diameter lamps are used in commercial applications, with the remaining 35 percent being used in home applications.

Halogen small-diameter directional lamps have a typical rated life of 4,000 hours. LED replacement lamps have a typical rated life of 25,000 hours.[19] A consumer would have to buy 6.25 halogen lamps over the lifetime of one LED lamp. By improving the efficiency levels to a level that halogen does not meet, consumers will buy 5.25 fewer lamps over a 25,000-hour operational period. Halogen lamps cost about $6, leading to avoided lamp replacement costs of $31.50 worth of halogens per LED replacement. However, LED lamps are expected to be more expensive, at $10 per lamp, making the net replacement savings $27.50.

---

17 Available at http://www.energy.ca.gov/2014publications/CEC-400-2014-020/CEC-400-2014-020-SD.pdf, page 18.

18 Available at http://www.maxximastyle.com/mr16-led-light-bulbs/mr16-led-flood-light-bulb-400-lumens-5-watts-neutral-white-35-watt-equivalent.

19 Twenty-five thousand hours is the most common rating in Lighting Facts and ENERGY STAR data.

While 90 percent of the replacements are assumed to occur in halogen sales, 10 percent of the baseline sales are assumed to be lower efficiency LEDs. The baseline LED products have an assumed efficacy performance of 40 LPW. The increased efficiency in each evaluated scenario led to reductions in annual operating costs, although at lower magnitude than the halogen to LED replacements. There are no assumed avoided lamp replacement purchases for baseline LEDs, as the product life is equivalent to the replacement LEDs in each scenario.

It is possible that there is also a savings in the purchase price in comparing compliant LED small-diameter directional lamps with a noncompliant one. More efficient LED lamps have a lower purchase cost than less efficient LEDs. [20] However, for this analysis, the difference was assumed to be zero.

LED replacement lamps also have a lower operating cost than halogen lamps. Take, for example, the 50-watt halogen baseline unit in Table 2 and the LED that would meet the proposed scenario at 11 watts. The annual energy consumption in a commercial setting is 186 kilowatt-hours per year (kWh/yr) for the halogen and 41 kWh/yr for the LED, yielding a reduction of 145 kWh/yr. At a commercial electricity rate of $0.155per kWh, there is a reduction in operating costs of $22 per year per lamp replacement.

The reduced lamp operating cost and lamp replacement cost were calculated separately for residential and commercial, with residential replacements occurring at a slower pace due to lower hours of annual use. Separate residential and commercial electricity retail price rates were used in the analysis, as well as a changing rates for each year based on Energy Commission electricity price forecasts.[21]

LED Lamps

Costs

LED lamps that already comply with efficiency standards are not significantly more expensive in terms of retail price than those that do not. If costs were considered in this way, the incremental costs would be close to $0 per lamp. Instead, the costs of the proposed regulations as characterized in the standardized regulatory impact assessment are the expected incremental cost of improving a noncompliant lamp into a compliant lamp. This approach requires consideration of compliance rates as only a percentage of lamps available today would need to undergo this improvement. Table 3 describes the compliance rates and incremental costs used to develop the statewide costs for modeling economic impacts of the regulations.

---

20 There are significant improvements in efficacy of LEDs and associated electronics. Higher-efficiency LEDs require smaller heat sinks and driver components in the lamp, causing reduction in manufacturing costs.

21 *California Energy Demand 2019-20124 Final Forecast: Mid-Case Final Baseline,* http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-SF-V1.pdf.

Table 3: Compliance Rate and Incremental Cost of LED Lamps

LED Lamp Type	Baseline		Less Stringent		Proposed		More Stringent	
	%	Cost*	%	Cost*	%	Cost*	%	Cost*
Medium Screw Base Omnidirectional	100	$0.00	95	$0.01	5	$0.50	1	$0.68
Medium Screw Base Directional	100	$0.00	83	$0.05	1	$1.50	0	$1.76
Candelabra	100	$0.00	79	$0.06	8	$1.00	3	$1.00

*The incremental cost for the proposed standards was developed in the draft staff report published August 2014.[22] The costs for the alternative scenarios were assumed to be linear, and were scaled from proposed standards costs. For example, if the standard saved twice as much energy, then the costs were assumed to be twice as much.[23]

Savings

The savings for LED lamps will come exclusively from reduced operating costs, as the proposed and alternative scenarios would only cause the displacement of other LED lamps with similar lifetimes, resulting in no lamp replacement savings.

To calculate the operational energy savings per unit, assumptions must be made about the levels of usage for the lamp. The medium screw base and candelabra base LEDs are primarily residential products; usage of 2.3 hours per day is assumed per lamp. The annual energy consumption of a lamp is calculated by using Equation 1, where lamp power is measured in watts.

$$Equation\ 1 - \quad Annual\ Energy\ Use = Lamp\ Power\ \times 2.3\frac{hours}{day} \times 365\frac{days}{year} \times \frac{1\ kilowatt}{1000\ watts}$$

A small number of lamps, mainly medium screw base directional lamps found in retail stores, was adjusted to have a higher use: 6.9 hours per day, or 3 times as much use. Table 4 shows the breakdown of residential, commercial, and industrial use of LED lamps.

22 The staff report is available online: http://www.energy.ca.gov/2014publications/CEC-400-2014-020/CEC-400-2014-020-SD.pdf.

23 Technologies and efficiency costs are generally modeled on a nonlinear curve, where the prices become disproportionally higher as manufacturers run against scientific barriers that get more expensive to overcome. However, given the rapid improvements over the most recent year, it is reasonable to assume that the technology is on the more "linear" part of such a curve, not near the scientific limit, and therefore a linear approximation is suitable.

Table 4: LED Lamp Units by Sector

	Residential	**Commercial**	**Industrial**
Medium Screw Base Omnidirectional	97.46%	2.52%	0.01%
Medium Screw Base Directional	94.15%	5.84%	0.01%
Candelabra	100.00%	0.00%	0.00%
Total	**97.12%**	**2.87%**	**0.01%**

The wattages evaluated for each scenario were derived from an assumed LPW and typical lumen output for each category. The typical lumen output was assumed to be 800, 950, and 350 for medium screw base omnidirectional, medium screw base directional, and candelabra lamps, respectively. The wattages were applied to Equation 1 to derive annual energy use. The annual operating cost is then calculated by multiplying a residential or commercial electricity price rate to the annual energy use. These rates ranged from $0.167 and $0.152 per kWh in 2017 and rise to $0.205 and $0.186 per kWh in 2029 for residential and commercial retail price rates, respectively. The resulting annual energy use and operating cost per unit for each scenario are summarized in Table 5.

Table 5: Annual Energy Use and Operating Cost of LED Lamps

LED Lamp Type	Baseline		Less Stringent		Proposed		More Stringent	
	Energy (kWh/yr)	Cost*	Energy (kWh/yr)	Cost*	Energy (kWh/yr)	Cost*	Energy (kWh/yr)	Cost*
Medium Screw Base Omnidirectional	8.98	$1.50	8.95	$1.50	6.75	$1.13	5.94	$0.99
Medium Screw Base Directional	12.55	$2.10	12.42	$2.07	8.2	$1.37	7.46	$1.24
Candelabra	4.10	$0.69	4.02	$0.67	2.72	$0.45	2.72	$0.45

*Costs are presented with 2017 rates only in this table; however different rates were applied for commercial lamps and varied by year analyzed. The table represents Tier 2 standards for the proposed and more stringent scenarios. There is only one tier for the less stringent scenario.

The monetary savings are derived by taking the difference of operating costs in the baseline scenario versus one of the standards scenarios. For example, the annual savings for the medium screw base omnidirectional LED lamp more stringent scenario is $1.50 minus $0.99, which means a consumer can be expected to save $0.51 per lamp per year. These savings were then applied to the number of LED shipments each year. The statewide savings accumulate as the prior year shipments continue to save energy along with the current year shipments. This accumulation occurs from the proposed implementation date of the standard until the end of the analysis period. The replacement of an LED from the installed stock does not occur during the 10-year analysis period because the life of the LED lamp is assumed to be 25,000 hours or roughly 25 years in homes.

The method used to analyze LED lamp savings did not incorporate compliance rates. Instead, the baseline energy consumption is calculated by taking the average efficiency of all products available in the market. The new energy efficiency level in each scenario is then calculated by taking all products that do not comply and setting them to meet the minimum standard to comply exactly. A new average efficiency is then calculated. This method means that the total shipments get multiplied by the savings.

CHAPTER 3:
Changes in California Jobs

Energy Commission staff evaluated the effect on jobs from implementation of proposed and alternate LED efficiency standards between 2017 and 2029. The number of jobs created in 2029 is an indicator of the steady state or long-term job change in the California economy from the proposed regulations. The 2017 to 2029 effect to employment over 13 years following adoption of proposed efficiency regulations is summarized in Table 6.

Table 6: Regulatory Effects to Jobs in California

	Less Stringent	Proposed	More Stringent
Job-years in 2029	3,252	3,812	3,979
Total job-years 2017-2029	48,089	54,098	56,157

Source: Energy Commission Staff – Appliances and Existing Buildings Office

Results from the macroeconomic modeling show that higher LED efficiency standards lead to greater levels of job creation. This job creation makes sense given the amount of savings that consumers receive on their electricity bills as a result of the efficiency standards. These savings are reallocated from consumer spending on electricity to spending on other goods and services within the California economy, which translates into jobs. Utility sector jobs are expected to decrease due to lower electricity retail sales. However, increases in personal disposable income and reduction in commercial operating costs of businesses more than offset this loss and yield positive job growth numbers.

In terms of the California economy, the impact on jobs of the proposed and alternative standards is minor. The changes in jobs shown in Table 6 represent just a 0.02 percent change from baseline employment levels. Higher incremental costs of LED lamps with the proposed standards leads to a net loss of 201 jobs only in the first year of implementation in 2017. Energy savings and avoided lamp replacement costs yield positive annual job growth of 3,547 in 2018 and 3,812 jobs in 2029. Average annual job growth is 4,161 over the period of analysis.

The increases in job growth lead to corresponding increases in personal income across all three levels of lamp efficiency standards analyzed. The proposed standards yield an estimated $5.65 billion[24] increase in real disposable personal income between 2017 through 2029. The more stringent standards show a slightly higher increase at $5.8 billion, and the less stringent standards are proportionately lower at $5.2 billion.

24 All monetary figures presented in this report are net present value in 2015. All net present value calculations use a 3 percent annual discount rate.

CHAPTER 4: Changes in California Businesses

The proposed regulations will reduce overall costs to California businesses by lowering monthly electricity bills as more efficient LED lamps are installed. The incremental cost to produce these more efficient LED lamps is small compared to the lifetime energy savings gained from using them.[25] Staff estimates commercial businesses will save about $227 million annually and $2.75 billion total on electricity bills between 2017 and 2029 as a result of the proposed standards.

LED small-diameter directional lamps that replace halogen or incandescent lamps also provide a net savings in business expenses, as one LED lamp lasts as long as the equivalent of six non-LED lamps. The LED lamps have higher initial purchase price ($10 vs. $6). The estimate of net reduction in lamp business expenses equals $506 million between 2017 and 2029. These savings will accrue primarily to the commercial retail sector, where these lamps are typically found.

The REMI PI + model (Version 1.7.2) was used to estimate macroeconomic impacts of the proposed and alternative scenarios. One important factor to consider with evaluating impacts to businesses is the effect regulations will have on prices. The REMI model analysis of proposed and alternative regulations shows that prices will change very little compared to the baseline. During the analysis period, overall prices (Personal Consumption Expenditure index variable) are estimated to decline by a factor of 0.01 to 0.02 percent. This price decline is small compared to expected changes in overall prices within the California economy over the next 15 years.

The overall effect to California businesses will be positive: reduced electricity costs, a reduction in lamp replacement costs, and a small reduction in overall prices throughout the state's economy.

25 See cost and savings from scenarios in Chapter 2.

CHAPTER 5: Competitive Advantages and Disadvantages for California Businesses

The proposed regulations have advantages and disadvantages to utilities, manufacturers, and retailers in the state. Electric utilities will see a decrease in demand for electricity relative to a baseline forecast. Because investor-owned energy utilities' revenue is decoupled from energy sales, these utilities will see minimal impacts from the proposed regulations.

The proposed regulations will, by design, give an advantage to manufacturers of more efficient products. The proposed performance standards are not based on any particular patent or technology and therefore give a broad advantage rather than a specific advantage. The distribution of compliant products is spread among many manufacturers. Assembly of LED lamps does not occur in significant volume within the state – most are assembled in China. However, there are California-based LED corporations, particularly research and design facilities such as Soraa, Cree, and Philips Lumileds. These companies will benefit from the diminishing incandescent small-diameter directional lamp market, which will drive up LED sales. There are no manufacturers of halogen/incandescent small-diameter directional lamps in California.

Retailers will see slightly higher priced LEDs and will sell fewer lamps overall as incandescent and halogen small-diameter directional lamps are replaced with longer lasting technologies. Small-diameter directional lamps make up a small portion of both volume and retail space in a hardware or big box store lighting section. However, while the retail sector may have fewer sales of lamps, the majority of small-diameter lamps are used in retail spaces. Therefore, the retail sector will reap direct savings through fewer lamp purchases and lower operating costs.

The decrease in overall energy prices estimated with the macroeconomic model would create a slight competitive advantage for California businesses.

CHAPTER 6:
Changes in State Investment

Energy Commission staff used estimates of direct energy savings (electricity) to model the macroeconomic impacts of proposed and alternative lamp efficiency standards to the overall California economy. The impacts were modeled over a 13-year period (2017-2029), although staff anticipates that future federal general service LED appliance efficiency regulations could supersede the proposed standards before 2029. If new federal general service LED standards are proposed in less than 13 years, then the resulting economic impacts would be for a short period and less than those analyzed and reported within this assessment.

The overall result of conserving electricity with the proposed lamp efficiency standards is an increase in gross domestic product (GDP) and gross private domestic fixed investment (GPDFI). As noted earlier, the jobs impact is positive due to residential and commercial savings on utility costs being reallocated to other spending categories. In addition, real disposable personal income increases by $392 million in 2018 to $436 million in 2029, with the implementation of the proposed standards.

The proposed regulations are estimated to increase GDP by $145 million in 2018 and $256 million in 2029. This modeled increase in GDP is the result of lower annual electricity bills and reallocation of spending by businesses and residences on other goods and services within the California economy.

Staff estimates that GPDFI increases and falls between 2017 and 2029. In total, GPDFI increases by $128 million over the analysis period. The average annual change in GPDFI between 2017 and 2029 for the proposed standards is a $10 million increase. The proposed standards yield a decline in GPDFI of $5 million in 2017, a high annual increase in GPDFI of $60 million in 2020, and a final year decline of $50 million in 2029. The levels of increased and reduced private fixed investment are very small compared to the whole California economy and represent up to a 0.01 percent change from the baseline in either direction. Staff finds the overall effect of the regulations on investment in California to be small compared to benefits of reduced electricity consumption, increased jobs, increased personal income, improved air quality, and reduced greenhouse gas emissions.

CHAPTER 7: Changes in Incentives for Innovation

The technologies necessary to meet the proposed and alternative standards are widely available as a result of past and ongoing investments in research and development. There are many product models across multiple manufacturers that comply with the proposed standards, fewer with more stringent standards and more with less stringent standards. The proposed standards will cause the spread of existing, efficient technologies into products that may not currently contain them, thereby increasing the number of products that would comply with the proposed and alternative standards.

Future innovations in the products proposed to be regulated can be organized into three types: innovations that would decrease energy use, innovations that are neutral to energy use, and innovations that would increase energy use.

The proposed standards clearly provide incentives for technologies and innovations that can reduce the energy use of LED lamps. The proposed regulations put pressure on manufacturers of existing products to adjust from status quo designs that would have difficulty meeting the performance standards. These changes lead to increased industry investment in technology and form the core of innovation. This investment also generates expertise and fuels secondary innovation. In addition, for small-diameter directional lamps, the regulations would add reporting and marking requirements that would make lamp performance more transparent, thereby encouraging competition and innovation.

In some cases, innovation does not come with any change in energy use. For example, changing the shape of a lamp's optics may not change its efficiency, but may lead to more pleasing light output. Generally, these types of innovations are neither promoted nor hindered by energy performance standards.

Some innovations incorporate features that might require additional energy consumption in regulated products. The regulations mandate lower energy consumption, resulting in an upper limit for innovations that would otherwise increase the consumption of energy. The result of the innovation can be positive, neutral, or negative with regard to energy consumption. The proposed regulations would have a neutral effect on innovations that would increase consumption, but not in excess of the performance standard. The proposed regulations would have a negative effect on innovations that would cause energy consumption to exceed the standard. This means that manufacturers will have to either modify the innovation to conform to the standard or forgo the innovation. The regulations would have a positive effect on innovation where the energy-consuming innovation drives the demand for energy-saving innovations to comply with the proposed standards.

The economic analysis of the proposed regulations shows an increase in personal disposable income. This income can be used to buy innovative products that are beyond what consumers consider baseline. Further, the utility bills of California businesses would decrease from the proposed cost-effective regulations. Reduced spending on utilities frees up capital for businesses to invest in research and development in other areas of innovation.

CHAPTER 8:
Benefits and Costs to Californians

The proposed and alternative scenarios provide a wide range of benefits to California households and commercial businesses. The benefits that were quantified for this assessment include electricity conservation, utility bill savings, reduced lamp replacement costs, jobs impact, changes in personal income, reduced air pollution, and reduced greenhouse gas emissions. Estimates were made for annual incremental costs to residential and commercial consumers of small-diameter directional lamps and general service LED lamps.

Electricity Savings

Both the proposed and alternative standards would yield significant electricity savings within California. Electricity is conserved directly through installation of more energy-efficient LED lamps. The proposed lamp efficiency standards yield total annual electricity savings estimated at 21 gigawatt-hours (GWh) in 2017, an implementation jump to 2,040 GWh in 2018, and 3,144 GWh electricity savings by 2029. Total cumulative electricity savings over the 13-year period of analysis is 32.8 terawatt-hours (TWh). This cumulative quantity of electricity savings is equivalent to the annual output of fifteen 500-megawatt power plants. More stringent standards would have more savings; less stringent standards would have less energy savings, directly correlating to savings on electricity bills. These savings are summarized in Table ES-1.

The net present value of annual residential electricity bill savings under the proposed standards is estimated to be $44.28 million in 2018 and up to $133 million by 2029. Residential consumers will see electricity bill savings of $1.3B over the analysis period. Commercial businesses electricity bill savings over the same period range from a low of $239 million to a high of $250 million. Businesses will see electricity bill savings of $3B between 2017 and 2029. Electric utilities will have lower sales of $4.3B over the analysis period. Tables 7, 8, 9, and 10 contain the annual undiscounted electricity bill savings for small-diameter directional and general service LED lamps. These savings increase over time as more and more lamps are replaced with higher efficiency products.

Table 7: Small-Diameter Directional Lamp Annual Electricity Savings – Commercial (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$0.0	$0.0	$0.0
2018	$275.9	$270.2	$253.1
2019	$283.0	$277.1	$259.7
2020	$290.0	$284.1	$266.2
2021	$296.8	$290.7	$272.4
2022	$303.6	$297.4	$278.6
2023	$310.7	$304.3	$285.1
2024	$317.8	$311.2	$291.6
2025	$326.3	$319.5	$299.4
2026	$335.0	$328.1	$307.4
2027	$338.9	$331.9	$311.0
2028	$347.5	$340.4	$318.9
2029	$356.4	$349.0	$327.0

Table 8: Small-Diameter Directional Lamp Annual Electricity Savings – Residential (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$0.0	$0.0	$0.0
2018	$40.5	$39.7	$37.5
2019	$41.5	$40.7	$38.4
2020	$42.6	$41.8	$39.4
2021	$43.6	$42.7	$40.3
2022	$44.6	$43.7	$41.2
2023	$45.6	$44.7	$42.2
2024	$46.7	$45.8	$43.2
2025	$47.9	$47.0	$44.3
2026	$49.2	$48.3	$45.5
2027	$49.8	$48.9	$46.1
2028	$51.1	$50.2	$47.3
2029	$52.5	$51.5	$48.6

Table 9: General Service LED Lamp Annual Electricity Savings – Commercial (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$0.4	$0.4	$0.0
2018	$0.9	$0.9	$0.1
2019	$4.3	$3.4	$0.1
2020	$6.8	$5.4	$0.2
2021	$8.7	$6.9	$0.2
2022	$10.4	$8.2	$0.2
2023	$11.7	$9.2	$0.2
2024	$12.8	$10.1	$0.3
2025	$13.8	$10.9	$0.3
2026	$14.6	$11.5	$0.3
2027	$15.2	$12.0	$0.3
2028	$15.9	$12.6	$0.3
2029	$16.6	$13.2	$0.3

Table 10: General Service LED Lamp Annual Electricity Savings – Residential (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$3.1	$3.1	$0.2
2018	$8.7	$8.7	$0.6
2019	$51.4	$40.7	$1.2
2020	$81.9	$63.8	$1.7
2021	$104.2	$80.8	$2.1
2022	$124.3	$96.3	$2.5
2023	$139.0	$107.6	$2.8
2024	$150.4	$116.7	$3.1
2025	$160.5	$124.8	$3.4
2026	$169.5	$132.0	$3.7
2027	$175.4	$136.9	$3.9
2028	$183.3	$143.2	$4.1
2029	$191.0	$149.4	$4.4

Staff estimates the air quality and greenhouse gas (GHG) benefits of conserving this amount of electricity (see below) but did not attempt to estimate a wider range of potential benefits to California, such as those associated with improved grid reliability or avoided power plant or transmission line construction costs.

Job Effects

Job effects of the proposed and alternative standards were estimated using the REMI PI+ model for California as a single region (Version 1.7.2). The cumulative 13-year jobs impact is positive for all levels of standards analyzed, with job growth increasing as the lamp efficiency standards increase in stringency. The reduced spending by households and businesses on utility bills is reallocated to spending on other goods and services within the economy. The reallocation of spending more than offsets reduced economic activity within the electric utilities sector of the California economy.

Total job-years increase between 2017 and 2029 by 54,098 under the proposed standards. Estimated job-years rise by 3,547 in 2018, and the average annual increase is 4,161 over the period analyzed. For comparison, the low efficiency alternative averaged an increase of 3,699 job-years, while the most stringent alternative averaged 4,320. These levels are small compared to California's overall economy, which has a baseline employment level in 2017 of roughly 22.87 million jobs. The jobs impact of all alternative scenarios represents a 0.02 percent change in California's employment levels. While the employment impact is small, it is nonetheless positive for the California economy.

Personal Income

In addition to the electricity bill savings described above, the proposed standards will increase real disposable personal income by $392 million in 2018 and $436 million in 2029, as a result of higher employment levels with implementation of the lamp efficiency standards. The net present value of cumulative increases in disposable income with the proposed standards is $5.65 billion, which is certainly beneficial for the California economy. This increase in personal disposable income results from consumers and commercial businesses saving money on utilities and spending it on other goods and services, leading to a gain in employment levels within the state. As with employment and electricity savings, personal disposable income rises with increased stringency of the standards. For comparison, the lowest stringency alternative yields an increase of $5.2 billion in disposable income, while the most stringent efficiency alternative yields an increase of $5.8 billion.

Air Quality

Air quality benefits of proposed and alternative lamp energy efficiency regulations are significant as a result of avoided electricity generation, but difficult to quantify given uncertainty in the mix of generation resources over the next 15 years. Staff used the emissions factors shown in Table 11 for low and high criteria emissions reductions associated with electricity savings of alternative lamp efficiency standards.

Table 11: Criteria Pollutant Emissions Factors for Avoided Electricity Generation

	Particulate Matter 2.5 microns (lbs/MWh)	Oxides of Nitrogen (lbs/MWh)	Sulfur Dioxide (lbs/MWh)	Proposed Standards Cumulative Reductions (2017-2029)
Low Emission Factor	0.03	0.05	0.004	$PM_{2.5}$: 492 tons NOx: 820 tons SO_2: 66 tons
High Emission Factor	0.07	0.40	0.007	$PM_{2.5}$: 1,148 tons NOx: 6,558 tons SO_2: 115 tons

Sources: D. McCubbin and B. Sovacool - *Energy Policy* 53 (2013) page 433; California Energy Commission staff – Appliances and Existing Buildings Office.

Proposed lamp efficiency regulations over the next 13 years are estimated to reduce small particulate matter of 2.5 microns or less ($PM_{2.5}$) emissions by between 492 tons and 1,148 tons.

Oxides of nitrogen emissions (NO_x) reductions are estimated to be a low of 820 tons and a high of 6,558 tons. Sulfur dioxide (SO_2) emissions have reduction estimates of 66 tons to 115 tons. Additional benefits of reducing carbon monoxide and volatile organic compounds (VOCs) were not estimated. The higher standards alternative had slightly higher criteria emissions benefits, while the lower alternative had significantly lower emissions benefits.

Benefits of reducing these criteria emissions were estimated using the U.S. Environmental Protection Agency's COBRA Model. The COBRA Model provides a high and low estimate of avoided public health impacts due to reductions in criteria emissions. The proposed standards are estimated to avoid annual public health losses of between $3.3 million and $22.2 million. Over a ten-year period public health benefits are estimated to range between $33 million and $222 million.[26]

Greenhouse Gas Emissions

The proposed regulations are estimated to avoid 10.3 million metric tons of carbon dioxide (CO_2) between 2017 and 2029. Avoided electricity generation and associated greenhouse gas (GHG) emissions reductions vary directly with stringency of the energy efficiency alternatives. As with reductions in criteria emissions, there is significant uncertainty about the long-term electricity generation resources that will be displaced by the large electricity demand reductions that result from implementation of the alternative scenarios. For this assessment, staff estimated that efficiency impacts result in reduction of 690 pounds of CO_2 per megawatt-hour of electricity generation avoided.

The U.S. EPA provides a range of estimates for avoided global damages due to emissions of fossil CO_2.[27] A low value of $13 per metric ton CO_2 applied to the low lamp efficiency alternative yields a cumulative net present value GHG emission reduction benefit of $76.5 million over the 13-year analysis period. The total GHG benefit for proposed lamp efficiency standards, using a midpoint value for social cost of carbon at $47 per metric ton of CO_2, is roughly $373 million.

Annual GHG emissions damages avoided are $0.3 million in 2017 and increase to $30.6 million by 2029. Similar to the public health benefits of criteria emission reductions, GHG emission reduction benefit estimates also contain significant uncertainties. It is also important to recognize the vast amount of scientific and economic research that has been conducted on the public health and other impacts of both criteria and GHG emissions.

A second type of GHG emission reduction benefit is avoided cost of purchasing CO_2 allowances for California's Cap and Trade Program. The value of CO_2 allowance savings was estimated to

---

26 Emissions reductions for 2018 were used to model annual health benefits (minimal reductions occur in 2017), using a 3 percent discount rate for the high estimate and a 7 percent discount rate for the low estimate. Numerous simplifying assumptions are used to estimate annual public health benefit from reduced criteria emissions associated with avoided fossil fuel electricity generation from lamp efficiency standards.

27 For social cost of carbon, see http://www.epa.gov/climatechange/EPAactivities/economics/scc.html.

be $95 million over the analysis period, assuming an allowance value of $12 per metric ton. Avoided cost of CO_2 allowances is $0.7 million in 2017 and rises to $7.8 million in 2029.

Costs

The net present value of total residential spending on small-diameter directional lamps due to the proposed regulations is -$16 million over the 13-year period. Commercial businesses have much higher lamp usage rates than residential applications. Total commercial spending on small-diameter directional lamps declines by $507 million over the analysis period. Only in 2017 and 2018 do California businesses spend more on lamp replacement, as conventional halogen small-diameter directional lamps are replaced with higher retail-priced LED lamps. Businesses save millions of dollars in lamp replacement costs between 2019 and 2029 under all alternatives analyzed in this assessment. This same pattern is seen in the residential sector, but over a longer period of time due to the fewer hours of annual use. The lower number of hours means that the inefficient lamps will take longer to be replaced and it also means that savings from avoided replacements happen less frequently.

Residential incremental costs of general purpose LED lamps are estimated to be $16.9 million in 2017 and fall to $10.8 million by 2029. Total residential incremental costs over the 13-year period is $262.4 million in net present value terms. This figure is considerably smaller than the estimated residential electricity bill savings over that period of $902.9 million.

Table 12: Small-Diameter Directional Lamp Annual Costs – All Scenarios (undiscounted $2015)

	Residential (Million $2015)	Commercial (Million $2015)	Total (Million $2015)
2017	$0.0	$0.0	$0.0
2018	$4.9	$33.4	$38.3
2019	$5.0	-$54.4	-$49.4
2020	$5.0	-$61.0	-$56.0
2021	$5.1	-$61.8	-$56.7
2022	-$0.9	-$62.6	-$63.5
2023	-$6.2	-$63.4	-$69.6
2024	-$6.3	-$64.2	-$70.5
2025	-$6.4	-$65.1	-$71.5
2026	-$6.5	-$65.9	-$72.4
2027	-$6.6	-$66.8	-$73.3
2028	-$6.6	-$67.6	-$74.3
2029	-$6.7	-$68.5	-$75.2

Table 13: General Service LED Annual Lamp Costs – Residential (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$20.6	$16.9	$0.0
2018	$35.7	$27.6	$0.0
2019	$64.1	$47.7	$0.0
2020	$49.4	$37.4	$0.0
2021	$39.6	$30.5	$0.0
2022	$37.3	$28.8	$0.0
2023	$30.6	$24.1	$0.0
2024	$26.7	$21.3	$0.0
2025	$24.3	$19.6	$0.0
2026	$22.7	$18.3	$0.0
2027	$21.4	$17.4	$0.0
2028	$20.7	$16.8	$0.0
2029	$20.1	$16.3	$0.0

Table 14: General Service LED Annual Lamp Costs – Commercial (undiscounted $2015)

	Scenario		
	More Stringent (Million $2015)	Proposed (Million $2015)	Less Stringent (Million $2015)
2017	$0.8	$0.6	$0.0
2018	$1.1	$0.9	$0.0
2019	$1.8	$1.4	$0.0
2020	$1.4	$1.1	$0.0
2021	$1.1	$0.9	$0.0
2022	$1.0	$0.8	$0.0
2023	$0.8	$0.6	$0.0
2024	$0.7	$0.6	$0.0
2025	$0.6	$0.5	$0.0
2026	$0.6	$0.4	$0.0
2027	$0.5	$0.4	$0.0
2028	$0.5	$0.4	$0.0
2029	$0.5	$0.4	$0.0

Incremental costs of general service LED lamps to California businesses are estimated to be $0.6 million and declines to $0.3 million by 2029. Cumulative business costs for general purpose LED lamps under the proposed standards are estimated to be $7.3 million. This cost figure is much lower than the estimated electricity bill savings for California businesses from more efficient general purpose LED lamps of $78.3 million. The incremental cost per lamp remains fixed throughout the analysis period (see Table 3) and fluctuations year-over-year are directly related to the change in yearly baseline shipments. For example, the peak of costs in 2019 coincides with the peak of LED shipments seen in Figure 4 on page 9 of this report. As the shipments reach equilibrium so do costs.

CHAPTER 9:
Conclusion and Summary

The magnitude of economic impact is far greater than the $50 million dollar threshold for conducting a standardized regulatory impact assessment, with savings to consumers exceeding $4 billion over 10 years. As a percentage of the California economy, the scale of impact is relatively minor. The proposed regulations and alternative scenarios provide economic benefits to California across all metrics considered. These benefits include increased employment, competitiveness, personal income, and investment in the state.

The proposed standards will have a net cost to California consumers in 2017 of $13.2 million in net present value terms. This net cost in the first year of the regulations is due to aggregate spending on higher incremental costs of more efficient LED lamps combined with a lag in savings that results from lower lamp replacement expenditures over time. The proposed standards yield significant positive savings to consumers from 2018 ($266 million) through 2029 ($361 million).

The proposed standards provide greater net benefits to California than the less stringent scenario but slightly less net benefits than the more stringent scenario. The proposed standards are estimated to provide $903 million more net benefits than the less stringent alternative. The increased net benefits from the more stringent scenario total $270 million and suggest that additional economic benefit could be achieved. However, more stringent levels were developed by staff for this analysis and have not received review or comment from stakeholders involved in the pre-rulemaking efforts. Pursuing the more stringent levels could lead to significant delay in the implementation of small-diameter directional lamp and general service LED lamp standards, as the Energy Commission would seek to vet the more stringent standards with stakeholders before proceeding to the formal rulemaking. This delay in itself would cause a loss of the economic benefit characterized for the proposed standards in the assessment. For these reasons, the Energy Commission is likely to support the proposed scenario and levels in lieu of an alternative analyzed in this standardized regulatory impact assessment.

APPENDIX A:
Macroeconomic Modeling: Methods and Assumptions

This appendix provides a brief description of methods used to assess the macroeconomic impacts of proposed and alternative lamp energy efficiency standards for this standardized regulatory impact assessment. The impacts associated with jobs, investment, personal income, gross domestic product, and prices were estimated using the most current version of REMI PI+ Model (Version 1.7.2) that was purchased by the Energy Commission in July 2015. Staff used the single statewide region model (Build 3907) to assess these macroeconomic impacts.

Impacts were estimated for a 13-year period beginning in 2017 and ending in 2029. It is possible that new federal LED energy efficiency standards could replace the proposed standards before 2029. A shorter impact analysis period would reduce the estimated impacts provided within this assessment. A lengthy period of assessment is justified given that one LED lamp can last as long as six halogen or incandescent lamps that it replaces. The longer lifespan of LED lamps in low usage residential applications means that reduced lamp replacement costs can extend years into the future.

The inputs used to run the macroeconomic model include:

- Reduced residential spending on electricity
- Reduced commercial businesses spending on electricity
- Increased retail costs of LED lamps
- Reduced directional lamp replacement costs to all consumers
- Reduced sales of electricity
- Reduced sales and manufacturing of directional lamps

Seven variables were used to model the macroeconomic effects of three alternative levels of the lamp energy efficiency standards:

- – Consumer Spending – Electricity (Variable: 638)
- – Consumer Spending – Household Supplies (Variable: 628)
- – Consumer Reallocation – All Categories (Variable: 78)
- – Electricity Fuel Costs – All Commercial Sectors (Variable: 82)
- – Production Costs – Retail Trade (Variable: X7889)
- – Exogenous Final Demand – Electric Power Generation (Variable: X6409)
- – Exogenous Final Demand – Electric Lighting Equipment Manufacturing (Variable: X6447)

The electricity savings estimates were converted to estimates of utility bill savings to consumers and commercial businesses using population - and utility provider-based weighted averages of residential and commercial electricity prices. Estimates of retail electricity rates by service provider were obtained from the Energy Commission's *2014-2024 Baseline Final Forecast – Mid Demand Case*.[28] The average price trend over the last five years of the forecast was used to extrapolate retail prices for the period 2025-2029.

The residential electricity price ranged from $167,295 per GWh in 2017 to $190,956 per GWh in 2029. Commercial sector electricity rates were slightly lower than residential rates and ranged from $152,278 per GWh in 2017 to $173,149 in 2029. This is a simplified approach to estimation of electricity bill savings. There are several factors that introduce uncertainty into estimates of retail electricity prices over the next 15 years. The Energy Commission's retail electricity price forecast has a conservatively low annual rate of increase, which would tend to understate the magnitude of consumer electricity bill savings.

Economic impacts resulting from changes in criteria air pollutant emissions were estimated using the U.S. EPA COBRA Model.[29] Estimates of annual emission reductions in 2018 were used as inputs to the model. The emission factors are based upon simplistic assumptions about avoided electricity generation resources. The air pollutants modeled include small particulate matter (PM 2.5), sulfur dioxide (SO_2), and oxides of nitrogen (NO_x). A macroeconomic effect associated with reduced GHG emissions as a result of the proposed regulations was estimated using a social cost of carbon of $47 per metric ton of CO_2.[30]

All economic impact values reported in this analysis are in 2015 dollars. All net present value calculations use a 3 percent discount rate.

Two important caveats on assessment of the economic impacts are worth mentioning. First, the air quality benefits of the proposed regulations are likely understated due to quantification of only three types of criteria air pollutant reductions ($PM_{2.5}$, SO_2, and NOx) that result from reduced electricity generation. Omitted air quality benefits arise from reduced carbon monoxide and volatile organic compounds associated with some sources of electricity power generation.

A second caveat relates to unquantified economic impacts that are expected to result from implementing the proposed lamp energy efficiency standards but were too difficult to estimate for this analysis. No estimates are provided for electricity system benefits of reduced demand between 2017 and 2029 as a result of the proposed standards. Cumulative electricity demand will be reduced by 32.8 TWh by 2029, which should provide a range of benefits to California's electricity delivery systems.

---

28 The Energy Commission's 2014-2024 Baseline Final Forecast – Mid Demand Case, available at http://www.energy.ca.gov/2013_energypolicy/documents/demand-forecast/mid_case.

29 The U.S. EPA COBRA Model is available at http://epa.gov/statelocalclimate/resources/cobra.html.

30 The federal government uses standardized values of economic impacts of GHG emissions, based upon models of global climate change damages. Estimates of social cost of carbon are available at http://www.epa.gov/climatechange/EPAactivities/economics/scc.html.