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California Energy Commission

DRAFT STAFF REPORT

Analysis of Proposed Efficiency Standards for Linear Fluorescent Lamps Exempt from Federal Regulation

2019 Appliance Efficiency Rulemaking

Docket Number 18-AAER-08

California Energy Commission

Gavin Newsom, Governor

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California Energy Commission

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PREFACE

The Energy Policy Act of 1992 statutorily prescribed the first federal energy conservation standards for general service fluorescent lamps. The U.S. Department of Energy has twice amended the federal standards to more stringent efficiency levels. The 1992 statute explicitly excluded eight types of linear fluorescent lamps from the definition of general service fluorescent lamps:

(1) Fluorescent lamps designed to promote plant growth
(2) Fluorescent lamps specifically designed for cold temperature applications
(3) Colored fluorescent lamps
(4) Impact-resistant fluorescent lamps
(5) Reflectorized or aperture lamps
(6) Fluorescent lamps designed for use in reprographic equipment
(7) Lamps primarily designed to produce radiation in the ultra-violet region of the spectrum
(8) Lamps with a Color Rendering Index of 87 or greater[1]

These eight lamp types are exempt from the federal energy conservation standards for general service fluorescent lamps. Other linear fluorescent lamps not subject to the federal standards include lamps that do not meet the regulatory definition of a "fluorescent lamp" because of their shape or length, such as 2-foot, 3-foot, or circline fluorescent lamps.[2]

Among the linear fluorescent lamps not covered by federal energy conservation standards, there are four fluorescent lamp types commonly used in general lighting applications:

(1) Impact-resistant linear fluorescent lamps
(2) Linear fluorescent lamps with a color rendering index of 87 or greater
(3) 2-foot linear fluorescent lamps
(4) 3-foot linear fluorescent lamps

Energy efficiency standards for these four lamp types are technically feasible and cost effective, and would result in achieving significant energy savings and monetary savings for California consumers and businesses.

On January 19, 2018, the California Energy Commission issued an order instituting rulemaking to begin the process of considering efficiency standards, test procedures, labeling requirements, and other efficiency measures to amend the Appliance Efficiency Regulations (California Code of Regulations, title 20, §§1601-1609).[3] In the order instituting rulemaking, the

1 42 U.S.C. § 6291(30)(B).

2 10 C.F.R. 430.2.

3 https://efiling.energy.ca.gov/GetDocument.aspx?tn=222253&DocumentContentId=26676.

Energy Commission identified a variety of appliances, including high color rendering index linear fluorescent lighting, with the potential to save energy and/or water.

On April 4, 2018, 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 May 24, 2018.[4]

The Commission has reviewed all the information received. This report contains the draft proposed regulations for state-regulated linear fluorescent lamps.

4 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223131&DocumentContentId=31403.

ABSTRACT

This staff report discusses draft energy efficiency standards (California Code of Regulations, title 20, §§1601-1609) for certain types of linear fluorescent lamps that are not covered by federal energy conservation standards for general service fluorescent lamps. The scope of the draft standards includes impact-resistant linear fluorescent lamps, linear fluorescent lamps with a color rendering index of 87 or greater, and 2-foot and 3-foot linear lamps.

Staff proposes minimum efficiency standards for impact-resistant linear fluorescent lamps and linear fluorescent lamps with color rendering index of 87 or greater that are equivalent to the existing federal energy conservation standards for general service fluorescent lamps. Staff proposes to set a minimum efficiency standard for 2-foot and 3-foot linear lamps that are technology neutral and would apply to fluorescent and light-emitting diode light sources.

The draft standards would be effective one year after the California Energy Commission adopts regulations.

Energy Commission staff analyzed the cost effectiveness and technical feasibility of the draft standards. Statewide energy use, energy savings, and related environmental impacts and benefits are included in this report.

Keywords: Appliance Efficiency Regulations, energy efficiency, linear fluorescent, fluorescent, lamp, T12, T8, tube lamp, impact-resistant fluorescent, high-CRI, CRI, color rendering index, lighting, lamps, GSFL.

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EXECUTIVE SUMMARY

This report presents the California Energy Commission staff's analysis of draft efficiency standards for linear fluorescent lamps exempt from federal energy conservation standards.

Staff proposes new standards for four types of linear fluorescent lamps that are not covered by federal efficiency standards. The scope of the draft regulations covers impact-resistant linear fluorescent lamps and fluorescent lamps with a color rendering index (CRI) of 87 or greater, and 2-foot and 3-foot linear lamps. Staff proposes to define state-regulated general service fluorescent lamps as impact-resistant fluorescent lamps and fluorescent lamps with a color rendering index of 87 or greater, including only the following:

- 4-foot lamps with medium bipin base
- 4-foot lamps with standard output and miniature bipin base
- 4-foot lamps with high output and miniature bipin base
- 8-foot lamps with standard output and single pin base
- 8-foot lamps with high output and recessed double contact base
- 2-foot U-shaped lamps with medium bipin base

Staff proposes to define the term "less than 4-foot linear lamps" to include standard output 2-foot and 3-foot linear lamps with medium bipin or miniature bipin bases.

Staff proposes to set minimum energy efficiency standards for state-regulated general service fluorescent lamps that are aligned with the federal standards for general service fluorescent lamps.[5] Staff proposes to set a minimum energy efficiency standard for less than 4-foot linear lamps at approximately the average efficiency level for 2-foot and 3-foot linear light-emitting diode lamps. Staff proposes an effective date for covered products that are sold or offered for sale in California that is one year after adoption of any regulations.

Staff estimates the first year energy savings from the proposed standards to be 268.6 gigawatt-hours for state-regulated general service fluorescent lamps and 72.8 gigawatt-hours for less than 4-foot linear lamps. After complete stock turnover, energy savings are estimated to be 1,980 gigawatt-hours per year for state-regulated general service fluorescents and 914 gigawatt-hours per year for less than 4-foot linear lamps. This equates to over $293.8 million in annual monetary savings from reduced utility bills for state-regulated general service fluorescent lamps and $134.5 million in annual monetary savings from reduced utility bills for less than 4-foot linear lamps. The benefit-to-cost ratio of the draft standards ranges from 1.5 to 8.4, indicating a cost-effective proposal.

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5 Code of Federal Regulations, title 10, §430.32, available at https://www.ecfr.gov/cgi-bin/text-idx?SID=0407827eb2f4ee53c63ca242de3a07cf&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_132.

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[6] 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 total statewide costs and benefits of the standard over the lifetime of the standard, the economic effect on California businesses, and alternative approaches and the associated costs.

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

CHAPTER 2:
Efficiency Policy

The Warren-Alquist Act[7] establishes the California Energy Commission as California's primary energy policy and planning agency. Section 25402(c)(1) of the California Public Resources Code[8] mandates that the Energy Commission reduce the inefficient consumption of energy and water by prescribing efficiency standards and other cost-effective measures[9] for appliances that require a significant amount of energy and water to operate on a statewide basis.

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 efficiency standards have shifted the marketplace toward more efficient products and practices, reaping large 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 34,707 gigawatt-hours (GWh) of electricity in 2017 alone, resulting in about $8.26 billion in savings[10] to California consumers.[11] Since the mid-1970s, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. In addition, the California Public Utilities Commission (CPUC) in the 1990s 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.[12] There remains immense potential for additional savings by increasing the energy efficiency of appliances.

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7 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.

8 Cal. Pub. Resources Code § 25402(c)(1), available at http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25402.

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

10 Using current average electric power and natural gas rates of: residential electric rate of $0.182 per kilowatt-hour, commercial electric rate of $0.159 per kilowatt-hour, residential natural gas rate of $1.206 per therm, commercial natural gas rate of $0.846 per therm. This estimate does not incorporate any costs associated with developing or complying with appliance standards.

11 California Energy Commission. (2018, May 29). Workshops and Meetings for the 2017 Integrated Energy Policy Report - Committed Efficiency by Planning Area. Retrieved from California Energy Commission: https://www.energy.ca.gov/2017_energypolicy/documents/#demand.

12 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.

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)[13] and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016),[14] as well as the recommendations contained in the California Air Resources Board's (CARB) *Climate Change Scoping Plan.*[15] Energy efficiency regulations are also identified as key components in reducing electrical energy consumption in the *2015 Integrated Energy Policy Report* (*IEPR*)[16] and the 2011 update to the CPUC's *Energy Efficiency Strategic Plan.*[17] Finally, former 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.[18] California made this commitment to the Subnational Global Climate Leadership Memorandum of Understanding (Under 2 MOU) agreement along with 167 jurisdictions representing 33 countries.[19]

On October 7, 2015, former Governor Brown 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.[20] Appliance efficiency standards will be critical in meeting this goal.[21] 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

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13 AB 32, California Global Warming Solutions Act of 2006, available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32.

14 SB 32, California Global Warming Solutions Act of 2006, available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB32.

15 *Climate Change Scoping Plan* available at https://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf.

16 California Energy Commission, *2015 Integrated Energy Policy Report*, 2015, available at http://energy.ca.gov/2015_energypolicy/.

17 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.

18 Gov. Edmund G. Brown Jr., 2015 Inaugural Address, available at http://gov.ca.gov/news.php?id=18828.

19 Subnational Global Climate Leadership Memorandum of Understanding, available at http://under2mou.org/background/.

20 *Clean Energy & Pollution Reduction Act SB 350 Overview*, available at: https://www.energy.ca.gov/sb350/. *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.

21 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.

public buildings into energy-efficient buildings.[22] 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 growing energy needs.[23]

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.[24]

Zero-Net-Energy Goals

The *California Long-Term Energy Efficiency Strategic Plan*,[25] adopted in 2008 by the CPUC and developed with the Energy Commission, CARB, the state's utilities, and other key stakeholders, is California's roadmap to achieving maximum energy savings between 2009 and 2020, and beyond. It includes four "big, bold strategies" as cornerstones for significant energy savings with widespread benefit for all Californians:[26]

- All new residential construction in California will be zero-net energy (ZNE) by 2020.
- All new commercial construction in California will be ZNE by 2030.
- Heating, ventilation, and air conditioning (HVAC) will be transformed to ensure that energy performance matches California's climate.
- All eligible low-income customers will have the opportunity to participate in the low-income energy efficiency program by 2020.

These strategies were selected based on the ability to achieve significant energy efficiency savings and bring energy-efficient technologies and products into the market.

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22 *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.

23 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p. 2.

24 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p. 3.

25 California Energy Commission and CPUC, *Long-Term 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.

26 California Energy Commission and CPUC, *Long-Term Energy Efficiency Strategic Plan*, available at http://www.cpuc.ca.gov/NR/rdonlyres/14D34133-4741-4EBC-85EA-8AE8CF69D36F/0/EESP_onepager.pdf, p. 1.

On April 25, 2012, former Governor Brown further targeted ZNE consumption for state-owned buildings. Executive Order B-18-12[27] requires ZNE consumption for 50 percent of the square footage of existing state-owned buildings by 2025 and ZNE consumption from all new or renovated state buildings beginning design after 2025.

To achieve these goals, the Energy Commission has committed to adopting and implementing building and appliance regulations that reduce wasteful energy or water consumption. The *Long-Term Energy Efficiency Strategic Plan* directs the Energy Commission to develop a phased and accelerated "top-down" approach to more stringent codes and standards.[28] It also calls for expanding the scope of appliance standards to plug loads, process loads, and water use. The Commission adopted its detailed plan for fulfilling these objectives in the *2013 IEPR.*[29]

Governor Brown's Clean Energy Jobs Plan

On June 15, 2010, as a part of his campaign, former Governor Brown proposed the *Clean Energy Jobs Plan*,[30] 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.

Improving Energy Efficiency in Existing Buildings

Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) requires the Energy Commission, in collaboration with the CPUC and stakeholders, to develop a comprehensive program to achieve greater energy efficiency in California's existing buildings.[31] The Energy Commission adopted the Existing Buildings Energy Efficiency Action Plan on September 9, 2015, setting out a complementary portfolio of programs, projects, and practices that would achieve improved energy efficiency in existing buildings. The action plan highlights the increase in the energy consumption and number of plug-in appliances, or "plug loads," and the increasing share of the overall energy consumption of a building. As a result, a key strategy in the action plan is to set appliance efficiency standards for plug loads to improve the energy efficiency of these appliances.

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27 Office of Edmund G. Brown Jr., Executive Order B-18-12, April 25, 2012, available at https://www.gov.ca.gov/news.php?id=17508.

28 California Energy Commission and CPUC, *Long-Term Energy Efficiency Strategic Plan*, p. 64.

29 California Energy Commission, *2013 IEPR*, pp. 21-26.

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

31 *Existing Buildings Energy Efficiency Action Plan*, available at https://efiling.energy.ca.gov/getdocument.aspx?tn=206015.

CHAPTER 3: Background

Introduction

The Energy Policy and Conservation Act of 1975 directed the U.S. Department of Energy (DOE) to establish minimum energy conservation standards for household appliances including lamps. Congress set the first energy efficiency standards for certain types of general service fluorescent lamps (GSFL) through the Energy Policy Act of 1992 (EPAct). The standards went into effect in 1995. EPAct also required DOE to reevaluate these standards in two rulemaking cycles to determine whether they should be amended. In its first cycle of amendments in 2009, DOE modified GSFL standards and test procedures to include additional GSFLs with an effective date of July 2012. A significant number of manufacturers were granted a two-year waiver to continue manufacturing GSFLs that would not have complied with the new standards. In 2015, DOE published its second rulemaking amendment to update GSFL standards, which became effective on January 26, 2019.

However, certain types of fluorescent lamps are statutorily excluded from the scope of GSFLs, making them exempt from the federal energy conservation standards for GSFLs. Some of the most notable exclusions are impact-resistant fluorescent lamps and lamps with a color rendering index of 87 or greater. Other linear fluorescent lamps, such as those less than 4-feet in length, do not meet the federal definition of fluorescent lamps and are not covered by federal energy conservation standards. As a result, these unregulated lamps are often used in general lighting applications, resulting in wasted energy consumption. T12 fluorescent lamps, in particular, are very energy inefficient and remain on the market today as a result of the loopholes in the scope of coverage for GSFLs. Although shipments and sales of T12 fluorescent lamps vary among different sources, all indications show that their market share remains persistent (**Figure 3-8**). For example, a report prepared for the Massachusetts Energy Efficiency Advisory Council indicates a major supplier's estimated national sale of T12 lamps in 2014 was as high as 15 percent of all linear fluorescent lamps that they sold that year.[32] Northwest Energy Efficiency Alliance (NEEA) also stated in comments submitted on May 24, 2018,[33] in response to the Energy Commission's invitation to comment, that the market share of T12 lamps has remained reasonably consistent over time despite DOE's determination in its 2015 rulemaking that the market would likely shift away from T12 lamps.[34]

32 T12 Phase-out Market Research prepared for Massachusetts Energy Efficiency Advisory Council: http://ma-eeac.org/wordpress/wp-content/uploads/T12-Phase-Out-Market-Research-Final-Report.pdf.

33 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223571-1&DocumentContentId=53654.

34 80 Fed. Reg. 4042, 4055 (January 26, 2015).

Less than 4-foot linear fluorescent lamps are another category of lamps that are entirely excluded from the federal GSFL standards because they don't meet the definition of fluorescent lamps. New technologies, such as light-emitting diode (LED) technology, present significant energy-saving opportunities in these lamp types.

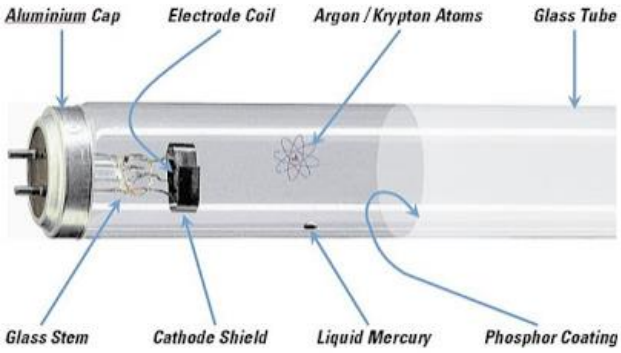
Together, these products present an exceptional opportunity to save energy by setting minimum energy efficiency standards that are technically feasible and cost effective. The purpose of the draft regulations is to close these loopholes and set energy efficiency standards for additional linear lamps.

Product Description

Linear lamps are a straight tubular-shaped class of lamps that typically incorporate one of two primary light source technologies – fluorescent or LED.

Linear lamps found in structures built prior to the last decade are predominantly fluorescent type. Linear fluorescent lamps, sometimes referred to as fluorescent tube lamps, have general applications in residential, commercial, and industrial buildings. In the residential sector, homes in California often have fluorescent tube lamps in their garages, laundry rooms, under kitchen cabinets, or in the kitchen. Linear fluorescent lamps are the dominant lighting technology in commercial and industrial buildings, such as in retail stores, offices, factories, and hospitals. The DOE's 2015 U.S. Lighting Market Characterization report estimated that there were more than 2.3 billion linear fluorescent lamps installed in the United States in 2015.[35]

Figure 3-1: Internal Elements of a Linear Fluorescent Lamp



Source: www.electraphysics.blogspot.com

Linear fluorescent lamps use fluorescent technology. These type of lamps normally consist of a glass tube filled with low-pressure mercury vapor, and argon or krypton gas that has phosphor coating on its internal surface and connects two metal electrode coils, called cathodes, one at

35 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

each end, as shown in **Figure 3-1**. When sufficient voltage is applied to cathodes, electrical current flows between two electrodes through the inert gas in the glass tube, which in turn excites the mercury vapor and produces ultraviolet light. However, because light photons with short wavelengths such as ultraviolet are invisible to human eyes, a phosphor powder coating on the tube's glass is utilized to convert the ultraviolet light to white light within the visible spectrum.

Linear Tube Lamps Form Factors

The most common tube sizes of linear tube lamps are what referred to as T12, T8, and T5 where the "T" stands for the tubular shape of the lamp and the subsequent number represents the tube's diameter in one-eighths of an inch. For example, T12 is a linear tube lamp with 1.5 inch (12/8 inch) diameter (**Figure 3-2**). Additionally, linear tube lamps are manufactured in various lengths. The most popular lengths are 2, 3, 4, and 8 feet.

Figure 3-2: Linear Tube Lamps

Source: www.earthled.com

Another notable characteristic of a linear tube lamp is its base type. The most common base types are bipin, single pin, and recessed double contact (**Figure 3-3**). The majority of linear tube lamps, such as those used in households or office buildings, have bipin bases.

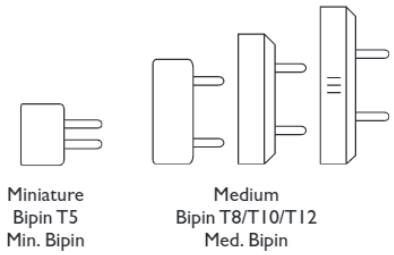
Figure 3-3: Linear Tube Lamp Bases

Source: www.earthled.com

Bipin bases are typically available in two sizes: medium bipin that are used for T8, T10, and T12 lamps, and miniature bipin used mostly for T5 lamps (**Figure 3-4**).

Single-pin fluorescent lamps operate with instant start ballasts. High-output and very high-output linear fluorescent tube lamps that draw higher current typically have recessed double contact bases.

Figure 3-4: Miniature Bipin and Medium Bipin Bases



Source: https://docplayer.net

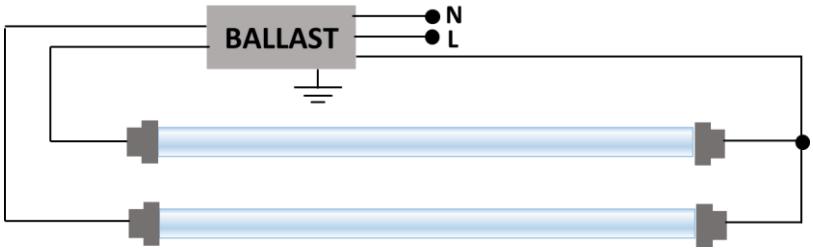
Linear LED lamps are made from solid state devices where two dissimilarly doped semiconductors are joined together to form a diode. This diode is illuminated when the electric current crosses through the junction causing the photonic energy equal to the band gap caused by the junction to be released. Linear LED lamps, also called tubular LEDs (TLED) are typically far more energy efficient than their counterpart linear fluorescent lamps. Linear LED lamps are viable replacement solutions for the majority of linear fluorescent lamps. There are several types of TLED lamps that can be retrofitted into existing lamp sockets as a direct replacement for linear fluorescent lamps without the need to replace the ballast.[36] Per Underwriters Laboratories (UL) categorization, there are three main types of TLED replacement lamps: type-A, type-B, and type-C.

UL Type-A Linear LED Lamps

Figure 3-5 shows an example of UL type-A circuit connections. UL type-A TLED lamps have an internal LED driver and offer the easiest installation among all types. They can be swapped with a fluorescent tube lamp without any modification to the existing fixture's structure. However, they are also the least efficient type of LED tube lamps because the existing fluorescent ballast remains connected in the lamp's electrical circuit and consumes power. Additionally, the life and the maintenance cost of the ballast affects the lifetime and the maintenance cost of the overall light fixture. Type-A TLED lamps are also limited in dimming and controllability, and the ballast compatibility should be verified prior to the installation.

36 https://www.energy.gov/sites/prod/files/2016/04/f30/mccullough_tleds_lightfair2016.pdf.

Figure 3-5: UL Type-A TLED Circuit Connection

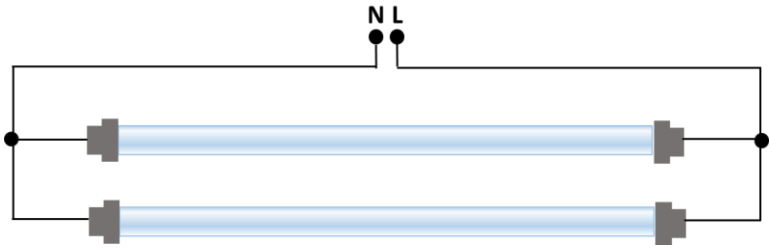


Source: Energy Commission Staff

UL Type-B Linear LED Lamps

UL type-B TLED lamps also have internal LED drivers. However, unlike type-A TLED lamps, type-B TLED lamps connect directly to the alternating current (AC) mains power. The installation of type-B TLED lamps require electrical modifications to the light fixture to remove the ballast and rewire electrical connections. **Figure 3-6** through **Figure 3-8** show typical circuit connections for different kinds of type-B TLED lamps.

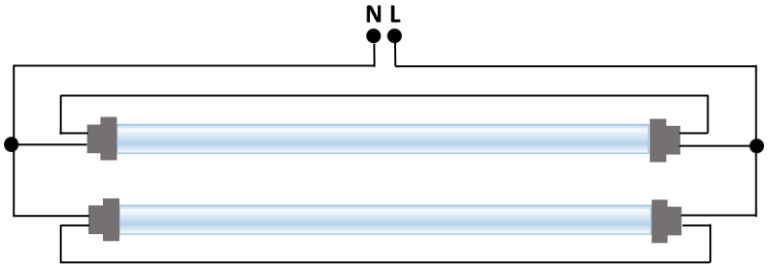
Figure 3-6: Example of UL's Type-B TLED Circuit Connection



Source: Energy Commission Staff

By removing the ballast, more energy is saved, ballast compatibility issues are eliminated, and maintenance cost is reduced compared to type-A TLED lamps. The light fixture's lifetime is not dependent on the ballast's life, which is a notable benefit considering that the average life of a ballast is shorter than the average life of a TLED. However, most type-B TLEDs are not dimmable.

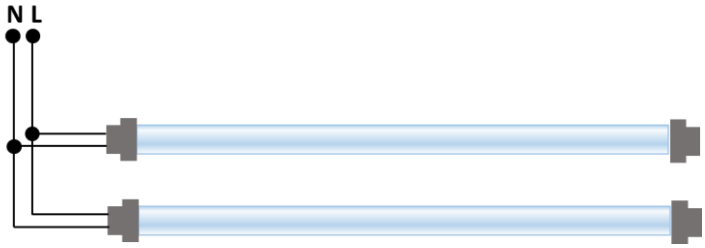
Figure 3-7: Example of UL's Type-B TLED Circuit Connection



Source: Energy Commission Staff

Since this type of LED lamp is powered directly from the AC mains power, installers should follow appropriate safety precautions. Additionally, there could be some serious safety risks when retrofitting existing fluorescent fixtures with LED lamps that require circuit connections similar to **Figure 3-7** or **Figure 3-8**. If an unsuspecting maintenance person inserts a fluorescent lamp into the retrofitted fixture by mistake, it will immediately short the circuit and present the risk of electrocution. This is because the pins of a bipin fluorescent lamp are internally connected causing the Null and Line wires to be shorted in these types of circuit connections. This issue does not apply to the circuit connection type in **Figure 3-6**; however, a fluorescent lamp inserted into this retrofitted fixture would not start because the ballast is removed.

Figure 3-8: Example of UL's Type-B TLED Circuit Connection



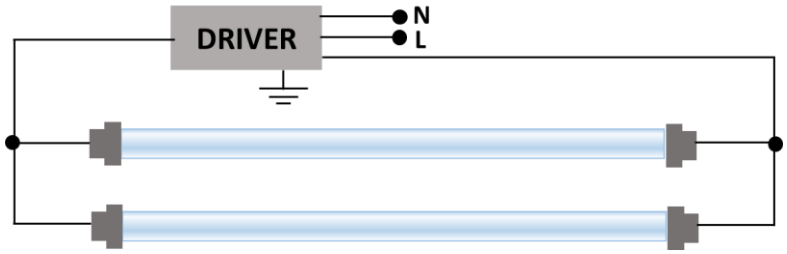
Source: Energy Commission Staff

UL Type-C Linear LED Lamps

In type-C TLED lamps, the LED driver is not integrated with the lamp, offering the opportunity to replace the lamp or the driver individually if either one fails. However, similar to type-B TLED lamps, retrofitting this type of lamp in existing light fixtures requires electrical alterations to remove the ballast and rewire the circuit connections.

Figure 3-9 and **Figure 3-10** show the schematic circuit connections where the LED driver is connected to the AC mains power and the lamps are powered through the driver.

Figure 3-9: Example of UL's Type-C TLED Circuit Connection

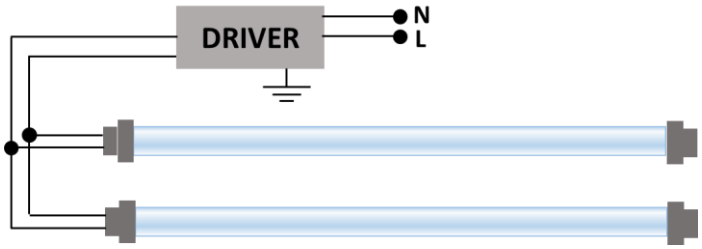


Source: Energy Commission Staff

Typically, multiple lamps can be powered through a single LED driver and because the driver's output is low voltage, it is safe to handle the lamps without the same precautions that are necessary when handling a lamp with line voltage connections. "Low voltage" refers to the

voltages less than or equal to 49 volts per American National Standards Institute (ANSI) C84.1 (240.20[A]), which specifies low voltage distribution (system voltage). “Line voltage” refers to the voltages that are greater than 49 volts per the same standard.

Figure 3-10: Example of UL's Type-C TLED Circuit Connection



Source: Energy Commission Staff

In addition, type-C TLED lamps offer more expanded performance capabilities such as compatibility with dimming systems.

Energy Use

Lighting generally is one of the largest sources of energy consumption in residential and commercial buildings. Nationally, linear fluorescent lamps account for roughly 27 percent of all installed lamps and consume the largest portion of energy consumed by all types of light technologies.[37] Energy efficiency of a lamp is based on the amount of visible light it produces compared to the amount of electrical power it consumes and has a unit of lumens per watt (lpw).

The average energy efficiency of linear fluorescent lamps is about 89 lpw.[38] Among the most popular sizes of linear fluorescent lamps, T5 lamps are the most efficient with an average efficiency of about 100 lpw; T12 lamps are the least efficient with an average efficiency ranging from 65 to 80 lpw; and T8 lamps have an average efficiency ranging 80 to 97 lpw.

Generally, LED lamps are the most energy efficient type of linear tube lamps with an average energy efficiency of about 115 lpw and reaching as high as 166 lpw.[39] Linear LED lamps are widely available in a variety of lengths and tube sizes. Although the TLED market is growing at a fast pace, more than 75 percent of linear tube lamp shipments are fluorescent.[40] When DOE

37 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

38 Ibid.

39 2016 US DOE’s report “The Lowdown on TLEDs”: https://www.energy.gov/sites/prod/files/2016/04/f30/mccullough_tleds_lightfair2016.pdf.

40 NEMA’s Q4, 2017 linear lamps indexes: https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-Year-Over-Year-Decline-in-Fourth-Quarter-2017-while-T-LED-Market-Penetration-Incre.aspx.

adopted more stringent minimum energy performance standards for GSFLs in 2009, it was assumed that energy inefficient lamps that are noncompliant, such as all T12 and some T8 lamps, would be entirely eliminated from the market within a few years after 2012 when the standards became effective.[41] Moreover, an earlier amendment to federal energy conservation standards for fluorescent ballasts, essentially requiring all new ballasts to be electronic starting in 2005, was expected to help accelerate the market entirely away from T12 lamps. However, according to the DOE's 2015 U.S. Lighting Market Characterization (LMC) report, there was an estimated inventory of about 600 million T12 lamps in 2015 in the United States. This number indicates that the rate of decline of these inefficient lamps has been dramatically slower than what was expected by DOE. **Table 3-1** summarizes estimated national and state inventory and market share for linear tube lamps collected from DOE's 2015 LMC report.[42]

Estimated inventory of linear tube lamps in California is obtained by prorating the national inventory of lamps by 12.09 percent, which is the ratio of California's population compared to the entire United States population.[43]

Table 3-1: Estimate of Linear Tube Lamps Inventory and Market Share

Linear Tube Lamp Type	US Inventory (2015)	California Inventory (2015)	Estimated Share
FL T12	593,414,000	72,040,460	26.26%
FL T8	1,499,974,000	182,096,844	66.38%
FL T5	141,061,000	17,124,805	6.24%
LED	25,302,000	3,071,663	1.12%
Total	2,259,751,000	274,333,772	100.00%

Source: Energy Commission staff

Data from the National Electrical Manufacturers Association (NEMA) for the fourth quarter of 2017 indicates that T12 lamps still account for 11.4 percent of national linear tube lamp shipments.[44] This percentage has remained relatively stable since 2015 (**Figure 3-11**).

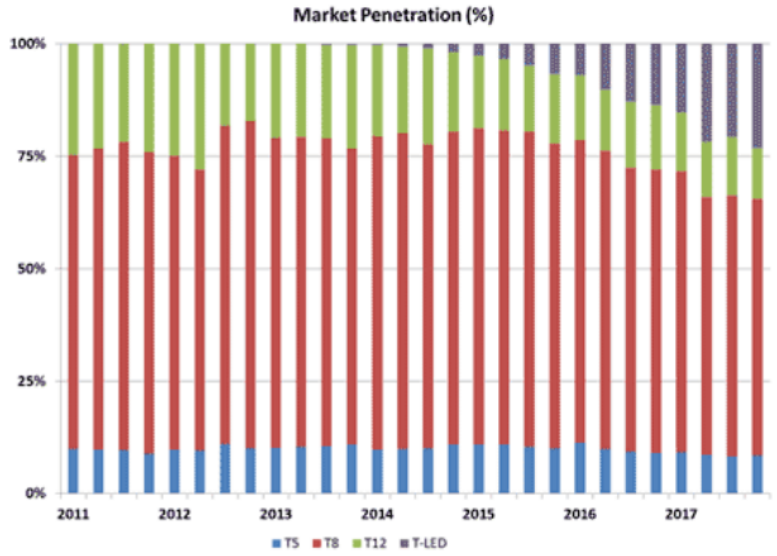
41 In the April 2009 notice of proposed rulemaking for General Service Fluorescent Lamps and Incandescent Reflector Lamps, DOE predicted that all T12 lamps are effectively eliminated from the market at GSFL's TSL4: https://www.regulations.gov/document?D=EERE-2006-STD-0131-0004. DOE adopted TSL4 in its 2009 final rule: https://www.govinfo.gov/content/pkg/FR-2009-07-14/pdf/E9-15710.pdf.

42 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

43 2015 population estimates are obtained from the U.S. Census Bureau: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk.

44 https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-Year-Over-Year-Decline-in-Fourth-Quarter-2017-while-T-LED-Market-Penetration-Incre.aspx.

Figure 3-11: Market Penetration of Linear Fluorescent Lamps



Source: National Electrical Manufacturers Association

This trend is consistent with the data submitted by the Northwest Energy Efficiency Alliance (NEEA) for the Northwest market (**Figure 3-12**). It indicates the market share of high CRI linear fluorescent lamps, where the vast majority are T12, has remained relatively constant since 2016.[45]

T12 lamps can only continue to be sold legally in the United States because of statutory exemptions from the federal regulations.[46] The vast majority of such inefficient lamps, with the exception of a few true specialty lamps, are either impact-resistant lamps or lamps with a CRI of 87 or greater, causing them to be exempt from the federal GSFL standards. At the time of the DOE rulemaking in 2009, these types of lamps were recognized as specialty lamps because they were expensive and had limited market offerings. However, as noted in the comments,[47] by 2017, major lighting manufacturers offered entire lines of low-cost, low-efficiency T12 lamps that take advantage of the federal exemptions. Comments from NEEA indicate that the marketshare for high-CRI lamps is growing.[48] These loophole lamps are no longer specialty lamps. They are inexpensive and inefficient replacements for failed T12 fluorescent lamps, which run mostly on magnetic ballasts, resulting in energy waste for both the lamp and the ballast.

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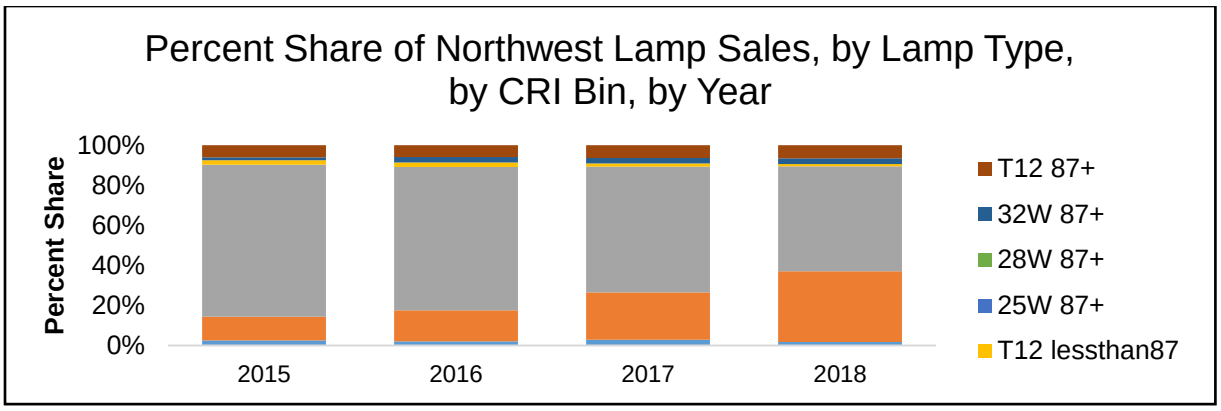
45 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223571-2&DocumentContentId=53653.

46 42 U.S.C. § 6291(30)(B).

47Comments by ASAP, ACEEE, NRDC, and NEEP: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223576&DocumentContentId=53664.

48 Comments from NEEA: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223571-1&DocumentContentId=53654.

Figure 3-12: Share of Northwest Lamp Sales



Source: Northwest Energy Efficiency Alliance (NEEA)

Another group of lamps excluded from federal regulations that present an opportunity for energy savings are 2-foot and 3-foot linear lamps, with an average energy efficiency of about 65 lpw, less than 4-foot lamps have the lowest average energy efficiency among all linear fluorescent lamps.[49] More energy efficient retrofit linear LED lamps and fixtures are widely available on the market.

49 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

CHAPTER 4:
Regulatory Approaches

Federal Approaches

There are federal efficiency standards and test procedures for GSFLs. The first minimum energy performance standards for fluorescent lamps were established by the national Energy Policy Act of 1992 (EPAct 1992). In July 2009, DOE amended the standards for GSFLs to extend the scope to include additional lamps and to adopt test procedures for the newly covered GSFLs. These amended standards became effective in July 2012.

In its second rulemaking cycle, DOE amended the GSFL energy conservation regulations with more stringent standards and published its final rule on January 26, 2015, with the effective date of January 26, 2018.

Federal regulations define fluorescent lamps as low pressure mercury electric-discharge source in which a fluorescing coating transforms some of the ultraviolet energy generated by the mercury discharge into light and only includes the following:

- Any straight-shaped lamp (commonly referred to as 4-foot medium bipin lamps) with medium bipin bases of nominal overall length of 48 inches and rated wattage of 25 or more;
- Any U-shaped lamp (commonly referred to as 2-foot U-shaped lamps) with medium bipin bases of nominal overall length between 22 and 25 inches and rated wattage of 25 or more;
- Any rapid start lamp (commonly referred to as 8-foot high output lamps) with recessed double contact bases of nominal overall length of 96 inches;
- Any instant start lamp (commonly referred to as 8-foot slimline lamps) with single pin bases of nominal overall length of 96 inches and rated wattage of 49 or more;
- Any straight-shaped lamp (commonly referred to as 4-foot miniature bipin standard output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 25 or more; and
- Any straight-shaped lamp (commonly referred to 4-foot miniature bipin high output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 44 or more. [50]

50 Code of Federal Regulations, title 10, §430.2, available at https://www.ecfr.gov/cgi-bin/text-idx?SID=0407827eb2f4ee53c63ca242de3a07cf&mc=true&node=pt10.3.430&rgn=div5#se10.3.430_12.

Federal statute[51] defines a subset of these fluorescent lamps that can be used to satisfy the majority of fluorescent lighting applications as general service fluorescent lamps. However, the following lamps are statutorily excluded from the definition of GSFLs:

- Fluorescent lamps designed to promote plant growth;
- Fluorescent lamps specifically designed for cold temperature applications;
- Colored fluorescent lamps;
- Impact-resistant fluorescent lamps;
- Reflectorized or aperture lamps;
- Fluorescent lamps designed for use in reprographic equipment;
- Lamps primarily designed to produce radiation in the ultra-violet region of the spectrum; and
- Lamps with a Color Rendering Index (CRI) of 87 or greater.

Federal regulations define lamp efficiency as the ratio of the lamp's measured lumen output to the lamp's measured electrical power input, in units of lumens per watt (lpw). A lamp's lumen output defines its brightness. It is the total luminous flux produced by the lamp, in units of lumens. A lamp's electrical power input is the total electrical power input to the lamp, including both arc and cathode power, in units of watts.

Table 4-1 shows current federal energy conservation standards for GSFLs with the minimum energy efficiency in lpw.

Table 4-1: Federal Standards for Linear Fluorescent Lamps

Lamp Type	Correlated Color Temperature (Kelvin)	Minimum Efficiency (lpw)
4-foot medium bipin	≤ 4,500	92.4
	> 4,500 and ≤ 7,000	88.7
2-foot U-shaped	≤ 4,500	85
	> 4,500 and ≤ 7,000	83.3
8-foot slimline	≤ 4,500	97
	> 4,500 and ≤ 7,000	93
8-foot high output	≤ 4,500	92
	> 4,500 and ≤ 7,000	88

51 U.S. Code, Title 42, §6291(30)(B).

Lamp Type	Correlated Color Temperature (Kelvin)	Minimum Efficiency (lpw)
4-foot miniature bipin standard output	≤ 4,500 > 4,500 and ≤ 7,000	95 89.3
4-foot miniature bipin high output	≤ 4,500 > 4,500 and ≤ 7,000	82.7 76.9

Source: Code of Federal Regulations, Title 10, section 430.32(n)(4)

There are no federal minimum energy efficiency standards for less than 4-foot linear fluorescent lamps and no federal minimum energy efficiency standards for linear LED lamps.

Other State Approaches

Colorado, Hawaii, Vermont, and Washington recently adopted test procedures and minimum efficiency requirements for high-CRI fluorescent lamps at levels consistent with federal standards for general service fluorescent lamps. The statutes of these states define a high-CRI fluorescent lamp as a fluorescent lamp with a color rendering index of 87 or greater that is not a compact fluorescent lamp. Connecticut, Massachusetts, Rhode Island, and Washington, D.C. are considering setting standards for high-CRI fluorescent lamps. However, no other state has any standards for other linear fluorescent lamps that are exempted from the federal regulations, such as impact-resistant lamps, less than 4-foot linear fluorescent lamps, or linear LED lamps.

Stakeholder Proposals Received

The California Statewide Investor Owned Utilities (IOUs) Codes and Standards Enhancement (CASE) Program submitted a CASE report in response to the Commission's invitation to comment.[52] The CASE team recommended standards for 4-foot and 8-foot high-CRI and impact-resistant linear fluorescent lamps, and 2-foot and 3-foot linear fluorescent lamps with energy efficiency levels for all lamps consistent with the efficiency levels that are currently only achievable through LED technology.

Philips Lighting proposed no state standards for linear fluorescent lamps with CRI of 87 or higher, commonly referred to as high-CRI linear fluorescent lamps, citing skepticism that any state regulation would be cost effective.[53]

52 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223787&DocumentContentId=53983.

53 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223535&DocumentContentId=53609.

NEMA also proposed no state standards for high-CRI linear fluorescent lamps stating that they will naturally exit the market without state regulatory action.[54]

The Appliance Standards Awareness Project (ASAP), American Council for an Energy-Efficient Economy (ACEEE), Natural Resources Defense Council (NRDC), and Northeast Energy Efficiency Partnerships (NEEP) proposed the current minimum energy efficiency requirements for the federal GSFLs for high-CRI fluorescent lamps. Additionally, they proposed to consider the other more ambitious proposals by the IOU CASE team.[55]

The Northwest Energy Efficiency Alliance (NEEA proposed to set standards for federally exempted linear fluorescent lamps and in particular high-CRI lamps, that are similar to those for the federally regulated products, to close the loopholes created by the federal exemptions.[56]

54 https://efiling.energy.ca.gov/GetDocument.aspx?tn=224236&DocumentContentId=54498.

55 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223576&DocumentContentId=53664.

56 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223571-1&DocumentContentId=53654.

CHAPTER 5:
Alternative Considerations

Energy Commission staff considered three alternative standards based on the stakeholder proposals received: (1) maintaining the status quo and proposing no state standards for linear lamps; (2) a more stringent minimum efficiency standard for state-regulated GSFL; and (3) federal minimum efficiency standards for "loophole" lamps and LED efficiency levels for less than 4-foot linear lamps.

The second alternative would eliminate impact-resistant linear fluorescent lamps and linear fluorescent lamps with CRI of 87 or higher and replace them with linear LED lamps. The third alternative would require impact-resistant linear fluorescent lamps and linear fluorescent lamps with CRI of 87 or higher to meet the same minimum efficiency standards as most other linear fluorescent lamps, and would replace less than 4-foot linear fluorescent lamps with linear LED lamps.

Alternative 1: No State Standards for Linear Fluorescent Lamps

Philips Lighting and NEMA proposed no state standards for linear fluorescent lamps. Staff evaluated the effect of not setting standards for linear fluorescent lamps. As the energy and cost analysis in Chapter 8 shows, the proposed standards are extremely cost effective and forgoing regulations means forgoing significant energy savings and monetary benefits to California consumers and businesses from the standards. Moreover, sales of T12 lamps have not been phased out as fast as predicted by DOE and NEMA.[57] There are no positive benefits for California to forgoing regulation. As a result, this alternative was not chosen.

Alternative 2: More Stringent Minimum Efficiency Standard for State-Regulated GSFLs

For all lamps in the scope of this proposal, the CASE team suggested setting the efficiency levels higher than the federal standards, at levels consistent with the average efficiency of linear LED lamps. Although it would be technically feasible and cost effective to set the standards at those higher efficiency levels, staff believes that for the high-CRI and impact-resistant linear fluorescent lamps, it would create an inconsistency with the federal regulations. This might encourage some manufacturers to purposefully lower the lamp's CRI, or change the impact-resistance properties of the lamp in order to be subjected to the lower DOE GSFL

57 In the April 2009 notice of proposed rulemaking for General Service Fluorescent Lamps and Incandescent Reflector Lamps, DOE predicted that all T12 lamps are effectively eliminated from the market at GSFL's TSL4: https://www.regulations.gov/document?D=EERE-2006-STD-0131-0004. DOE adopted TSL4 in its 2009 final rule: https://www.govinfo.gov/content/pkg/FR-2009-07-14/pdf/E9-15710.pdf.

standards and be able to continue using a fluorescent light source. Setting standards for state-regulated GSFLs, and particularly for high-CRI linear fluorescent lamps that are higher than the federal standard levels will also create inconsistency with the other three states that have set, or are in the process of setting, their standards for these lamps.

Furthermore, the higher efficiency standards for these types of lamps do not necessarily result in higher energy savings, as the lamp types affected merely represent loophole products. Because consumers who want to replace their non-compliant linear fluorescent lamps with linear fluorescent lamps, simply choose a federally-compliant GSFL or TLED that matches the form factor they need, a higher standard would not compel such consumers to choose LED lamps given that federally-compliant GSFLs will continue to exist. Therefore, this alternative for state-regulated GSFLs was not chosen.

However, staff is proposing the higher energy efficiency levels recommended by the CASE team for the less than 4-foot linear lamps because these type of lamps are not subject to any federal or state standards and the noted inconsistencies do not apply to them.

Alternative 3: Federal Minimum Efficiency Standards for Loophole Lamps and LED Efficiency Levels for Less than 4-foot Linear Lamps

For high-CRI and impact-resistant linear fluorescent lamps, energy efficiency standards with levels consistent with the federal standards for GSFLs are considered to create consistency with the federal efficiency standards for GSFLs and the efficiency standards in other states for high-CRI lamps. This proposal saves significant amount of energy by closing the loopholes in the federal regulations that exempt such products from GSFL minimum efficiency standards.

For 2-foot and 3-foot linear lamps, minimum efficiency standards with levels consistent with the efficiencies of linear LED lamps are proposed to maximize the energy savings. Currently, there are no federal or other state standards for any type of straight linear lamps that are shorter than four feet. Therefore, unlike the high-CRI and impact-resistant linear fluorescent lamps, consistency with other standards is not a consideration for this group of lamps.

This alternative saves significant energy, is cost effective, and is technically feasible; therefore, staff proposes alternative 3.

CHAPTER 6:
Staff Proposal for Linear Fluorescent Lamps

Based on the best available data, Energy Commission staff has analyzed energy savings, Cost effectiveness, and technical feasibility of regulating linear fluorescent lamps that are frequently used in general lighting applications but are not in the scope of federal regulations. Staff has determined that the proposed standards would save significant energy and are extremely cost effective for California consumers and businesses. The proposed standards are technically feasible and are attainable with products available on the market.

In this chapter, the proposed scope, definitions, test procedures, efficiency standards, certification, and marking requirements for state-regulated GSFLs and less than 4-foot linear lamps are presented.

Scope and Definition

Staff proposes to cover state-regulated GSFLs and less than 4-foot linear lamps in the scope of this rulemaking. The products covered under this proposal are used in general lighting applications, have technically feasible and cost-effective replacements, and present an opportunity for significant energy savings.

Staff proposes to define a new term called state-regulated general service fluorescent lamps, which includes impact-resistant linear fluorescent lamps and linear fluorescent lamps with a CRI of 87 or greater. This definition clarifies what products are included in the scope of the proposed regulation. It adds these two categories of lamps but is otherwise aligned with the federal definition of the GSFL. State-regulated GSFLs only includes lamps with same specific form factors that are included for federally-regulated GSFLs for purposes of consistency. Those are 4-foot lamps with a standard output and medium- or miniature-bipin base, 4-foot lamps with a high output and miniature-bipin base, 8-foot lamps with a standard output and single-pin base, 8-foot lamps with a high output and recessed double-contact base, and 2-foot U-shaped lamps with medium-bipin base.

Staff also proposes to define a new term called less than 4-foot linear lamps, which are defined as straight-shaped lamps with nominal overall lengths of 2 feet or 3 feet. It identifies which types of less than 4-foot lamps are included in the proposed scope of covered products. Although this definition closely follows the federal definition of GSFL, it is intended to be agnostic in terms of the lighting source technology. Less than 4-foot linear lamps are limited to medium-bipin and miniature-bipin bases. Staff believes these lamps have a general application, and LED lamp replacements are widely available.

State-regulated GSFLs and less than 4-foot linear lamps do not include the following types, consistent with the remaining statutory exclusions for federally-regulated GSFLs:

- Lamps designed to promote plant growth;

- Lamps specifically designed for cold temperature applications;
- Colored lamps;
- Reflectorized or aperture lamps;
- Lamps designed for use in reprographic equipment; and
- Lamps primarily designed to produce radiation in the ultra-violet region of the spectrum.

State-regulated GSFLs are limited to fluorescent light source technology, while the less than 4-foot linear lamps include all light source technologies.

Test Procedure

For linear fluorescent lamps that are in the scope of state-regulated GSFLs, staff proposes to use the same federal test procedure as is mandatory for federally regulated GSFLs.[58] Adopting this test procedure aligns with the test procedure required in other states for high-CRI linear fluorescent lamps. Linear LED lamps that can be used as substitutes for state-regulated GSFLs do not have any testing requirements, because they are not in the scope of staff's proposal.

Fluorescent lamps currently available and in the scope of less than 4-foot linear lamps, do not comply with the proposed efficiency standards. However, if less than 4-foot linear fluorescent lamps that can meet these standards are developed, staff proposes they be tested using the same test procedure as the state-regulated GSFLs because the lamp's length does not have any affect in the test procedure.

LED lamps that fall under the scope of less than 4-foot linear lamps are either integrated LED, where the lamp and driver are packaged in the same housing (e.g., type-A and type-B linear LED retrofit lamps) or non-integrated LED (e.g., type-C linear LED retrofit lamps). For less than 4-foot type-A and type-B linear LED lamps, staff proposes to use the federal test procedure for integrated LED lamps.[59] For less than 4-foot type-C linear LED lamps, staff proposes to use the federal test procedure for non-integrated LED lamps.[60]

These federal test procedures measure the necessary data for correlated color temperature (CCT), CRI, and efficiency.

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58 Code of Federal Regulations (CFR), Title 10, §430.23(r) and Appendix R to Subpart B of part 430—*Uniform Test Method for Measuring Average Lamp Efficacy (LE), Color Rendering Index (CRI), and Correlated Color Temperature (CCT) of Electric Lamps.*

59 CFR, Title 10, §430.23(ee) and Appendix BB to Subpart B of part 430—*Uniform Test Method for Measuring the Input Power, Lumen Output, Lamp Efficacy, Correlated Color Temperature (CCT), Color Rendering Index (CRI), Power Factor, Time to Failure, and Standby Mode Power of Integrated Light-Emitting Diode (LED) Lamps.*

60 CFR, Title 10, §430.23(gg)(6) and Appendix DD to Subpart B of part 430—*Uniform Test Method for Measuring the Energy Consumption and Energy Efficiency of General Service Lamps That Are Not General Service Incandescent Lamps, Compact Fluorescent Lamps, or Integrated LED Lamps.*

Efficiency Standards

As noted previously, lamps in the scope of state-regulated GSFLs are those excluded from the federal regulations based on the lamp's CRI value or its impact-resistant properties. Staff proposes to align the state-regulated GSFL standards with the federal efficiency standards for federally regulated GSFLs to establish consistency between state and federal standards for these similar products. Although setting higher efficiency levels for state-regulated GSFLs is still cost effective and attainable through available LED lighting sources, it would create an inconsistency without additional benefits because less efficient federally regulated GSFL replacement lamps that have lower CRI or are not impact-resistant will always be available. The proposed efficiency levels will close a loophole in the federal regulations and thereby offer significant cost-effective and technically feasible energy savings to California.

Because there are no federal regulations for linear lamps that are less than 4-foot, staff proposes a minimum efficiency standard of 115 lpw, consistent with the average efficiency of available linear LED lamps. This efficiency level is higher than the efficiency for state-regulated GSFLs and currently can only be met using LED light sources. The proposed efficiency levels have higher potential energy savings, that are cost effective and technically feasible, than the federally-regulated GSFL efficiency levels. Because this category of lamps is entirely unregulated, the higher efficiency levels would not result in inconsistences with other standards.

Both efficiency standards are proposed to be effective one year after adoption by the full Commission and would apply to products manufactured on or after that date.

Certification Requirements

Staff proposes that all linear lamps within the scope of state-regulated GSFLs and less than 4-foot linear lamps that are sold or offered for sale in California, must be certified to the Energy Commission as meeting the proposed requirements when tested per required test procedures. Linear LED lamps that can be used as substitutes for state-regulated GSFLs do not have any certification requirements because they are not in the scope of staff's proposal.

Marking Requirements

Staff does not propose any new product-specific labeling or marking requirements for linear lamps within the scope of state-regulated GSFLs or less than 4-foot linear lamps. However, the existing, general marking requirements are applicable. These require the name, model number, and the date of manufacture to be permanently, legibly, and conspicuously placed on the lamp itself or on the unit(s) packaging.[61] Federal regulations require GSFLs to be labeled with an encircled "E" to indicate compliance with federal minimum efficiency standards. Although, the proposed standards for state-regulated GSFLs and less than 4-foot linear lamps are at levels

61 California Code of Regulations, title 20, §1607(b).

that meet or exceed the federal minimum efficiency standards, staff does not propose such marking to avoid confusion with products in the scope of federal regulations.

CHAPTER 7:
Technical Feasibility

Non-compliant lamps within the proposed scope of this rulemaking have six form factors:

- 4-foot
- 2-foot U-shaped
- 8-foot standard output (SO)
- 8-foot high output (HO)
- 2-foot, and 3-foot

To determine the technical feasibility of the proposed standards, Energy Commission staff evaluated available linear and U-shaped lamps with different types of lighting technologies. This includes fluorescent and LED types that could replace the inefficient and non-compliant lamps.

State-Regulated General Service Fluorescent Lamps

For 4-foot and 8-foot SO state-regulated GSFLs, staff found several fluorescent T8 lamps on the market that meet or exceed the proposed efficiency standards. For impact-resistant state-regulated GSFLs, in particular, there are a number of moderately priced linear LED and fluorescent T8 and T5 lamps available that comply with the proposed efficiency levels. For 2-foot U-shaped lamps, there are LED lamps and fluorescent replacement lamps on the market that can comply with the proposed standards.

For state-regulated GSFLs with CRI of 87 or higher, staff found one T8 fluorescent lamp model[62] on the market that has a CRI above 87 and that exceeds the proposed energy efficiency levels with a price comparable to typical T8 lamps. This shows that it is technologically feasible to produce high-CRI fluorescent lamps that comply with the proposed standards without a considerable incremental price. Moreover, there are ample fluorescent lamp models on the market with a CRI of 85 that meet or exceed the proposed efficiency levels. These can potentially replace non-compliant lamps. Although the CRI of 85 is slightly lower than the minimum CRI of 87 for the lamps in the high-CRI category, the difference is not likely to be noticeable for most consumers and may serve as a potential replacement option for state-regulated GSFLs. Moreover, the energy efficiency of most of the lamps that have CRI of 85 exceeds the proposed efficiency levels. This means potentially improving the CRI of those lamps by a few points would not drastically reduce their efficiency and would still put them in compliance with the proposed efficiency standards.

62 https://www.1000bulbs.com/product/56690/F-32L359.html.

Linear LED lamps are another energy efficient and feasible replacement option. The manufacturer costs and retail prices of LED lamps have been dropping continuously and their market share has been increasing since they were introduced. It is expected that the price of these lamps will continue to fall and their market share will continue to grow as more products become available.[63] Linear LED lamps are available in a variety of bases (single, bipin, miniature bipin, etc.), diameters (T5, T8, T12, etc.), and lengths. There are three types of linear LED lamps that can retrofit linear fluorescent lamps as explained in Chapter 3. Regardless of type, LED lamps far surpass the proposed energy efficiency levels. Type-B and type-C linear LED lamps are more energy efficient than type-A lamps because they both bypass the energy wasting magnetic ballasts used with the vast majority of existing T12 lamps.

Energy Commission staff concluded that 4-foot and 8-foot SO state–regulated GSFL lamps can be replaced with either T5 or T8 linear fluorescent lamps or LED linear lamps. T5 fluorescent lamps are typically more energy efficient than T8 fluorescent lamps without a significant price difference. However, for the energy and cost calculations, staff made a more conservative assumption that all of the fluorescent replacement lamps are T8.

For the replacement of 8-foot HO impact resistant lamps, there are several energy efficient fluorescent T8 lamp options available. For 8-foot high-CRI HO lamps, there are several T8 lamps with a CRI of 85 and 86 available. Although the CRI of these lamps is slightly lower than the minimum CRI of 87 to be considered high-CRI lamps, the difference is most likely not perceivable to the average consumer, and these lamps could be considered as replacement lamps. The energy efficiency of the lamps with a CRI of 85 and 86 is higher than the proposed efficiency levels. Improving the CRI of those lamps by a few points would not significantly reduce their energy efficiency and they would still meet the proposed standards.

Although there are also several models of 8-foot HO linear LED lamps on the market, their lumen output does not go beyond 5,500 lumens. For that reason, all replacement lamps for 8-foot HO are assumed to be fluorescent type.

Less than 4-foot Linear Lamps

In general, LED lamps provide far better electrical energy efficiency and longer lifespan than any other lighting technologies, including fluorescent. With the increasing popularity of LED lamps, their market share is steadily growing and new models enter the market constantly with improved light quality and energy efficiency, and covering wider ranges of output lumens.

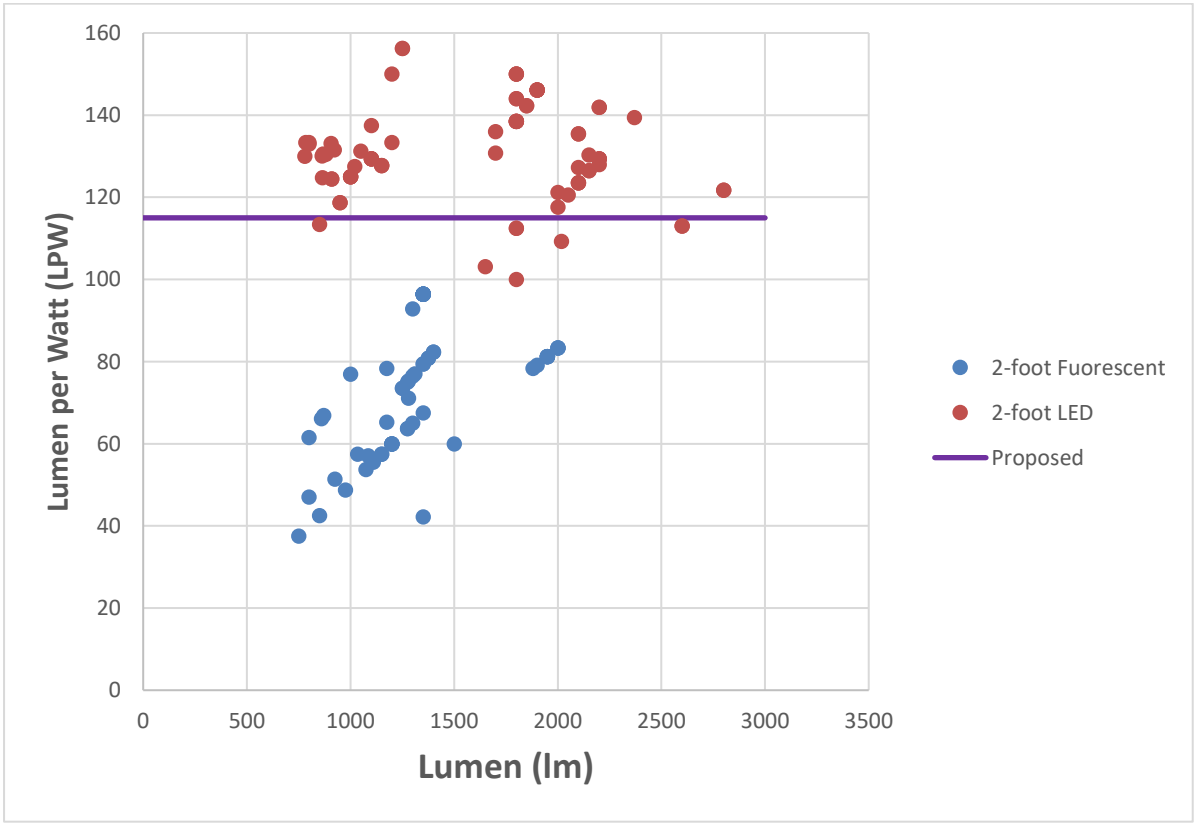
Less than 4-foot lamps in the scope of this proposal include 2-foot and 3-foot lamps with standard output brightness and medium-bipin or miniature-bipin bases. The proposed

63 Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps: https://www.eenews.net/assets/2017/05/04/document_gw_04.pdf.

efficiency requirement for less than 4-foot lamps is about the average efficiency for linear LED lamps driven from the Design Lights Consortium (DLC®) database.[64] Staff analyzed available 2-foot and 3-foot linear LED lamps on the market in terms of light output and energy efficiency to ensure the technical feasibility of the proposed standards. There are numerous linear LED lamps on the market that can retrofit 2-foot or 3-foot linear fluorescent lamps.

Figure 7-1 shows a sample of 2-foot LED lamps on the market along with the 2-foot fluorescent lamps in the scope of this proposal. This result shows that there are compliant LED lamps available on the market to replace any 2-foot fluorescent lamp in the scope of this proposal. Similarly, **Figure 7-2** shows 3-foot linear LED lamps on the market and 3-foot fluorescent lamps in the proposed scope. It shows that compliant LED lamps are available for light output brightness ranges that is expected for standard output lamps. Therefore, the proposed standards are technically feasible and attainable.

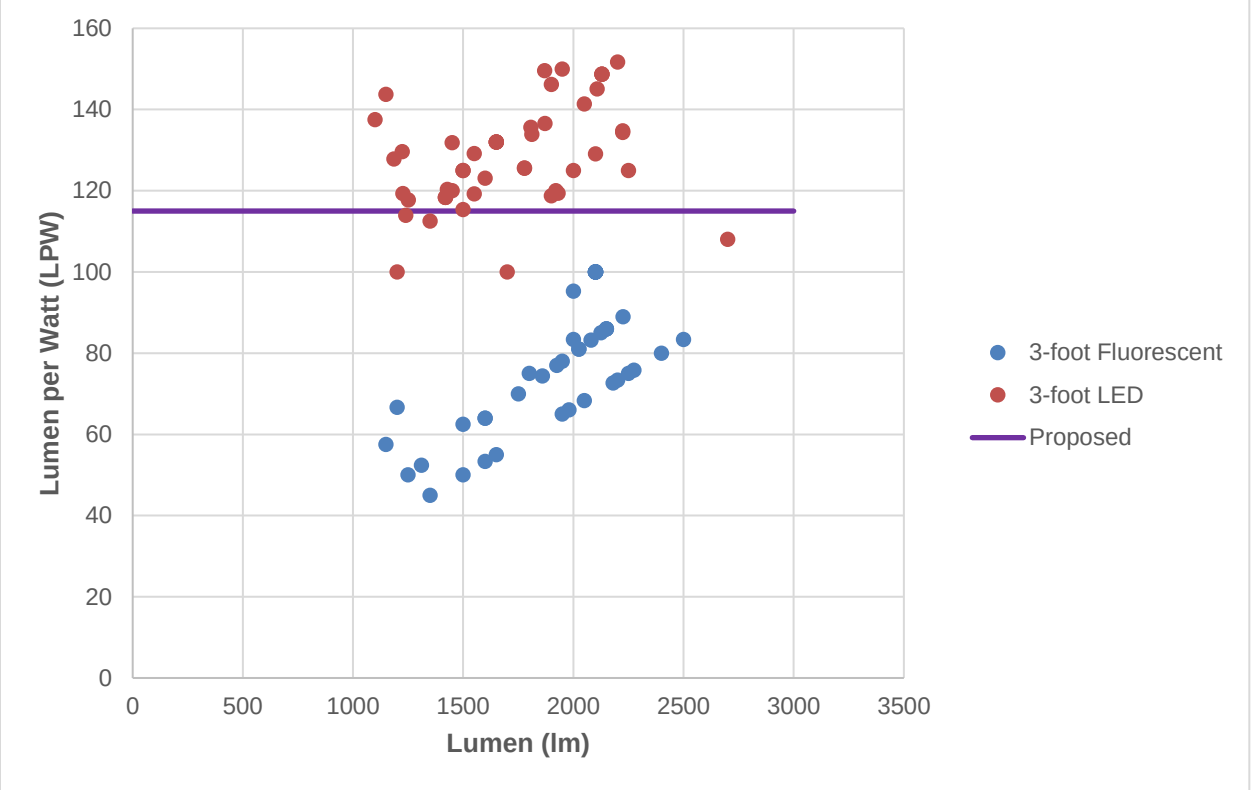
Figure 7-1: Luminous Efficiency vs. Lumen Output for 2-foot Linear Lamps



Source: Energy Commission staff

64 The Lowdown on TLEDs: https://www.energy.gov/sites/prod/files/2016/04/f30/mccullough_tleds_lightfair2016.pdf, p. 10.

Figure 7-2: Luminous Efficiency vs. Lumen Output for 3-foot Linear Lamps



Source: Energy Commission staff

CHAPTER 8:
Savings and Cost Analysis

The proposed energy efficiency standards for the linear fluorescent lamps exempted from the federal standards and for less than 4-foot linear lamps would significantly reduce energy consumption in the state. Energy Commission staff analyzed the cost effectiveness of the proposed efficiency standards for linear fluorescent lamps and for less than 4-foot linear lamps, to ensure that the energy saving benefits over the lifetime of a compliant lamp would exceed the increased incremental price of the lamp and other relevant incremental costs such as installation and ballast disposal. In addition to the cost analysis, this chapter includes the estimated statewide electricity savings for both the first year the proposed standards are in effect and after all existing stock of noncompliant lamps are replaced with compliant lamps.

Despite the increasing market share of LED linear tube lamps, according to NEMA's shipment data for the fourth quarter of 2017, more than 76 percent of linear lamps sold in the United States are fluorescent.[65] A significant portion of them are comprised of energy inefficient lamps that circumvent the federal regulations through loopholes created by regulatory exemptions. In fact, according to the NEMA report, 11.4 percent of all linear lamps sold in the United States are T12 fluorescent lamps. These lamps are energy inefficient and mostly run on magnetic ballasts that are considerably more energy inefficient than electronic ballasts. This further adds to energy waste. In addition, some energy inefficient T8 lamps in use or on the market use the same federal exemptions as T12 lamps to avoid complying with the federal energy efficiency standards.[66] The inefficient T8 lamps were not taken into account in the energy savings evaluation of the proposed standards. Therefore, the energy savings assessments in this report are underestimated and calculated conservatively.

Staff assumptions and calculations to support analysis are included in Appendix A.

Stock and Sales

To estimate the stock of 4-foot and 8-foot T12 lamps, staff used the estimated inventory of lamps from 2010 and 2015 DOE LMC reports. Staff used the lamps' average lifetimes to extrapolate the stock and annual sales growth rates and project the national stock levels and annual sales of the 4-foot and 8-foot T12 lamps. To project California's stock levels and shipments, a simple scaling of 12.09 percent was used. This scaling percentage reflects the ratio of California's population over the entire United States population, and is applied to the

65 https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-Year-Over-Year-Decline-in-Fourth-Quarter-2017-while-T-LED-Market-Penetration-Incre.aspx.

66 https://www.bulbs.com/product/F32T8-TL941-ALTO-32W.

estimated national stock levels and shipments. It is assumed that 85 percent of 8-foot lamps are standard output and 15 percent are high output.

An approach similar to the one used for state-regulated GSFLs is applied to estimate California's statewide stock and annual sales for the less than 4-foot T12, T8, and T5 linear fluorescent lamps. Because the DOE LMC reports the inventory of T5 lamps as an aggregate for all lamp lengths, staff analyzed available T5 retail models and assumed that the number of available models for a particular lamp's length correlates with its market share. Using that approach, staff estimates that about half of T5 lamps are less than 4-foot. A summary of the projected stock and shipments of linear fluorescent lamps in 2021 is shown in **Table 8-1**.

Table 8-1: Projected Stocks and Shipments of Linear Fluorescent Lamps in 2021 (in thousands)

	4-foot T12	8-foot SO T12	8-foot HO T12	Less than 4-foot, T12	Less than 4-foot, T8	Less than 4-foot, T5
National Stock	346,363	14,827	2,617	526.42	26,683	84,830
California Stock	41,887	1,793	316	63.66	3,227	10,259
Stock and Shipment Growth Rate per year	-6.96%	-17.70%	-17.70%	-25.95%	3.74%	3.12%
National Shipment	33,174	1,935	341	79.32	7,042	2,684
California Shipment	4,012	234	41	9.59	852	22,196

Source: Energy Commission staff

Energy Savings

Both LED and fluorescent lamp types can replace non-compliant state-regulated GSFL lamps, with the exception of 8-foot HO lamps which are assumed to be replaced by T8 fluorescent type lamps. Although LED lamps have higher initial cost than fluorescent lamps, they offer higher energy savings and are overall more cost effective due to their higher levels of energy efficiency and their longer lifetimes.

To calculate the annual energy consumption of each light fixture, the power consumption for the fixture is multiplied by its average hours of operation per year. The light fixture's annual energy consumption is then divided by the number of lamps in each light fixture to obtain the average annual energy consumption for each lamp.

Table 8-2 shows the average power consumption of the non-complying lamps that are used as the baseline.[67] **Table 8-3** lists the power consumption for the replacement lamps that are compliant with the proposed standards. For less than 4-foot linear lamps, the power consumption of 2-foot lamps is used.

67 Default fixture wattage reference table from Commonwealth Edison Electric Company: https://webtools.dnvgl.com/projects62/Portals/3/TA_Files/PY7_FixtureWattage_Table_v08.pdf.

The annual average hours of operations is 2,591.50 and is from the weighted average daily operating hours by end-use sector in DOE's 2015 LMC report.[68]

Table 8-2: Average Power Use per Unit for non-Compliant Lamps

Lamp Type	Number of lamps per fixture	Lamp's Power (W)	Fixture's Power (W)
4-foot T12	2	40	94
8-foot Standard Output T12	2	73	173
8-foot High Output T12	2	110	257
Less than 4-foot T12	2	20	56
Less than 4-foot T8	2	17	33
Less than 4-foot T5	2	14	34

Source: Energy Commission staff

Table 8-3: Average Power Use per Unit for Compliant Lamps

Lamp Type	Number of lamps per fixture	Lamp's Power (W)	Fixture's Power (W)
4-foot T8	2	32	59
4-foot LED	2	15	30
8-foot Standard Output T8	2	50	109
8-foot Standard Output LED	2	36	72
8-foot High Output T8	2	86	160
Less than 4-foot LED	2	9	18

Source: Energy Commission staff

Table 8-4 shows the average annual per unit energy use of the non-compliant and compliant lamps, and the average annual per unit energy savings when a non-compliant lamp is replaced with a compliant fluorescent or LED lamp individually.

To evaluate the overall energy savings when all non-compliant lamps are replaced, the portion of lamps replaced with fluorescent or LED are estimated. Staff used the shipment trend of linear lamps from the lamp indices published by NEMA and the linear projection methodology recommended by the CASE team to extrapolate the share of each replacement lamp technology from 2021 to 2031.[69]

68 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

69 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223575&DocumentContentId=53663.

Table 8-4: Average Energy Use per Unit

Lamp Type	Energy Use - Baseline (KWh/yr/unit)	Energy Use – Compliant T8 (KWh/year/unit)	Energy Use – Compliant LED (KWh/yr/unit)	Energy Savings (KWh/yr/unit)
4-foot T12	121.8	76.4	38.9	T8: 45.4 LED: 82.9
8-foot Standard Output T12	224.2	141.2	93.3	T8: 83.0 LED: 130.9
8-foot High Output T12	333.0	207.3	-	125.7
Less than 4-foot T12	72.6	-	23.3	49.3
Less than 4-foot T8	42.8	-	23.3	19.5
Less than 4-foot T5	44.1	-	23.3	20.8

Source: Energy Commission staff

Table 8-5: Overall Energy Savings from Annual Sales

Lamp Type	Annual Sales in 2021 (Thousands)	Replacement: Compliant T8	Replacement: Compliant LED	Energy Saving from Annual Sale (GWh/yr)
4-foot Standard Output T12	4,012	62%	38%	239.7
8-foot Standard Output T12	234	62%	38%	23.7
8-foot High Output T12	41	100%	-	5.2
Less than 4-foot T12	10	-	100%	0.5
Less than 4-foot T8	852	-	100%	16.6
Less than 4-foot T5	2,684	-	100%	55.7
Total	7,833	-	-	341.4

Source: Energy Commission staff

Lifecycle Energy Savings and Cost Savings

For the state-regulated GSFLs, staff assumed that none of the T12 linear fluorescent lamps that are currently on the market would be able to comply with the proposed standards. Moreover, staff assumed that all 4-foot and 8-foot linear fluorescent lamps, other than T12s, are compliant with the proposed standards. Therefore, only attributes for the T12 lamps are used to estimate the energy and cost savings of the proposed standards for state-regulated GSFLs.

For less than 4-foot linear lamps, staff assumed that none of the linear fluorescent lamps on the market comply with the proposed efficiency levels.

The energy savings for the linear fluorescent lamps are determined by the difference in the energy efficiency of linear fluorescent lamps that are on the market today and the energy

efficiency of the lamps replacing them that are compliant with the proposed regulations. Lifecycle energy savings are each unit's energy savings throughout the life of the replaced lamp.

Incremental costs are the initial additional costs that consumers pay for installing a compliant product in place of a non-compliant product. The cost of the compliant lamps in this analysis includes the cost for the parts, installation, sales tax, and disposal of the removed ballasts. In this report, all disposed ballasts are assumed to be magnetic. This assumption leads to more conservative cost estimates because pre-1979 magnetic ballasts may contain polychlorinated biphenyls (PCBs), which are toxic materials regulated by the U.S. Environmental Protection Agency (EPA). The EPA requires fluorescent light ballasts not stamped with "No PCBs" to be considered as containing PCB.[70] Hence, magnetic ballasts have a higher average disposal cost than electronic ballasts.

Table 8-6 shows the per-unit lifecycle cost savings and the incremental costs for the various lamp replacements. The proposed standards are very cost effective with the benefit to cost ratio ranging from 1.5 to 8.4, resulting in a relatively short time period for the savings to compensate for the initial incremental cost.

70 EPA, Storage and Disposal: Ballasts https://www3.epa.gov/region9/pcbs/ballast.html.

Table 8-6: Costs and Benefits per Unit

Lamp Type	Design Life Baseline (years)	Design Life Compliant (years)	Life-Cycle Energy Saving (KWh/unit)	Lifecycle Cost Saving ($/unit)	Incremental Cost ($/unit)	Net Benefit Ratio (Benefit/Cost)
4-foot Standard Output T12	8	T8: 12 LED: 19	T8: 544.8 LED: 1,575.1	T8: $83.19 LED: $238.75	T8: $35.58 LED: $38.69	T8: 2.3 LED: 6.2
8-foot Standard Output T12	5	T8: 9 LED: 19	T8: 747 LED: 2,487.1	T8: $153.01 LED: $497.21	T8: $52.31 LED: $59.12	T8: 2.9 LED: 8.4
8-foot High Output T12	5	8	1005.6	$144.49	$74.00	1.9
Less than 4-foot T12	3	19	934.8	$165.64	$36.01	4.6
Less than 4-foot T8	10	19	369.4	$56.46	$38.48	1.5
Less than 4-foot T5	11	19	393.9	$61.15	$37.41	1.6

Source: Energy Commission staff

Table 8-7 shows the overall estimated energy and cost savings for the first year after the proposed standards are effective and after the entire stock is turned over. The proposed standards save an estimated 2,895 GWh of electricity per year after the stock is turned over. That translates to more than $428 million in electricity cost savings per year, through reduced utility bills, after the entire stock is turned over.

This analysis also indicates that the proposed standards will save a significant amount of energy, in addition to being cost effective and technically feasible.

Table 8-7: First year and Stock's Net Energy and Cost Savings

Lamp Type	Unit Stock (thousands)	First year Energy Savings (GWh/yr)	Stock Energy Savings (GWh/yr)*	Weighted Average Electricity Rates ($/KWh)	First year Monetary Savings ($M/yr)	Annual Monetary Savings ($M/yr)*
4-foot T12	41,887	239.7	1,870.4	0.149	$35.7	$278.7
8-foot Standard Output	1,793	23.7	91.9	0.137	$3.2	$12.6
8-foot High Output	316	5.2	18.3	0.137	$0.7	$2.5
Less than 4-foot T12	64	0.5	1.1	0.147	$0.07	$0.2
Less than 4-foot T8	3,227	16.6	196.4	0.147	$2.4	$28.9
Less than 4-foot T5	10,259	55.7	717.3	0.147	$8.2	$105.4
Total	**57,546**	**341.4**	**2,895**	**-**	**$50.27**	**$428.3**

* After stock turn over

Source: Energy Commission staff

CHAPTER 9:
Environmental Impacts

Fluorescent lamps are considered hazardous waste because they contain mercury, known to possibly contribute to birth defects and damage to the nervous system and vital organs. The proposed standards do not have any adverse impact on the environment because the energy efficiency requirements only apply to the lamps manufactured on or after the proposed effective date of the state regulations. These standards do not impose an early replacement of inefficient lamps that are in use or disposal of lamps that are already manufactured; therefore, they do not increase disposal of additional toxic materials.

After the effective date of the proposed standards, T12 lamps must be replaced with either fluorescent lamps with smaller diameters that are not compatible with T12 ballasts or LED lamps. In either case, the ballast must be removed and properly disposed. Older ballasts may contain PCBs, which are a toxic substance and require special handling and disposal. The average life of a ballast is typically longer than the average life of a lamp. This difference is more substantial for inefficient T12 lamps, causing lamps to be replaced before the ballast. The proposed standards may accelerate the disposal of ballasts containing PCBs; however they do not increase the overall amount of PCBs. Federal energy conservation requirements required new ballasts to be electronic and PCB free because the EPA banned them in the late 1970s.[71] In California, fluorescent light ballasts containing PCBs are required to be handled, transported, and recycled according to Title 22, California Code Regulations, division 4.5, chapter 42.[72]

Linear fluorescent lamps are typically replaced at the end of their life when they cease to function. While some inefficient fluorescent lamps might be replaced with more efficient and more durable LED or fluorescent lamps, in the absence of the proposed standards, a large portion will be replaced with inefficient identical lamps. Proposed standards will eliminate inefficient lamps from the market, and replace them with either LED or fluorescent lamps that are more energy efficient, more durable, and in the case of LED lamps, also non-toxic waste. This progression will result in an overall reduction of toxic and hazardous waste over time and will benefit the environment.

Furthermore, the proposed standards will save substantial energy, which 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

71 https://archive.epa.gov/epa/aboutepa/epa-bans-pcb-manufacture-phases-out-uses.html.

72 Requirements for Management of Fluorescent Light Ballasts Which Contain Polychlorinated Biphenyls (PCBs): https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IAB45BA20D4BB11DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).

reduced GHG and criteria pollutant emissions, primarily from lower generation in hydrocarbon-burning power plants, such as natural gas-fired power plants.

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 1601. Scope.

…[skipping (a)-(j)]

(k)

Lamps, which are federally regulated general service fluorescent lamps, federally regulated incandescent reflector lamps, general service incandescent lamps, general service lamps, less than 4-foot linear lamps, state-regulated general service fluorescent lamps, state-regulated light-emitting diode (LED) lamps, state-regulated small-diameter directional lamps, and includes GU24 base lamps.

Section 1602. Definitions.

…[skipping (a)-(j)]

(k) Lamps.

… [skipping through "Clear type lamp"]

"Cold temperature fluorescent lamp" means a fluorescent lamp specifically designed to start at −20 ˚F when used with a ballast conforming to the requirements of ANSI C78.81 and ANSI C78.901, and is expressly designated as a cold temperature lamp both in markings on the lamp and in marketing materials, including catalogs, sales literature, and promotional material.

… [skipping through "Connected LED lamp"]

"Designed and marketed" for state-regulated lamps 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).

… [skipping through "Frost type lamp"]

"High-CRI fluorescent lamp" means any fluorescent lamp with a CRI of 87 or greater.

"Impact-resistant fluorescent lamp" means any fluorescent lamp that:

1. Has a coating or equivalent technology that is compliant with NSF/ANSI 51 and is designed to contain the glass if the glass envelope of the lamp is broken; and
2. Is designed and marketed for the intended application, with:

   A. The designation on the lamp packaging; and

   B. Marketing materials that identify the lamp as being impact resistant, shatter-resistant, shatter-proof, or shatter-protected.

… [skipping through "Left-handed thread lamp"]

"State-regulated less than 4-foot linear lamp" means any straight-shaped linear lamp with nominal length of 2-foot or 3-foot that has either a medium bipin base or a miniature bipin base.

The term "State-regulated less than 4-foot linear lamp" does not include any lamp designed and marketed for the following applications:

(1) Lamps designed to promote plant growth;
(2) Lamps specifically designed for cold temperature applications;
(3) Colored lamps;
(4) Reflectorized or aperture lamps;
(5) Lamps designed for use in reprographic equipment; and
(6) Lamps primarily designed to produce radiation in the ultra-violet region of the spectrum.

… [skipping through "Specialty application mercury vapor lamp ballast"]

"State-regulated general service fluorescent lamp" means any impact-resistant fluorescent lamp or high-CRI fluorescent lamp that is one of the following types:

(1) Any straight-shaped lamp (commonly referred to as 4-foot medium bipin lamps) with medium bipin bases of nominal overall length of 48 inches and rated wattage of 25 or more;

(2) Any U-shaped lamp (commonly referred to as 2-foot U-shaped lamps) with medium bipin bases of nominal overall length between 22 and 25 inches and rated wattage of 25 or more;

(3) Any rapid start lamp (commonly referred to as 8-foot high output lamps) with recessed double contact bases of nominal overall length of 96 inches;

(4) Any instant start lamp (commonly referred to as 8-foot slimline lamps) with single pin bases of nominal overall length of 96 inches and rated wattage of 49 or more;

(5) Any straight-shaped lamp (commonly referred to as 4-foot miniature bipin standard output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 25 or more; or

(6) Any straight-shaped lamp (commonly referred to as 4-foot miniature bipin high output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 44 or more.

The term "state-regulated general service fluorescent lamp" does not include any lamp designed and marketed for the following applications:

(1) Lamps designed to promote plant growth;

(2) Lamps specifically designed for cold temperature applications;

(3) Colored lamps;

(4) Reflectorized or aperture lamps;

(5) Lamps designed for use in reprographic equipment; and

(6) Lamps primarily designed to produce radiation in the ultra-violet region of the spectrum.

…[skipping to the end of the section]

…

The following documents are incorporated by reference in Section 1602.

Number	*Title*
. . .	
NSF/ANSI 51-2007 ("NSF/ANSI 51")	Food equipment materials, revised and adopted April 2007

Section 1604. Test Methods for Specific Appliances

…[skipping (a)-(j)]

(k) Lamps.

(1) The test method for federally regulated general service fluorescent lamps, state-regulated general service fluorescent lamps, state-regulated less than 4-foot linear 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).

…[skipping (2)-(5)]

(6) The test method for state-regulated less than 4-foot integrated linear LED lamps is 10 C.F.R. section 430.23(ee) (Appendix BB to subpart B of part 430).

(7) The test method for state-regulated less than 4-foot non-integrated linear LED lamps 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 1605.1. Federal and State Standards for Federally Regulated Appliances.

(k) Lamps.

(1) Federally Regulated General Service Fluorescent Lamps.

Each of the following federally regulated general service fluorescent lamps manufactured on or after the effective dates shown shall meet or exceed the lamp efficacy standards shown in Table K-2.

Table K-2 Standards for Federally-Regulated General Service Fluorescent Lamps Manufactured On or After ~~July 15, 2012~~ January 26, 2018

Appliance	Correlated Color Temperature	Minimum Average Lamp Efficiency (LPW)	
		~~Effective July 15, 2012~~	~~Effective January 26, 2018~~
4-foot medium bipin	≤ 4,500	~~89~~	92.4
	> 4,500 and ≤ 7,000	~~88~~	88.7
2-foot U-shaped	≤ 4,500	~~84~~	85
	> 4,500 and ≤ 7,000	~~81~~	83.3
8-foot slimline	≤ 4,500	~~97~~	97
	> 4,500 and ≤ 7,000	~~93~~	93
8-foot high output	≤ 4,500	~~92~~	92
	> 4,500 and ≤ 7,000	~~88~~	88
4-foot miniature bipin standard output	≤ 4,500	~~86~~	95
	> 4,500 and ≤ 7,000	~~81~~	89.3
4-foot miniature bipin high output	≤ 4,500	~~76~~	82.7
	> 4,500 and ≤ 7,000	~~72~~	76.9

…[skipping to the end of the section]

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

…[skipping (a)-(j)]

(k) Lamps.

…[skipping (1)-(5)]

(6) Standards for state-regulated general service fluorescent lamps and state-regulated less than 4-foot linear lamps. State-regulated general service fluorescent lamps and state-regulated less than 4-foot linear lamps manufactured on or after January 1, 2021, shall meet the standards shown in Table K-10.

Table K-10 Standards for State-Regulated General Service Fluorescent Lamps and state-regulated Less than 4-foot Linear Lamps

Appliance	**Correlated Color Temperature**	**Minimum Average Lamp Efficiency (LPW)**
4-foot medium bipin	≤ 4,500K	92.4
	> 4,500K and ≤ 7,000K	88.7
2-foot U-shaped	≤ 4,500K	85
	> 4,500K and ≤ 7,000K	83.3
8-foot slimline	≤ 4,500K	97
	> 4,500K and ≤ 7,000K	93
8-foot high output	≤ 4,500K	92
	> 4,500K and ≤ 7,000K	88
4-foot miniature bipin standard output	≤ 4,500K	95
	> 4,500K and ≤ 7,000K	89.3
4-foot miniature bipin high output	≤ 4,500K	82.7
	> 4,500K and ≤ 7,000K	76.9
Less than 4-foot	All	115

…[skipping to the end of the section]

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

…[skipping to Table X]

Table X

Data Submittal Requirements

	Appliance	Required Information	Permissible Answers
	… [Skipping sections 1 through J]		
K	State-regulated general service fluorescent lamps and State-regulated less than 4-foot linear lamps	Linear lamp type	4-foot medium bipin 2-foot U-shaped 8-foot slimline 8-foot high output 4-foot miniature bipin standard output 4-foot miniature bipin high output Less than 4-foot
		Technology	Fluorescent, LED, Other
		Base type	Bi-pin, Miniature Bi-pin, Single-pin, Recessed Double Contact, Other
		Correlated Color Temperature (K)	
		Rated Color Rendering Index	
		Lamp Input Power (Watts)	
		Lumen Output (Lumens)	
		Efficiency (Lumens per Watt)	
		Nominal Lamp Length (inch)	
		Lamp's nominal diameter in one-eighths of an inch	5, 8, 10, 12, other

…[skipping to the end of the section]

Section 1607. Marking of Appliances. [Existing language for reference only]

(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

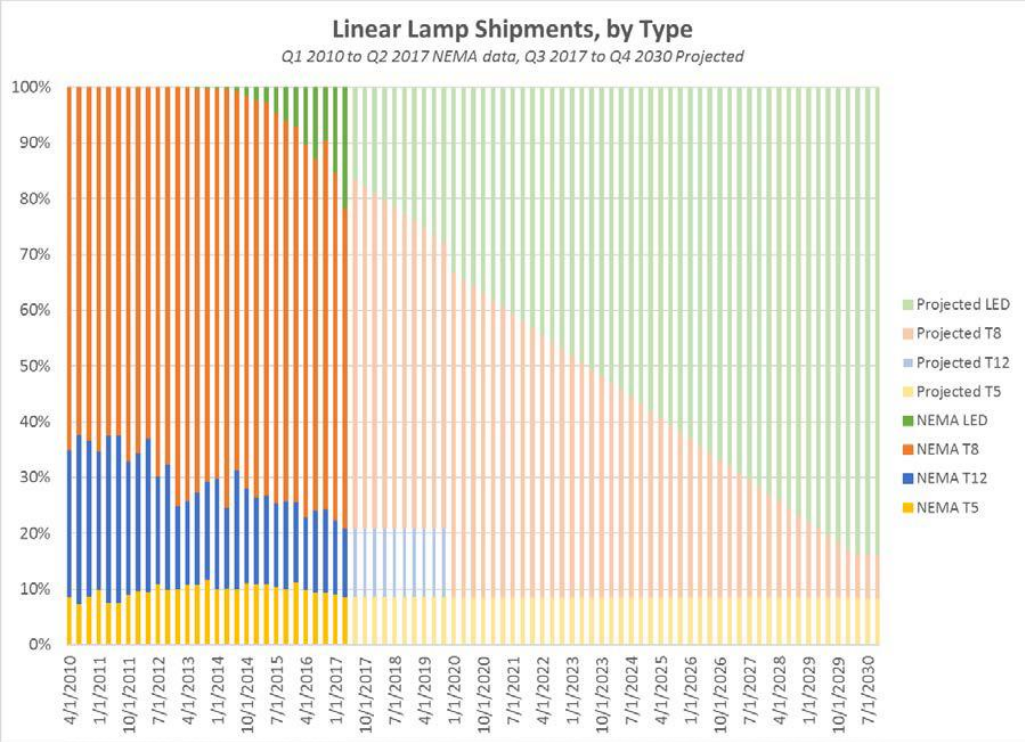
(3) date of manufacture, indicating (i) year and (ii) month or smaller (e.g. week) increment. If the date is in a code that is not readily understandable to the layperson, the manufacturer shall immediately, on request, provide the code to the Energy Commission.

APPENDIX A:
Staff Assumptions and Calculation Methods

Replacement Lamp Market Share

To estimate the market share of each lamp technology that can retrofit T12 lamps after the effective date of the proposed standards, staff used the methodology that was proposed by the CASE report, using the shipment trend of linear lamps from the lamp indices published by NEMA for 2017. In this methodology, the shipment of T12 and T5 lamps are assumed to remain flat while T8 declined and LED lamps increased linearly with the same rate. After the effective date of the proposed regulations, all T12 lamps will be eliminated and are assumed to be replaced by T8 and LED lamps with the same proportionality of their market share at that time. **Figure A-1** shows the market share of linear lamps by the lamp technology that NEMA published in solid colors and CASE team's projected market share in the transparent bars.[73]

Figure A-1: Historical and Projected Lamp Indices



Source: CASE Initiative

73 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223575&DocumentContentId=53663.

This approach was used to estimate the market share of replacing lamps from 2021 to 2031 (Table A-1).

Table A-1: Summary of Values and Assumptions

Year	Replacement %T8	Replacement %LED
2021	62%	38%
2022	56%	44%
2023	51%	49%
3024	45%	55%
2025	40%	60%
2026	35%	65%
2027	29%	71%
2028	24%	76%
2029	18%	82%
2030	13%	87%
2031	9%	91%

Source: California Energy Commission

Cost Estimates

To estimate the initial incremental cost of the complying product, the following are taken into account: the cost for the complying replacement lamp, the cost for a new electronic ballast (only applicable if the replacement lamp is a fluorescent lamp), the cost of labor for the installation, the cost of the ballast disposal, and applicable sales taxes. **Table A-2** shows the estimated average for each cost.

Table A-2: List of Cost Estimates

Lamp Types	Non-Compliant Lamp Cost ($)	Compliant T8 Cost ($)	Compliant LED Cost ($)	New Ballast Cost ($)	Labor Cost per Lamp ($)	Ballast Disposal Cost per Lamp ($)[74]
4-foot	2.36	1.80	9.00	4.30	30.15	1.25
8-foot SO	4.40	9.70	24.20	8.15	35.38	2.5
8-foot HO	5.90	8.80	-	28.45	35.38	5
Less than 4-foot	4.40 (T12) 2.10 (T8) 3.10 (T5)	-	8.70	-	30.15	1.25

Source: CASE Initiative[75]

For the proposed standards to be cost effective, the monetary savings resulting from replacing a non-complying lamp with a complying lamp must surpass the initial incremental cost. The lifetime saving consists of the value of the energy saved throughout the life of the complying product and the avoided cost of potential product replacements that otherwise would have

74 Assuming each ballast weighs two pounds on average and each ballast operates with two fluorescent lamps.

75 California IOUs CASE report: https://efiling.energy.ca.gov/GetDocument.aspx?tn=223787&DocumentContentId=53983.

been borne by consumers because non-complying products have a shorter life than the complying products. **Table A-3** summarizes the electricity rates for different sectors in California. In this table, the electricity rates for each form factor of lamps are calculated as the weighted average between the residential, commercial, and industrial electricity rates in California. The amount of the annual lighting electricity consumed by each sector from the 2015 DOE LMC report is used as the weighting factor in this calculation.[76]

Table A-3: Average Electricity Rates in California (No Discount Rates)

Lamps	Residential ($/KWh)	Commercial ($/KWh)	Industrial ($/KWh)	Weighted Average ($/KWh)
4-foot	0.1832	0.149	0.1143	0.149
8-foot SO	0.1832	0.149	0.1143	0.137
8-foot HO	0.1832	0.149	0.1143	0.137
Less than 4-foot	0.1832	0.149	0.1143	0.147

Source: U.S. Energy Information Administration, Electric Power Monthly (January 2019)

Table A-4 show the lifetime energy and cost savings for complying fluorescent and LED lamp replacements. The lifetime electricity savings is the electricity that is saved as a result of replacing a non-compliant lamp with a more efficient compliant lamp. In this table, lifetime refers to the life of the compliant products that are longer than the life of the non-compliant products. The lifetime cost savings is the difference between the cost of operating a non-compliant product versus the operating cost when it is replaced with a compliant product. The cost savings include the combination of the value of the electricity saved and the avoided cost of replacement non-compliant lamps that would have been acquired due to a shorter lifecycle and more frequent replacement.

76 2015 U.S. Lighting Market Characterization: https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

Table A-4: Lifetime Energy and Cost Savings per Unit for 4-foot Lamps

Year	Weighted Average Electricity Rates in State ($/KWh)	Lifetime Electricity Savings per unit (T8) (KWh/unit)	Lifetime Electricity Savings per unit (LED) (KWh/unit)	Lifetime Cost Savings per Unit (T8) ($/unit)	Lifetime Cost Savings per Unit (LED) ($/unit)
4-foot	0.149	544.8	1,575.1	$83.19	$238.75
8-foot SO	0.137	1,044.9	3,481.2	$153.01	$497.21
8-foot HO	0.137	1,005.5	-	$144.49	-
Less than 4-foot T12	0.147	-	935.5	-	$165.64
Less than 4-foot T8	0.147	-	369.3	-	$56.46
Less than 4-foot T5	0.147	-	393.9	-	$61.15

Source: California Energy Commission

Shipments and Stock

Table A-5 shows the projected stock of lamps in California and **Table A-6** shows the estimated annual shipments of lamps in California. To estimate the stock of 4-foot and 8-foot T12 lamps, staff used the estimated national inventory of lamps from 2010 and 2015 DOE LMC reports to estimate an average for the lamp's stock and shipment growth or decline rates. Linear interpolation was used to project the national stock of lamps for the years from 2021 to 2031. To extrapolate the annual shipments, staff used the projected stock of lamps along with the lamp's average lifetime. To estimate stock and shipment of the lamps in California, staff used simple scaling of 12.09 percent, the ratio of California's population over the entire United States population.

An approach similar to the one used for state-regulated GSFLs is applied to estimate California's statewide stock and annual shipments for the less than 4-foot T12, T8, and T5 linear fluorescent lamps. Because the DOE LMC reports the inventory of T5 lamps as an aggregate for all lamp lengths, staff analyzed available T5 retail models and assumed that the number of available models for a particular lamp's length correlates with its market share. Using that approach, staff estimates that about half of T5 lamps are less than 4-foot.

Table A-5: Projected Stocks of Lamps in California in Thousands

Year	4-foot	8-foot Standard Output	8-foot High Output	Less than 4-foot T12	Less than 4-foot T8	Less than 4-foot T5
2021	41,887	1,793	316	64	3,227	10,259
2022	38,970	1,476	260	47	3,348	10,580
2023	36,256	1,215	214	35	3,473	10,910
2024	33,372	1,000	176	26	3,603	11,251
		823	145	19	3,737	11,603

2025	31,382	677	120	14	3,877	11,965
2026	29,197	557	98	10	4,022	12,339
2027	27,164	459	81	8	4,172	12,724
2028	25,272	378	67	6	4,328	13,122
2029	23,512	311	55	4	4,490	13,532
2030	21,875	256	45	3	4,658	13,955
2031	20,351					

Source: California Energy Commission

Table A-6: Projected Annual Shipments of Lamps in California in Thousands

Year	4-foot	8-foot Standard Output	8-foot High Output	Less than 4-foot T12	Less than 4-foot T8	Less than 4-foot T5
2021	4,012	234	41	10	852	2,684
2022	3,732	193	34	7	884	2,768
2023	3,473	158	28	5	917	2,855
2024	3,231	130	23	4	951	2,944
2025	3,006	107	19	3	986	3,036
2026	2,796	88	16	2	1,023	3,131
2027	2,602	73	13	2	1,062	3,229
2028	2,420	60	11	1	1,101	3,329
2029	2,252	49	9	1	1,142	3,433
2030	2,095	41	7	1	1,185	3,541
2031	1,949	33	6	0	1,229	3,651

Source: California Energy Commission

APPENDIX B: Acronyms

Acronym	Description
AB	Assembly Bill
ANSI	American National Standards Institute
CARB	California Air Resources Board
CASE Team	Codes and Standards Enhancement Team
CPUC	California Public Utilities Commission
DOE	Department of Energy
GHG	Greenhouse Gas
GSFL	General Service Fluorescent Lamp
GWh	Gigawatt-hour
HO	High Output
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
kWh	Kilowatt-hour
LED	Light-Emitting Diode
MAEDbS	Modernized Appliance Efficiency Database System
MW	Megawatt
MWh	Megawatt-hour
PG&E	Pacific Gas and Electric
SB	Senate Bill
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SO	Standard Output
TLED	Tubular Light-Emitting Diode
UV	Ultraviolet
ZNE	Zero Net Energy