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Analysis of Standards Proposal for Federally Exempted Linear Fluorescent Lamps

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Non-Federally Regulated Linear Fluorescent Lamps

Codes and Standards Enhancement (CASE) Initiative
For PY 2018: Title 20 Standards Development

Analysis of Standards Proposal for
Federally Exempted Linear Fluorescent Lamps
18-AAER-08

May 24, 2018

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1. Purpose

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Appliance Efficiency Regulations (Title 20) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor-Owned Utilities (IOUs) – Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and SoCalGas® – sponsored this effort (herein referred to as the Statewide CASE Team). The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve the energy and water efficiency of various products sold in California. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for potential appliance standards. This CASE Report covers a standard proposal for a variety of linear fluorescent lamp types not covered under federal energy conservation standards.

2. Product/Technology Description

Linear fluorescent lamps are defined 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" (EPCA 1975), and includes, by statute, only the following:

- Any straight-shaped lamp (commonly referred to as 4-foot medium bipin lamps (standard output (SO))) with medium bipin bases of nominal overall length of 48 inches and rated wattage of 28 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 28 or more.
- Any rapid start lamp (commonly referred to as 8-foot high output (HO) lamps) with recessed double contact bases of nominal overall length of 96 inches and 0.800 nominal amperes, as defined in American National Standards Institute (ANSI) C78.1–1978 and related supplements.
- 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 52 or more, as defined in ANSI C78.3–1978 (R1984) and related supplement ANSI C78.3a–1985.

A subset of these lamps is defined as general service fluorescent lamps (GSFLs), lamps which can be used to satisfy the majority of fluorescent applications, but does not include any lamp designed and marketed for nongeneral lighting applications. These "nongeneral application lighting" lamps are differentiated by a number of attributes, such as the wavelength of light emitted or the lamp housing style, although some may indeed be used for general service lighting. For example, impact-resistant lamps, as well as lamps with a color rendering index (CRI) of at least 87 are excluded from the federal definition of GSFL and are subsequently not covered by any current federal regulations—despite their likely use in general service applications. Also excluded (implicitly) from the federal GSFL definition are straight-shaped lamps that are less than 4-feet in length (most products in this category are 2-feet in length).

Light-emitting diode (LED) lamps serve as viable, energy-efficient replacements for GSFLs. LEDs are sold in various diameters[1] (e.g., T5, T8, T12) and lengths (e.g., 2-foot, 4-foot), they are inherently impact resistant, and can produce high CRI[2] light. In recent years, LED replacements for GSFLs, known as tubular LEDs (TLED), have increased in market saturation as explained in Section 5.5.3. Moreover, TLEDs do not require fluorescent ballasts to sustain light production; a necessity and source of inefficiency for linear fluorescent lamps. The Statewide CASE Team has not identified any lighting

[1] The "T" designation in lamp nomenclature stands for tubular—the shape of the lamp. The number after the T represents the diameter of the lamp, in eighths of an inch. For example, a T8 lamp is eight-eighths of an inch, or one inch (2.54 cm), in diameter.
[2] High CRI refers to CRI values greater than or equal to 87.

application served by GSFLs that cannot be served by LEDs, with the exception of 8-foot High Output lamps, as discussed later.

3. Standards Proposal Overview

The Statewide CASE Team proposes to cover the following non-federally regulated linear fluorescent lamps:

- High CRI linear fluorescent lamps
- Less than 4-foot linear fluorescent lamps
- Impact resistant lamps

The Statewide CASE Team proposes efficacy requirements that will lead to the most energy savings while remaining cost-effective. These levels will most likely be met by TLED replacements, which will result in energy savings from higher efficacy and prolonged product lifetime. See Section 5.1 for details regarding the full scope of this proposal, and Section 4.3 for details on the proposed minimum efficacy standard.

The Statewide CASE Team estimates that adoption of this standard would result in 892 gigawatt hours per year (GWh/year) of electricity savings after stock turnover, a statewide net present value (NPV) of $130 million after stock turnover, and a benefit-to-cost (B/C) ratio ranging from 1.2 to 5.5, depending on lamp type (total present value (PV) of benefits divided by total PV of costs). Stock turnover will occur in late 2026[3] if the standard is adopted in 2019 (effective 2020). A summary of the Statewide CASE Team's analysis is shown in Table 1.

Table 1: Summary of Proposal

Topic	Description
Description of Standards Proposal/Framework of Roadmap	The Statewide CASE Team proposes minimum efficacy requirements for several non-federally regulated linear fluorescent lamp types covered by the scope in Section 5.1 are tested using the procedure described in Section 4.3.2.
Technical Feasibility	Several viable replacement options for high CRI linear fluorescent lamps, and 2-foot lamps currently exist in the market from various manufacturers. Therefore, the Statewide CASE Team has concluded that transitioning the market is technically feasible without causing undue harm to manufacturers and consumers. This is described in depth in Section 5.4.
Energy Savings and Demand Reduction	First year savings are estimated at 233 GWh/year and 37 megawatts (MW) of demand reduction in 2020. Savings after stock turnover are estimated at 892 GWh/year and 141 MW of demand reduction.
Environmental Impacts and Benefits	This proposal will yield savings of 99,558 metric tons of carbon dioxide equivalent (MTCO2e) in the first year and a total of 435,150 MTCO2e by 2030. These figures are based on the projected carbon intensity of the California electricity supply over the coming years (see Section 5.7).

[3] This value assumes a stock weighted stock turnover. Actual stock turnover times vary as the different products analyzed within the report have different lifetimes, ranging from 2.2 to 7.2 years. This means stock turnover will occur between 2022 and 2027.

Economic Analysis	Appliance standards can positively impact the economy through widespread energy savings among ratepayers, with minimal impact on the manufacturing community. This proposal will lead to significant cost savings for consumers with $130 million in first-year savings and $335 million after stock turnover.
Consumer Acceptance	The Statewide CASE Team does not expect consumer acceptance issues as a result of this proposal; the majority of the market has already replaced GSFLs with TLEDs.
Other Regulatory Considerations	The linear fluorescent lamps covered in this proposed standard are explicitly not covered by federal regulations; there is no federal preemption concern. Additionally, no Title 20 regulations currently exist that cover these products.

4. Proposed Standards and Recommendations

4.1 Proposal Description

This CASE Report builds on the United States Department of Energy (U.S. DOE) GSFLs energy conservation standard and test procedure. While standard stringency has previously increased for federally-regulated GSFLs (both in 2012 and again in a Final Rule published in 2017), manufacturers are now marketing and selling high CRI T12 lamps as inexpensive, extremely inefficient alternatives—presumably to circumvent efficacy standards. This loophole results in significantly reduced savings for U.S. DOE's Energy Conservation Program. California's Title 20 Regulations currently do not include any energy conservation standards for GSFLs or non-federally regulated linear fluorescent lamps; a new section is required. The Statewide CASE Team proposes to cover these non-federally regulated linear fluorescent lamps in order to close the loophole that currently allows manufacturers to produce and sell these inefficient lamps. See Section 3 for more details.

The Statewide CASE Team proposes minimum efficacy requirements for high CRI linear fluorescent lamps, 8-foot high output linear fluorescent lamps with a CRI of 87 or greater, linear fluorescent lamps less than four feet in length, and impact resistant fluorescent lamps. This requirement will improve the efficacy of linear fluorescent lamps used in general service applications by ensuring standards cannot be circumvented by improving CRI. The proposed levels will most likely be met by TLED replacements, which will result in energy savings from the higher efficacy with a prolonged product lifetime. The proposed efficacy levels for high CRI linear fluorescent lamps, linear fluorescent lamps less than 4 feet in length, and impact resistant fluorescent lamps are based on average efficacies of currently available linear LED lamps, and also the minimum efficacy for listing on the DesignLights Consortium (DLC) Qualified Products List (QPL) for linear replacement lamps category[4]. The proposed efficacy levels for 8-foot high output linear fluorescent lamps with CRI of 87 or greater are intended to bring this product category into parity with the existing federal requirements. At this time, the Statewide CASE Team does not recommend efficacy levels higher because the LED market for equivalent products is not yet able to fill their niche. However, as LED technology improves, there will be an opportunity to address this product class in the future. In summary, the Statewide CASE Team proposes efficacy requirements that will lead to the most energy savings while remaining cost-effective for each lamp type. The proposed requirements are shown in Table 2.

[4] The DesignLights Consortium's technical requirements for Linear Replacement Lamps can be accessed here: https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/

Table 2: Proposed Requirements for Non-Federally Regulated Linear Fluorescent Lamps

Lamp type	Correlated color temperature in degrees kelvin (CCT)	Minimum average lamp efficacy in lumens per watt (lm/W)
High CRI linear fluorescent lamps	All CCTs	110.0
8-foot HO linear fluorescent lamps with CRI of 87 or greater	≤4,500K	92.0
	>4,500K and ≤7,000K	88.0
Less than 4-foot linear fluorescent lamp	All CCTs	110.0
Impact Resistant Fluorescent Lamps	All CCTs	110.0

4.2 Proposal History

The Energy Policy and Conservation Act (EPCA) of 1975 along with the Energy Policy Act (EPA) of 1992 define energy conservation standards for GSFLs. However, there are several products which are not included in the definition for GSFLs as outlined in Section 2. Therefore, these particular linear fluorescent lamps are not considered preempted by the federal government. Thus, there are no federal preemption concerns for California associated with this rulemaking.

4.3 Proposed Changes to the Title 20 Code Language

The proposed changes to the Title 20 standards are provided in the following sections. Changes to the 2018 standards are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

The standard would be an addition to part (k) Lamps in Section 1605.3: State Standards for Non-Federally Regulated Appliance.

4.3.1 Proposed Definitions

The Statewide CASE Team proposes that the Energy Commission use the definitions contained within the Code of Federal Regulations (CFR) (specifically 10 CFR Part 430, Subpart B), as well as the modified definitions contained within the CFR (specifically 10 CFR Part 430, Subpart A):

"Fluorescent lamp" means a low-pressure mercury electric-discharge source in which a fluorescing coating transforms some of the ultraviolet energy generated by the mercury discharge into light~~.~~, including only the following:

(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; and

(6) 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.

"High CRI linear fluorescent lamp" means a fluorescent lamp that produces light that has a CRI equal to 87 or greater.

"Less than 4-foot linear fluorescent lamp" means any straight-shaped fluorescent lamp with nominal overall length of less than 48 inches.

"Impact-resistant fluorescent lamp" means any 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 designated and marketed for the intended application, with—
   i. The designation on the lamp packaging; and
   ii. Marketing materials that identify the lamp as being shatter-resistant, shatter-proof, or shatter-protected.

4.3.2 Proposed Test Procedure

The Statewide CASE Team proposes that the Energy Commission use the test procedure for GSFLs listed in the CFR (10 C.F.R. Part 430, Subpart B, Appendix R) as the test procedure for this equipment standard. This is the same test procedure outlined for federally regulated GSFLs in Title 20, Section 1604, part k (CCR 2017).

The U.S. DOE test procedure covers the measurement of lumens, electrical characteristics, CRI, and correlated color temperature (CCT) for GSFLs. It incorporates sections outlined in Illuminating Engineering Society (IES) North America Lighting Measurement 9 (IES LM-9), IES LM-58, ANSI C78.375, ANSI C78.81, ANSI C78.901, ANSI C82.3, and the International Commission on Illumination (CIE) 13.3. Modifications for lamps not listed in ANSI C78.81 nor ANSI C78.901 include specifications for reference ballast settings specified in Code of Federal Regulations (CFR) Part 430, Subpart B.

4.3.3 Proposed Standard Metrics

The Statewide CASE Team proposes lamp efficacy as the standard metric. Lamp efficacy is already defined in Title 20 (CCR §1602), but the Statewide CASE Team proposes alterations to the existing definition. The definition, with modifications, is included below.

"Lamp efficacy (LE)" means the ratio of measured lamp lumen output ~~of a lamp~~ in lumens ~~divided by~~ to the measured lamp electrical power input in watts (W), rounded to the nearest tenth, ~~expressed~~ in units of lumens per watt (LPW).

4.3.4 Proposed Standard

The text below was adapted from the U.S. DOE final rule and the Code of Federal Regulations (CFR) with the additions proposed in this CASE Report (U.S. DOE 2015; CFR YEAR).

Table 3: CFR Language with CASE Proposed Requirements for Non-Federally Regulated Linear Fluorescent Lamps

Lamp type	Correlated color temperature	Minimum average lamp efficacy (lm/W)
4-foot medium bipin	≤4,500K	92.4
	>4,500K and ≤7,000K	88.7

2-foot U-shaped	≤4,500K	85.0
	>4,500K and ≤7,000K	83.3
8-foot slimline	≤4,500K	97.0
	>4,500K and ≤7,000K	93.0
8-foot high output	≤4,500K	92.0
	>4,500K and ≤7,000K	88.0
4-foot miniature bipin standard output	≤4,500K	95.0
	>4,500K and ≤7,000K	89.3
4-foot miniature bipin high output	≤4,500K	82.7
	≤4,500K	92.4
High CRI linear fluorescent lamp	All CCTs	110.0
Less than 4-foot linear fluorescent lamp	All CCTs	110.0
8-foot high output, CRI of 87 or greater	≤4,500K	92.0
	>4,500K and ≤7,000K	88.0

4.3.5 Proposed Additional Reporting Requirements

The Statewide CASE Team proposes inclusion of the following information for each lamp entry in the Energy Commission's Modernized Appliance Efficiency Database System (MAEDbS):

- Manufacturer;
- Brand;
- Model Number;
- Regulatory Status;
  - C – Federally-Regulated Consumer Product
  - I – Federally-Regulated Commercial & Industrial Equipment
  - N – Non-Federally Regulated
  - V – Voluntarily Certified
  - Z – N/A
- Lamp Type;
  - 2U – 2-foot U-shaped general service fluorescent lamp
  - 4B – 4-foot medium bi-pin general service fluorescent lamp
  - 4H – 4-foot mini bi-pin high output general service fluorescent lamp

- 4S – 4-foot mini bi-pin std output general service fluorescent lamp
- 8H – 8-foot high output general service fluorescent lamp
- 8S – 8-foot slim line general service fluorescent lamp
- CB – candelabra base incandescent lamp
- GI - general service incandescent lamp
- IB – intermediate base incandescent lamp
- IR –incandescent reflector lamp
- LE – LED lamps
- MR – Modified spectrum incandescent reflector lamp
- MS – Modified spectrum general service incandescent lamp
- 2L – 2-foot linear LED lamp
- 3L – 3-foot linear LED lamp
- 4L – 4-foot linear LED lamp
- 8L – 8-foot linear LED lamp

- Bulb Finish;
  - C – Clear
  - F – Frost
  - W – Soft White
- ANSI Bulb Shape;
  - A – A-15
  - B – A-19
  - C – A-21
  - D – A-23
  - E – A-25
  - F – BT-14.5
  - G – BT-15
  - H – CA-22
  - I – CP-19
  - J – PS-25
  - K – PS-30
  - L – TB-19
  - M – A-17

- Average Lamp Efficacy;
- Rated Lumens;
- Nominal Rated Lamp Wattage (W);
- Correlated Color Temperature;
- Lamp Diameter (inches);
- Rated Voltage (V);
- Rated Lifetime (hours);
- Rated Color Rendering Index.

4.3.6 Proposed Marking and Labeling Requirements

The Statewide CASE Team does not propose any marking or labeling requirements.

5. Analysis of Proposal

5.1 Scope/Framework

The scope of fluorescent lamps subject to this standard covers:

- High CRI fluorescent lamps:
  - Fluorescent lamps that have a CRI of 87 or greater;
- 8-foot high output linear fluorescent lamps with CRI greater than 87
  - Fluorescent lamps that have a nominal length of 96 inches, lumen output greater than or equal to 8,000 lumens, and a CRI of 87 or greater.
- Impact-resistant fluorescent lamps:
  - 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
  - Is designated and marketed for the intended application, with:
    - The designation on the lamp packaging; and
    - Marketing materials that identify the lamp as being impact-resistant, shatter-resistant, shatter-proof, or shatter-protected (U.S. DOE 2015); and
- Less than 4-foot linear fluorescent lamp:
  - Any straight-shaped fluorescent lamp (most commonly 2-foot medium bipin lamps, though 3-foot lamps exist) with medium bipin bases of nominal overall length of less than 48 inches.

High CRI and impact-resistant fluorescent lamps are included in this scope because market research has shown that since the U.S. DOE standard on T12s was passed on January 26, 2015, manufacturers have started to produce more products that fall

into these two excluded categories.[5] As a result, high CRI and impact-resistant products have become more standard than specialty.

Additionally, less than 4-foot linear fluorescent lamps are within scope of this analysis as shipment information found in the 2015 U.S. DOE Lighting Market Characterization (2017) shows that this lamp type is a significant share of the market and provides potential for savings from standards.

8-foot high output linear fluorescent lamps with CRI of 87 or greater are included as well, but at the existing federal efficacy levels as linear LED lamps are not yet able to provide the lumen output needed for the high output (HO) T12s applications, so both scenarios.

This CASE Report presents results from a retrofit scenario that assumes the loophole products will be replaced by both fluorescent and light-emitting diode (LED) equivalent (with the exception of 8-foot high-output lamps, for which we assume that only T8 HO fluorescent lamps will replace all T12 HO lamps), the share of which are based on market penetration of linear LED products. Section 5.5.4 has more information on the current and projected future market penetration of the LED products.

5.2 Product Efficiency Opportunities

The Statewide CASE Team recommends that lamp efficacy for these products be determined by computing the ratio of the measured lamp lumen output and lamp electrical power input at equilibrium for the reference condition. Lamp lumen output is the total luminous flux produced by the lamp, at the reference condition, in units of lm. Lamp electrical power input means the total electrical power input to the lamp, including both arc and cathode power where appropriate, at the reference condition, in units of watts (W). These definitions are either already incorporated into Title 20 or are listed in Section 4.3.1; the full test procedure to measure efficacy is outlined further in Section 4.3.2.

Fluorescent T8 lamps and linear LED lamps[6] are both direct replacements that offer efficiency and other performance gains over the baseline lamps. However, many T12s currently on the market operate on magnetic ballasts and will need to be retrofitted to electronic ballasts to drive T8 lamps or LED tubes. As such, costs for retrofitting magnetic ballasts are included in this analysis. Fluorescent T8s are often the same price as or cheaper than T12 lamps and are roughly 20 percent more efficient. LED tubes, while still more expensive than fluorescent tubes, are over 50 percent more efficient and have significantly improved operating lifetimes, with potential for great color quality and options.

5.3 Interactions with Title 24, Part 6

Because this measure will result in retrofitting existing luminaires, the interactions with Title 24, Part 6 must be investigated. If the code detailed in Title 24, Part 6 is affected (triggered) during the retrofitting of loophole T12 systems (meaning that an alteration to a luminaire results in an application within the scope of the Title 24 Building Energy Efficiency Standards),[7] then indoor lighting requirements must be met in order to comply. These requirements include applicable lighting power density and lighting controls.

Section 141.0(b)2I of Title 24[8] describes Lighting Alterations and includes the following requirements: Alterations to indoor lighting systems that include 10 percent or more of the luminaires serving an enclosed space shall meet the Indoor Lighting Power Densities (LPD)[9] described in Section 140.6 of Title 24, and the lighting controls requirements in Table 141.0-E of

[5] The National Electrical Manufacturers Association (NEMA) periodically releases Lamp Index information that has shown that T12s have maintained a 12 to 15 percent share of the linear market in 2017, where U.S. DOE assumed T12s to about 2.6 percent in the same year. See Section 5.3 for more information.
[6] UL Type A LED lamps are fluorescent ballast compatible.
[7] http://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf
[8] At the time of writing this report, 2019 Title 24 (effective January 1, 2020) has not yet been adopted, but the Energy Commission has released 15-day language, which will be assumed to be adopted and effective along with this measure.
[9] LPD values are maximum allowed watts of lighting per square foot of room floor area.

Title 24. However, there are exceptions to this section of the code, most relevant of which is Exception 7 to Section 141.0(b)2I of Title 24 which says that if a building owner alters 50 or fewer luminaires per floor, or per tenant space, per year, then that building owner does not have to comply with Title 24, Part 6 requirements. Thus, if a building owner retrofits more than 10 percent of the total luminaires per space, or more than 5070 luminaries per space per year, Title 24, Part 6 is triggered.

The 2019 Title 24, Part 6 is expected to update the allowed LPD values for indoor lighting to reflect the increased efficacy and increased optical control associated with LED technology.[10] The LPD values were developed by accounting for increases in LED efficacy that have been occurring over recent years in all varieties of nonresidential LED luminaires. Additionally, increased efficacy has been mandated for certain lamp products by Title 20 Regulations that were adopted in 2016 as well as the U.S. DOE LED efficacy regulations that are being developed concurrently. Title 24, Part 6 does not mandate a particular technology as long as it requires no more adjusted lighting power than the allowed wattage. In the case of retrofitting loophole T12 luminaires, the building owner can install qualifying fluorescent T8 and electronic ballast lighting systems, but the building owner must be cognizant of the code triggers; if Title 24, Part 6 is triggered, installing less efficacious fluorescent lighting may exceed LPD requirements.

Additionally, if Title 24, Part 6 is triggered, there are variations in controls requirements depending on the power of the newly installed lighting system when compared to the incumbent system. If the newly installed lighting system is 80 percent of the allowable indoor lighting power requirements, or if the one-for-one luminaire alteration is 40 percent less wattage than the pre-alteration wattage, then multi-level controls, daylighting controls, and demand responsive controls are not required. In essence, if a building owner retrofits to a more efficient light system, then some control requirements can be avoided.

There are several different scenarios regarding building code compliance where T12 lamps will be retrofitted, and each may result in different costs that should be accounted for in this measure. The lowest cost scenario would be a building that retrofits less than 10 percent of the luminaires or fewer than 50 luminaires in a space, as Title 24, Part 6 is not triggered and the cost of the retrofit is restricted to materials and labor only. Scenarios that trigger code will be costlier—mostly due to the lighting controls requirements. However, if a more efficient system is installed, as mentioned above, the costs of controls can be reduced as well. As such, a better option, both in terms of code compliance and cost, is for building owners to comply by installing LED or equivalent technology. Figure 1 shows the flow of code compliance with regards to fluorescent retrofits resulting in luminaire alterations. While it is difficult to estimate how many projects will trigger code, the Statewide CASE Team assumes that building owners will consider these costs, which will influence their decision to install LEDs over fluorescent lighting.

[10] More information can be found in the 2019 Indoor Lighting Power Densities CASE Report: http://title24stakeholders.com/wp-content/uploads/2018/01/2019-T24-CASE-Report_NR-Indoor-Light-Sources_Final_December-2017.pdf

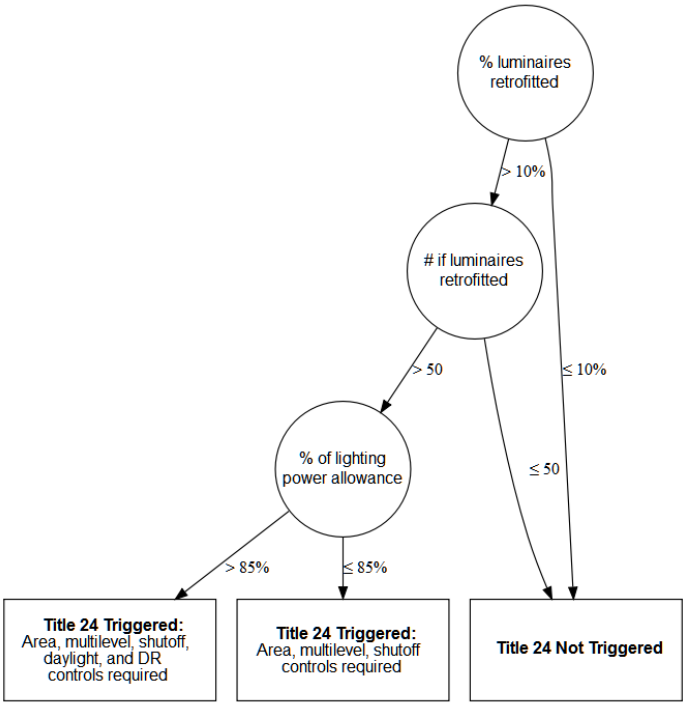

Figure 1: Flow diagram of code compliance with alterations.

Source: Statewide CASE Team Analysis 2018.

5.4 Technical Feasibility

5.4.1 4-Foot and 8-Foot Fluorescent T12s

T12s within the scope of this analysis come in three form factors: 4-foot SO, 8-foot SO, and 8-foot HO. To meet this proposed standard, consumers have several different options for compliance. The Statewide CASE Team assumes that most users that currently use high CRI T12 lamps do not have a specific need for high CRI; they are simply replacing the incumbent lamp with one that looks the most similar. As such, the Statewide CASE Team expects that most users will either opt to replace T12 lamps with equivalent T8 lamps, or will replace T12 lamps with LEDs. However, as LED luminaires become more common and affordable, the entire fixture may commonly be replaced. For the purposes of this analysis, the Statewide CASE Team only assumes that the loophole T12 products will be replaced by an equivalent lamp (removable) product.

The fluorescent retrofits assume that 4-foot T12s are 40W lamps operating on magnetic ballasts, and will be replaced by the commonly found 32W T8; the 8-foot SO T12s will be replaced by 59W T8s, and the 8-foot HO lamps will be replaced by 86W T8 HO lamps. All replacements will operate on electronic ballasts. The LED retrofits assume that the SO loophole products will be replaced by 4-foot LED tubes and 8-foot LED tubes, respectively. To use a cost conservative assumption, the Statewide CASE Team assumes that users that retrofit to linear LED lamps will remove the ballast and use a Type B (ballast bypass) LED lamp, which are intended to be connected directly to line voltage. Regardless of the type of lamp used as a replacement, the labor costs are assumed be the same, as it will take the same amount of time to remove the magnetic ballast and install an electronic ballast or bypass the ballast altogether.

Linear LED lamps provide significant improvements in efficacy and lifetime over fluorescent lamps; Table 4, Table 5, and Table 6 provide the summary of this information for average products on the market used as representative models in this

analysis. These tables show that LEDs are over twice as efficacious and up to three times as long-lived. However, in the case of the 4-foot lamps, there is a 24 percent drop in lumens. While the rated lamp lumens are clearly different, an actual installed LED system will have similar illuminance as its T8 counterpart. This is an effect of the directionality of LED light compared to radial emission of a fluorescent lamp, and will result in greater efficiency of the light fixture application.

Table 4: Comparison of Typical 4-Foot Fluorescent Lamps and Their LED Counterparts

	Typical T12 fluorescent	Typical Linear LED	Percent change
Lumens	2,400	1,830	-24%
Watts	40	15	-63%
Efficacy	60	122	103%
Lifetime	26,700	50,000	87%

Source: Statewide CASE Team Analysis 2018.

Table 5: Comparison of Typical 8-Foot Fluorescent Lamps and Their LED Counterparts

	Typical T12 fluorescent	Typical Linear LED	Percent change
Lumens	4,430	4,360	-2%
Watts	75	36	-52%
Efficacy	59	121	105%
Lifetime	12,000	50,000	317%

Source: Statewide CASE Team Analysis 2018.

This analysis does not include 8-foot HO LEDs. While there are products marketed as such, the lumen values are well below that of fluorescent HO products. Because linear LED lamps are not yet able to provide the lumen output needed for these applications, the retrofit scenario assumes that the T12 HOs are replaced by 86-watt T8 HO lamps, as shown in Table 6.

Table 6: Comparison of Typical 8-foot T12 HO Fluorescent Lamps and their T8 HO Counterparts

	Typical T12 HO	Typical T8 HO	% Change
Lumens	8,770	8,100	-8%
Watts	110	86	-22%
Efficacy	80	94	18%
Lifetime	12,000	22,000	83%

Source: Statewide CASE Team Analysis 2018.

5.4.2 2-Foot Fluorescent Lamps

The 2-foot fluorescent lamps within the scope of this analysis come in three lamp types: T12, T8, and T5. As shown in Table 7, replacing any three of the lamp types with LED technology results in comparable light quality as well as improved efficacy and lifetime. As such, Table 7 compares the same 2-foot linear LED lamp to each of the fluorescent options. In each case, there is an improvement in efficacy and lifetime and less than 20% reduction in lumen output. As mentioned above, the Statewide CASE Team expects similar illuminance from these LED systems compared to the fluorescent systems.

Table 7: Comparison of Typical 2-Foot Fluorescent Lamps and Their LED Counterparts

	Typical T12	Typical LED	Percent change	Typical T8	Typical LED	Percent change	Typical T5	Typical LED	Percent change
Lumens	1,160	1,130	-3%	1,380	1,130	-18%	1,350	1,130	-16%
Watts	20	9	-57%	17	9	-49%	14	9	-38%
Efficacy	58	130	124%	81	130	60%	96	130	35%
Lifetime	9,000	50,000	456%	24,800	50,000	102%	29,200	50,000	71%

Source: Statewide CASE Team Analysis 2018.

5.5 Statewide Energy Savings

5.5.1 Per-Unit Energy Savings Methodology

This section describes the methodology the Statewide CASE Team used to estimate energy and environmental impacts. The Statewide CASE Team calculated the impacts of the proposed code change by comparing non-qualifying products to qualifying products, as shown in Table 8 for the fluorescent retrofit options and Table 9 for the LED retrofits option. The analyses assume typical 2-lamp luminaires and per lamp wattages were determined by dividing typical fixture wattages[11], which include the ballast losses, by two. Because Type B (ballast bypass) linear LEDs are the cheapest option for retrofitting fluorescent fixtures, the nominal wattage of those products is used in these analyses.

Table 8: Per-Lamp Savings for Fluorescent Retrofits

Lamp type	Typical non-qualifying wattage	Typical qualifying wattage	Wattage savings
4-foot SO	47	29.5	17.5
8-foot SO	86.5	54.5	32
8-foot HO	128.5	80	48.5

Source: Statewide CASE Team Analysis 2018.

Table 9: Per-Lamp Savings for LED Retrofits

Lamp Type	Typical non-qualifying wattage	Typical qualifying wattage	Wattage savings
2-foot T12	28	9	19
2-foot T8	16.5	9	7.5
2-foot T5	17	9	8
4-foot SO	47	15	32
8-foot SO	86.5	36	51

Source: Statewide CASE Team Analysis 2018.

[11] Standard fixture wattages gathered from Appendix B, accessed: http://www.aesc-inc.com/download/spc/2013SPCDocs/PGE/App%20B%20Standard%20Fixture%20Watts.pdf

5.5.1.1 Annual Per-Unit Energy Use Methodology

To find the annual per-unit energy savings, the Statewide CASE Team applied half of typical 2-lamp fixture wattages to sector annual hours of operation as assumed by U.S. DOE. This is shown in Table 10 and Table 11 for the fluorescent and LED scenarios, respectively.

Table 10: Per-Unit Annual Energy Savings by Lamp Type, Fluorescent

Lamp type	Wattage savings	Annual hours of operation	Annual per-unit energy savings (kWh)
4-foot SO (residential, commercial and industrial)	17.5	4,051	71
8-foot SO (commercial and industrial)	32	4,325	138
8-foot HO (commercial and industrial)	48.5	4,325	210

Source: Statewide CASE Team Analysis 2018.

Table 11: Per-Unit Annual Energy Savings by Lamp Type, LED Scenario

Lamp type	Wattage savings	Annual hours of operation	Annual per-unit energy savings (kWh)
2-foot T12 SO (residential, commercial and industrial)	19	4,051	77
2-foot T8 SO (residential, commercial and industrial)	7.5	4,051	31
2-foot T5 SO (residential, commercial and industrial)	8	4,051	33
4-foot T12 SO (residential, commercial and industrial)	32	4,051	129
8-foot T12 SO (commercial and industrial)	51	4,325	218

Source: Statewide CASE Team Analysis 2018.

5.5.1.2 Peak Demand Methodology

Peak demand was calculated by multiplying daily electricity use by an assumed load factor. A load factor is the ratio of average annual load to coincident peak load. The Statewide CASE Team obtained end-use load factors through consultations with the Energy Commission. The load factors used in this report were developed by the Energy Commission using an Hourly Energy and Load Model (HELM) (Brown and Koomey 2002) on 2013 utility-level energy demand data. A complete table of updated values for several end uses is included in Appendix B: Load Factors. For the purposes of this report, the Statewide CASE Team used a load factor of 0.72 for all lamps.

5.5.2 Summary of Per-Unit Energy Use Impacts

Non-qualifying products are products that do not meet the proposed standard and qualifying products are products that meet the proposed standards. Electricity use and peak demand per unit for both non-qualifying and qualifying products are presented below in Table 12 and Table 13, respectively. The methodologies used to calculate these estimates is presented above in Sections 5.5.1.1 and 5.5.1.2.

Table 12: Non-Qualifying Product Energy Use Per Unit

Non-qualifying product class	Electricity use (kWh/year)	Peak demand (W)
2-foot T12 fluorescent lamp	113	18
2-foot T8 fluorescent lamp	67	11
2-foot T5 fluorescent lamp	69	11
4-foot T12 fluorescent lamp	190	30
8-foot T12 fluorescent lamp	374	59
8-foot T12 HO fluorescent lamp	556	88

Source: Statewide CASE Team Analysis 2018.

Table 13: Qualifying Product Energy Use Per Unit

Product class	Electricity use (kWh/year)	Peak demand (W)
4-foot T8 fluorescent lamp	119	23
8-foot T8 fluorescent lamp	236	43
8-foot T8 HO fluorescent lamp	346	62
2-foot LED linear lamp	36	6
4-foot LED linear lamp	61	15
8-foot LED linear lamp	156	26

Source: Statewide CASE Team analysis 2018.

5.5.3 Stock and Shipments

To estimate 4-foot and 8-foot fluorescent lamp stock in California, the Statewide CASE Team used the National Impacts Analysis and Shipments Analysis from the U.S. DOE's Final Rule on GSFLs, published in 2014.[12] Within this analysis, U.S. DOE offers total stock of lamps installed and shipments nationwide for each trial standard level (TSL) analyzed. In addition, the Statewide CASE Team used stock values from TSL 4, which was adopted in the 2014 Final Rule, with the year 2020 as the period of analysis. A summary of stock values in this data can be seen in Table 14. To estimate stock of 2-foot fluorescent lamps, the Statewide CASE Team used estimated share of lamps less than 4-foot at 7 percent from the 2015 U.S. DOE Lighting Market Characterization, coupled with the National Impacts Analysis and Shipments Analysis from the U.S. DOE's Final Rule on GSFLs. While using the estimated share of lamps less than 4-foot includes 3-foot as well as entirely 2-foot2-foot lamps, the Statewide CASE Team conservatively assumes a 2-foot standard for the analysis; retrofitting 2-foot fluorescent lamps with LEDs saves less than retrofitting 3-foot lamps, and 1' lamps are not typically used in general service applications

Because the data from U.S. DOE reflects national stock, the Statewide CASE Team multiplied these values by 12 percent to estimate California lamp stock for the analysis, as this is the percentage of California's population compared to the entire U.S. population.[13]

In the GSFL Final Rule, U.S. DOE also published shipments of lamps to be installed each year from 2013 to 2047; the Statewide CASE Team used these shipment numbers as a proxy for sales for 4-foot and 8-foot lamps., The same

[12] U.S. DOE's shipments analysis can be found in the GSFL / IRL (incandescent reflector lamp) docket folder: https://www.regulations.gov/docket?D=EERE-2011-BT-STD-0006

[13] 2016 U.S. population: 323.1 million. 2016 CA population: 39.25 million, or 12.15 percent of the U.S. population. Population numbers sourced using U.S. Census Bureau "U.S. Fact Finder Tool": https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

methodology was used to estimate shipments of 2-foot lamps. Table 14 summarizes the year 2020, which is the first year the standard would take effect.

Table 14: National and California Stock and Shipments of Fluorescent Lamps in 2020 (Thousands of Lamps)

	T12 4-foot medium bipin	T12 8-foot standard output	T12 8-foot HO	T12, T8, and T5 lamps < 4-foot
National stock in 2020	9,958	12,802	1,757	163,815
National shipments in 2020	795	4,894	658	28,316
California stock in 2020	1,204	1,548	212	19,805
California shipments in 2020	96	592	80	3,423

Source: U.S. DOE 2014a, 2017.

5.5.3.1 Lamp Type Trends

The National Electrical Manufacturers Association (NEMA) releases quarterly lamp indices of sales data for trends of various lamp types, including fluorescent lamps, collected from member companies. Figure 2 below shows the historical trends of T5, T8, T12, and LED stock data from NEMA. This data was available quarterly from Quarter (Q) 2 of 2010 to Q2 of 2017, with some gaps in data availability. Where data was unavailable, values from the graphs available were estimated and data points were extrapolated accordingly. These NEMA publications demonstrate a few key points relevant to this analysis:

- In the second quarter of 2017, T12 lamps claim a 12.4 percent share of the market of all T12, T8, T5, and linear LED lamps. While slightly declining from previous quarters, this share of the linear market has remained fairly consistent since the effective date of the first Federal Rulemaking on GSFLs in 2012. This rulemaking was expected to substantially eliminate T12s from the market, in favor of T8s, T5s, and LEDs. However, this market transition has not occurred as expected.
- The penetration of linear LED lamps is increasing, though still less than 25 percent in 2017. Since NEMA has started tracking linear LED lamps in Q4 of 2015, T12s have dropped roughly 4% in market share, T8s have dropped 15% in the same time, and LEDs have achieved 22% of the market. This suggests that LEDs are replacing T8s more often than they are replacing T12s.

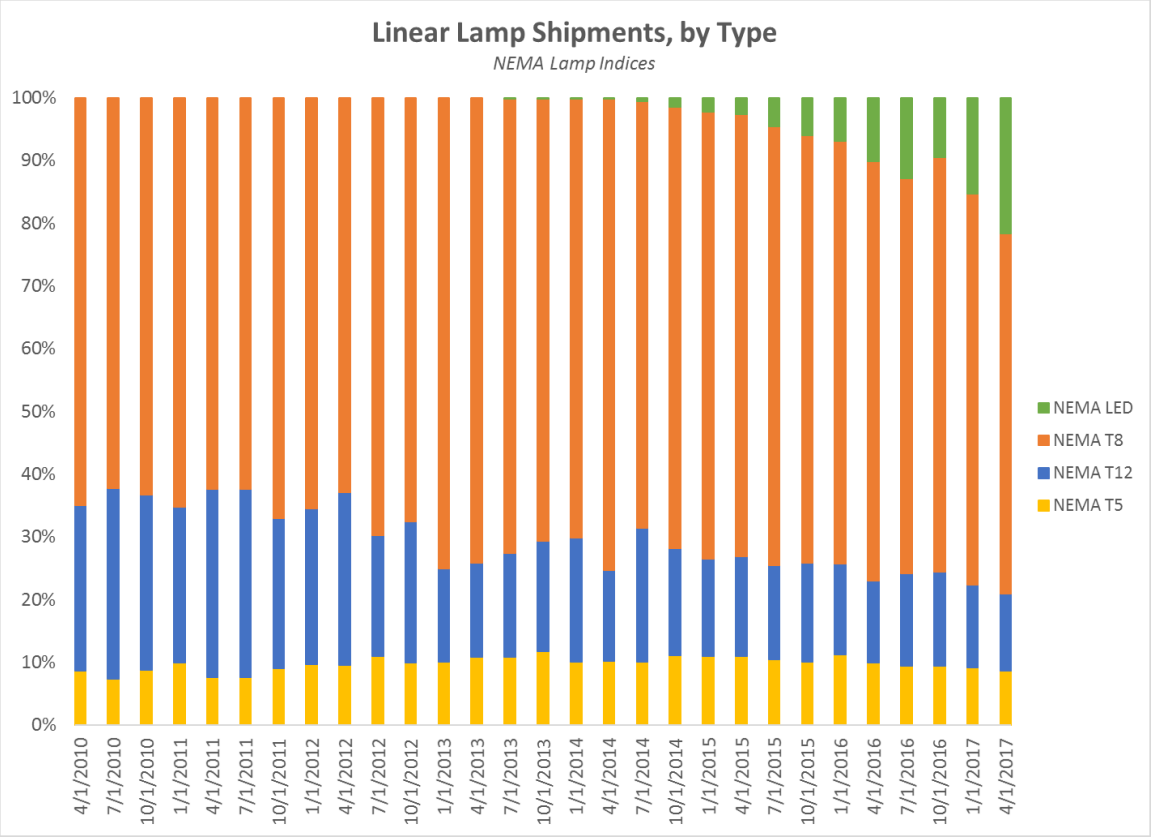

Figure 2: NEMA data on the share of linear fluorescent and LED lamp market penetration.

Source: National Electrical Manufacturers Association (NEMA) Lamp Indices: https://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx

Through conversations with market actors and knowledge of California utility efficiency programs, the Statewide CASE Team believes this trend of survival of the T12 market is focused in the small commercial sector. Small business owners typically do not procure maintenance contracts and often service their facilities themselves. When it comes to maintaining the lighting systems, the small business owner or employee will typically take a burned-out lamp to the hardware store and purchase the lamp that is closest in shape and size. If it is a T12, the consumer will buy a replacement T12 as long as it is on the shelf. Additionally, the small commercial sector is not easily reached by utility efficiency programs; they are not the "low-hanging fruit" of large commercial efficiency opportunities and have smaller facilities that are upgraded less often.

The U.S. DOE data assumes 92.6 percent of T12 lamps are shipped to commercial and industrial installations and the remaining 7.4 percent are shipped to residential spaces. The Statewide CASE Team uses these assumptions in the analysis described in Section 5.5.5.

5.5.4 Current and Future Shipments

As mentioned above, NEMA data shows that although the federal standards for GSFLs increased in stringency in 2012, and again in 2017 with the intention of phasing out the use of T12 lamps, T12 lamps have still maintained a significant market share. Based on the Statewide CASE Team's research, it is clear that manufacturers have used the high CRI exclusion to produce low efficacy T12 lamps with a high CRI instead of producing higher efficacy lamps overall.

With the initial data available from NEMA, the Statewide CASE Team then projected future shipments out to 2030. The Statewide CASE Team assumed a constant market share for T5s and T12s into 2030 (given relatively constant historical trends) and performed linear projections for T8s and LEDs; T8s declined linearly in market share and LEDs increased

linearly in market share (given historical trends that LEDs are taking over T8 market share). This projection represents the standards case in 2020, where T12s are assumed to be 0 percent of the market, T5s remain constant at 8.6 percent, T8s are the majority at 56.4 percent and LEDs are continuing their increase to 35 percent. The resulting market share projection for T5, T8, T12, and LED products in years 2020 to 2030 is shown in Table 15.

Table 15: Projected Market Share of Linear Products, 2020 to 2030

	T5	T8	T12	LED
2020	8.6%	56.4%	0%	35.0%
2021	8.6%	51.4%	0%	40.0%
2022	8.6%	46.5%	0%	44.9%
2023	8.6%	41.5%	0%	49.9%
2024	8.6%	36.6%	0%	54.8%
2025	8.6%	31.6%	0%	59.8%
2026	8.6%	26.7%	0%	64.8%
2027	8.6%	21.7%	0%	69.7%
2028	8.6%	16.7%	0%	74.7%
2029	8.6%	11.8%	0%	79.6%
2030	8.6%	8.2%	0%	84.6%

Source: Statewide CASE Team Analysis 2018.

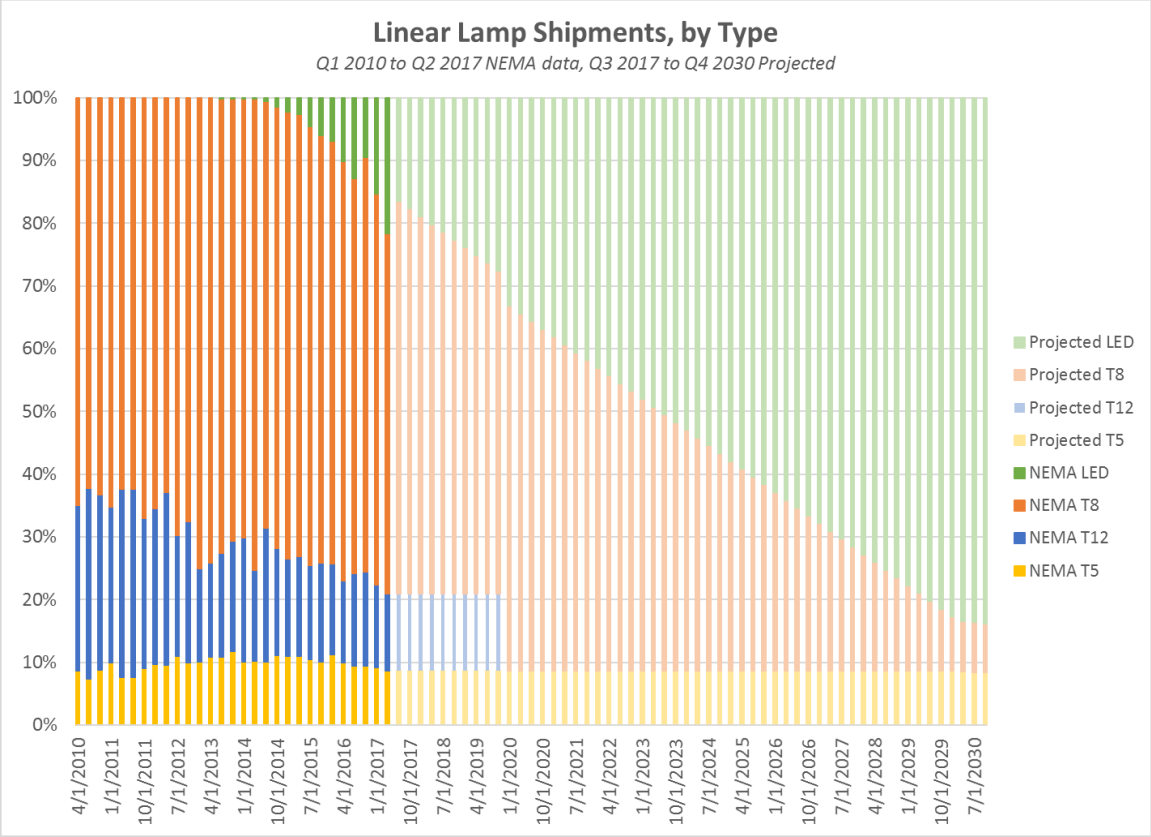

Figure 3: NEMA Lamp Indices data (solid bars) and Statewide CASE Team projections (transparent bars) of linear fluorescent and LED shipments from 2011 to 2030.

Source: NEMA 2010, 2017; Statewide CASE Team analysis years 2017 to 2030.

5.5.5 Statewide Energy Savings - Methodology

Statewide savings estimates were calculated by applying the per-unit energy savings presented in Section 5.5.1 to the statewide stock and sales forecast presented in Section 5.5.3 of the report. Demand reduction is calculated by dividing the annual energy savings by the total number of hours in a year (8,760) and the load factor of 0.72.

5.5.6 Statewide Energy Use – Non-Standards and Standards Case

This section shows energy use from the non-standards and standards case in Table 16 and Table 17, respectively. The difference between the two, which are the potential savings from the measure is shown in Table 18. This CASE Report analyzes savings from retrofitting all fluorescent lamps less than 4', and 4' and 8' T12 fluorescent products, shipments of which are expected to naturally decrease (as described in Section 5.5.4). As such, the savings expected from the measure will decrease over time, with savings tapering off after 2030.

Table 16: California Statewide Energy Use – Non-Standards Case (After Effective Date)

Year	Annual shipments		Stock	
	Electricity use (GWh/year)	On-site electricity demand (MW)	Electricity use (GWh/year)	On-site electricity demand (MW)
2020	524	82	1,772	281
2021	434	68	1,957	310
2022	358	56	2,071	328

2023	303	48	1,868	296
2024	260	41	1,866	296
2025	226	36	1,757	279
2026	202	32	1,619	257
2027	185	29	1,509	239
2028	171	27	1,420	225
2029	158	25	1,345	213
2030	147	23	1,275	202

Source: Statewide CASE Team analysis 2018.

Table 17: California Statewide Energy Use – Standards Case (After Effective Date)

Year	Annual shipments		Stock	
	Electricity use (GWh/year)	Electricity demand (MW)	Electricity use (GWh/year)	Electricity demand (MW)
2020	283	45	1,538	244
2021	232	37	1,526	236
2022	190	30	1,475	223
2023	161	25	1,252	190
2024	138	22	1,219	186
2025	121	19	1,068	164
2026	108	17	890	138
2027	99	16	813	127
2028	92	15	767	121
2029	86	14	727	115
2030	79	13	690	109

Source: Statewide CASE Team analysis 2018.

Table 18: California Statewide Energy Savings – Standards Case (After Effective Date)

Year	Annual shipments		Stock	
	Electricity use (GWh/year)	Electricity demand (MW)[a]	Electricity use (GWh/year)	Electricity demand (MW)[a]
2020	240	37	233	37
2021	202	31	430	74
2022	168	26	596	105
2023	143	22	616	106
2024	122	19	647	110
2025	106	17	689	114
2026	94	15	729	119
2027	85	13	696	112
2028	78	12	653	105
2029	73	12	618	98
2030	67	11	585	93

Source: Statewide CASE Team analysis 2018.
[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Brown and Koomey (2002).

Estimated stock turnover savings from the proposed measures are 892 GWh / year. Please note that this value is different from the table above because while the weighted average year for stock turnover is 2026, there are a range of stock turnover years that depend on the replacement product type.

5.6 Cost-Effectiveness

This section describes the methodology and approach the Statewide CASE Team used to analyze the economic impacts of the proposed standard.

5.6.1 Incremental Cost

The Statewide CASE Team used online retailers to collect average online price, performance, and availability data for qualifying and non-qualifying lamps. Incremental cost values were developed from analyzing five online lighting retailer websites and 31 total products. Table 19 below shows the incremental costs for each qualifying product, which includes the cost of the lamps and the appropriate ballasts, ballast disposal costs, along with labor costs in both the fluorescent and LED retrofit scenarios.

Table 19: Non-Qualifying and Qualifying Product Incremental Cost

Product type	Product cost	Incremental cost
2-foot fluorescent T12 (lamp only)	$4.40	N/A
2-foot fluorescent T8 (lamp only)	$2.10	N/A
2-foot fluorescent T5 (lamp only)	$3.10	N/A
4-foot fluorescent T12 (lamp only)	$2.20	N/A
8-foot fluorescent T12 (lamp only)	$4.40	N/A
8-foot fluorescent T12 HO (lamp only)	$5.90	N/A
4-foot fluorescent T8, electronic ballast, and labor	$41.25	$39.05
8-foot fluorescent T8, electronic ballast, and labor	$61.39	$56.99
8-foot fluorescent T8 HO, electronic ballast, and labor	$87.26	$81.36
2-foot LED tube, Type B replacing T12 lamp and removing ballast	$43.54	$39.14
2-foot LED Tube, Type B replacing T8 lamp, removing ballast	$43.54	$41.44
2-foot LED Tube, Type B replacing T5 lamp and removing ballast	$43.54	$40.44
4-foot LED tube, Type B replacing T12 lamp and removing ballast	$43.84	$61.64
8-foot LED tube, Type B replacing T12 lamp and removing ballast	$67.15	$62.75

Source: Various sources used. See Table 27 for full list. Accessed April 2018. Ballast disposal costs assumed to be $1.25 per pound.

In order to prove cost-effectiveness in all retrofit scenarios, the Statewide CASE Team assumes that all T12 lamps currently operate on magnetics ballasts and will need to be retrofitted when installing a T8 fluorescent lamp. For 2-foot-foot lamps,

this analysis assumes that T8 and T5 lamps operate on electronic ballasts. This analysis assumes that Type B lamps will be used when retrofitting to LEDs, as the lowest cost option is to simply remove the magnetic ballast and directly wire the terminals to line voltage rather than purchasing a new electronic ballast. Labor costs of removing the ballast and replacing the ballast are assumed to be the same, so those costs are included with the LED scenarios. Ballast prices were collected from online retailers and labor costs were retrieved from the 2018 RSMeans catalogue; the assumptions seen in Table 20 were included in the incremental costs presented in Table 19.

Table 20: Ballast Cost Assumptions

Ballast type	Ballast cost	Labor cost per fixture[a]	Total ballast cost per lamp
4-foot 2-lamp T8 medium bipin normal ballast factor	$8.60	$60.30	$34.45
8-foot 2-lamp T8 single pin slimline normal ballast factor	$16.30	$70.76	$43.53
8-foot 2-lamp T8 recessed double contact (RDC) base HO normal ballast factor	$56.90	$70.76	$63.83
2-foot 2-lamp ballast removal and direct wire	$0	$60.30	$30.15
4-foot 2-lamp ballast removal and direct wire	$0	$60.30	$30.15
8-foot 2-lamp ballast removal and direct wire	$0	$70.76	$35.38

Source: RS Means 2018; Statewide CASE Team Analysis 2018.

[a] Labor costs used from RSMeans, 2018 for Sacramento, CA.

5.6.2 Design Life

The Statewide CASE Team used U.S. DOE's National Impact Analysis values for hours of operation by sector, weighted by shipments, and coupled with current product lifetimes to estimate the design lives of the products shown in Table 21. Table 10 and Table 11 show the hours of operation assumed for each lamp type.

Table 21: Qualifying Product Lifetimes

Product type	Lifetime (years)
2-foot fluorescent T12	2.2
2-foot fluorescent T8	6.1
2-foot fluorescent T5	7.2
4-foot fluorescent T12	5.7
8-foot fluorescent T12	3.0
8-foot fluorescent T12 HO	2.7
4-foot fluorescent T8	8.4
8-foot fluorescent T8	5.9
8-foot fluorescent T8 HO	5.0
2-foot linear LED	12.3
4-foot linear LED	12.3
8-foot linear LED	12.3

Source: U.S. DOE 2014a; Statewide CASE Team Analysis 2018.

5.6.3 Lifecycle Cost / Net Benefit

The per-unit and total lifecycle costs and benefits of the proposed standard are presented in Table 22 below.

Table 22: Costs and Benefits Per Unit for Qualifying Products[a]

Product class	Product life (years)	Lifecycle costs/benefits per unit (PV)		NPV per unit
		Total PV costs	Total PV benefits	NPV
4-foot fluorescent T8	8.4	$39.05	$80.65	$41.60
8-foot fluorescent T8	5.9	$56.99	$118.23	$61.24
8-foot fluorescent T8 HO	5.0	$81.36	$151.02	$69.66
2-foot linear LED lamp (replacing T12)	12.3	$39.14	$121.88	$82.74
2-foot linear LED lamp (replacing T8)	12.3	$41.44	$48.11	$6.67
2-foot linear LED lamp (replacing T5)	12.3	$40.44	$51.32	$10.88
4-foot linear LED lamp	12.3	$41.64	$210.32	$168.68
8-foot linear LED lamp	12.3	$62.75	$345.84	$283.09

Source: Statewide CASE Team Analysis 2018.

[a] Cost savings will be realized through lower electricity bills. Average annual electricity was used, starting in the effective year.

[b] PV calculated using the Energy Commission's average statewide energy rates (CEC 2018) and a 3 percent discount rate. See Appendix A for details.

[c] Incremental cost is the cost difference between the baseline non-qualifying product and the qualifying product.

These cost and benefits are associated with installation (lamp and ballast removal / replacement and energy savings). There are also maintenance benefits that are not accounted for in these values; because LEDs last longer than fluorescent lamps, operation involves less maintenance—resulting in reduced labor costs for facilities. Additionally, the Statewide CASE Team assumes shipments of impact resistant fluorescent lamps to be zero, which is conservative; there are savings from retrofitting these lamps that are not accounted for in this analysis.

5.7 Environmental Impacts/Benefits

After passage of new federal standards for GSFLs in July 2012, the market shift from T12s to T8s, T5s, and LEDs did not occur as expected. Instead of switching to more efficient lamps, manufacturers are now marketing and selling exempted, high CRI T12 lamps as inexpensive, extremely inefficient alternatives, presumably in order to circumvent efficacy standards. Specialty fluorescent lamps were excluded to ensure that they were not affected by undue restrictions only meant for general service lamps. However, the increased production of inefficient lamps (resulting from efforts to circumvent the intention of the exclusions) has led to significant savings lost for energy efficiency programs.

In April 2015, Governor Brown signed Executive Order B-30-15 that established a greenhouse gas (GHG) reduction target of 40 percent below 1990 levels by 2030. Senate Bill 32 codifies that target into law and provides even further impetus for California to continue pursuing energy efficiency.

5.7.1 Greenhouse Gases

Table 23 presents the annual and stock greenhouse gas (GHG) savings for the first year the standards take effect (2020), and the year of full stock turnover (2030). The Statewide CASE Team calculated the avoided GHG emissions from the adoption of the standard, assuming an emissions rate varying by year, in accordance with California's projected emissions factors as outlined in the 2017 update to the California Air Resources Board (CARB) scoping plan to meet the 2030 greenhouse gas targets (CARB 2017). The estimated annual statewide GHG savings is 99,558 $MTCO_2e$ in the first year the standard is in effect.

Table 23: Estimated California Statewide GHG Savings for Standards Case

Year	Annual GHG savings (MTCO2e/year)	Stock GHG savings (MTCO2e/year)
2020	99,558	99,558
2022	78,377	176,595
2023	60,587	235,659
2024	47,072	211,513
2025	36,281	193,932
2026	28,841	189,753
2027	22,587	176,202
2028	18,632	154,068
2029	16,149	136,622
2030	14,508	124,356

Source: Statewide CASE Team analysis 2018.

5.7.2 Indoor or Outdoor Air Quality

The Statewide CASE Team is not aware of any adverse impacts on indoor or outdoor air quality that would result from this proposed standard. However, decreasing energy consumption (through increased energy efficiency) as a result of the proposed code change would likely result in an increase in outdoor air quality. Increasing energy efficiency is known to reduce air pollutants such as nitrogen oxides (NOx) due to a decrease in combustion of fossil fuels for electricity generation. It is important to note that these same affects would not be realized in a 100 percent renewable energy electric grid.

5.7.3 Hazardous Materials

The proposed standard will result in a switch from consumers using less efficacious to using more efficacious fluorescent tubes, which will not result in a significant impact on hazardous materials impacts. However, the proposed standard will also yield an increased use of LEDs in the place of fluorescent tubes. This switch from fluorescent tubes to LEDs will result in decreased mercury usage. Furthermore, reductions and increases in a number of other materials (with varying degrees of toxicity) will result from this switch (U.S. DOE 2013).

5.8 Impact on California's Economy

If set at a reasonable level, an appliance standard can positively impact the economy through widespread energy savings among ratepayers while also not severely impacting the manufacturing community. Table 24 below shows the lifecycle benefit-to-cost (B/C) ratio as well as the NPV of the first-year shipments and the NPV of the stock turnover. These values indicate to the Statewide CASE Team that the proposed standard will not have an adverse impact on California's economy.

Table 24: Statewide Total Lifecycle Costs and Benefits for Standards Case[a]

Product Class	Lifecycle B/C ratio[b]	NPV [c]	
		For first-year shipments	Stock turnover[d]
4-foot fluorescent T8	2.0	$2,467,033	$4,793,592
8-foot fluorescent T8	2.0	$22,366,459	$46,759,825
8-foot fluorescent T8 HO	1.8	$5,544,360	$9,491,900
2-foot linear LED lamp (replacing T12)	3.0	$4,458,567	$7,570,854
2-foot linear LED lamp (replacing T8)	1.1	$18,564,856	$60,338,715

2-foot linear LED lamp (replacing T5)	1.2	$6,402,553	$29,920,731
4-foot linear LED lamp	4.8	$6,210,833	$15,084,493
8-foot linear LED lamp	5.3	$64,188,261	$161,454,259

Source: Statewide CASE Team Analysis 2018.

[a] The analysis does not include cost savings associated with embedded energy savings.

[b] Total PV benefits divided by total PV costs. Positive value indicates a reduced total cost of ownership over the life of the appliance.

[c] It should be noted that while the proposed standard is cost-effective, it may be more cost-effective if using alternative rate structures. For example, marginal utility rates may more accurately reflect what customers save on utility bills as result of the standard.

[d] Stock turnover NPV is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year (i.e. the NPV of "turning over" the whole stock of less efficient products that were in use at the effective date to more efficient products, plus any additional non-replacement units due to market growth, if applicable). For example, for a standard effective in 2015 applying to a product with a five-year design life, the NPV of the products purchased in the fifth year (2019) includes lifecycle cost and benefits through 2024, and therefore, so does the stock turnover NPV.

5.9 Consumer Utility/Acceptance

The Statewide CASE Team does not expect consumer acceptance issues as a result of this proposal; the majority of the market has already replaced T12s with T8s or LEDs. Consumers have multiple choices for many different replacement products, including Type B and Type C LED lamps. The Statewide CASE Team has shown these replacement products to be cost-effective. Please see Section 5.4 for additional details on replacement products, and Section 5.6 on cost-effectiveness information.

5.10 Manufacturer Structure and Supply Chain Timelines

There are a number of manufacturers that offer products in scope. Some fluorescent manufacturers include:

- Eiko
  - 2-foot T8 Product: 49577, 17W 83 CRI
  - 2-foot T5 Product: 81148, 14W 85 CRI
  - 3-foot T8 Product: 49583, 25W 86 CRI
- GE
  - High CRI T12 Product: 30C506, 4-foot 34W 87 CRI
  - 2-foot T8 Product: 45748, 17W 78CRI
- Halco
  - 2-foot T8 Product: 109804, 17W 86 CRI
- Philips
  - High CRI T12 Product: 423889, 4-foot 40W 89CRI
  - 2-foot T12 Product: 27332, 20W 62 CRI
  - 2-foot T8 Product: 281899, 17W 85 CRI
- PLT
  - High CRI T12 Product: F40T12/DAY-Brite, 4-foot 40W 91CRI T12
- Plusrite
  - 2-foot T5 Product: FL/T5/841, 14W 85 CRI

- Sylvania
    - High CRI T12 Product: 24477, 4-foot 40W 88 CRI
    - High CRI T12 Product: 28983, 8-foot 75W 88CRI
    - 2-foot T12 Product: 22083, 20W 76 CRI
- Ushio
    - 2-foot T8 Product: 3000261, 17W 86 CRI
    - 3-foot T8 Product: 3000265, 25W 86 CRI

The Statewide CASE Team recommends an effective date of January 1, 2020 to give all manufacturers enough time to sell remaining stock of covered products.

5.11 Stakeholder Positions

Several stakeholders commented on high CRI fluorescent lamps as loopholes to the GSFL standards. The Energy Efficiency Organizations (EEOs) (Appliance Standards Awareness Project, Northwest Energy Efficiency Alliance, American Council for an Energy-Efficient Economy, Consumers Union, Natural Resources Defense Council, Northeast Energy Efficiency Partnerships, and Northwest Power and Conservation Council) commented that U.S. DOE's definition of GSFLs in the NOPR would not prevent manufacturers from selling high CRI lamps as inexpensive and inefficient alternatives to GSFLs (ASAP 2014). The EEOs also mentioned that they found multiple examples of high CRI fluorescent lamps marketed as suitable general replacement lamps from numerous manufacturers, including major manufacturers (ASAP 2014). Likewise, NEEP and Earthjustice noted that they also encountered examples of high CRI fluorescent lamps marketed as suitable general service lamps (NEEP 2014; Earthjustice 2014). NEMA was supportive of all the current excluded lamps from the GSFL rulemaking (NEMA 2014). Ultimately, U.S. DOE agreed that clarification was needed to ensure that the excluded lamps were not used as GSFL replacements (U.S. DOE 2015).

On May 16, 2018 Governor Phil Scott of Vermont signed into law new state energy efficiency standards on high CRI four and eight-foot linear fluorescent lamps with CRI at or above 87. The new Vermont energy efficiency standards require that covered lamps achieve the same efficiency levels as GSFLs covered by federal energy efficiency standards.

5.12 Other Regulatory Considerations

5.12.1 Federal Regulatory Background

In 1975, the 94th U.S. Congress passed the Energy Policy and Conservation Act (EPCA) with the stated goal of providing improved energy efficiency of major appliances and certain other consumer products (EPCA 1975). The Energy Policy Act of 1992 amended the EPCA to include explicit coverage of GSFLs as a consumer product for the purpose of energy conservation (EPA 1992). GSFLs are defined as fluorescent lamps which can be used to satisfy the majority of fluorescent applications. However, those that are impact-resistant and have a CRI of at least 87[14] are excluded from the definition, and therefore not included in U.S. DOE's coverage.[15]

U.S. DOE's conservation standards for GSFLs have been in effect since 1992, and were updated in 2012 and 2017. Currently, any GSFLs covered under U.S. DOE's scope and manufactured on or after January 26, 2018 must meet the standards outlined in Section 4.3.4.

[14] The Energy Policy Act of 1992 lists the CRI value to be 82, but the Energy Independence and Security Act of 2007 amends the value to 87.
[15] Other fluorescent lamps are excluded. See Section 2.

5.12.2 California Regulatory Background

There are currently no Title 20 Regulations that cover these fluorescent lamps. However, the scope of Title 20 allows coverage for the proposed standard as detailed in 20 CCR §1601.

5.12.3 Rebates and Incentives

The Statewide CASE Team is not aware of any current rebates or incentives offered by the IOUs for high CRI fluorescent lamps or impact-resistant fluorescent lamps.

5.12.4 Model Codes and Voluntary Standards

The Statewide CASE Team did not identify any model codes or voluntary standards for high CRI fluorescent lamps or impact-resistant fluorescent lamps. However, the Statewide CASE Team's proposal is based heavily on U.S. DOE's rulemaking for GSFLs.

5.12.5 Compliance

The Statewide CASE Team does not expect any issues with compliance since the majority of products on the market will meet the proposed standard. See Section 5.35.3 for additional information.

6. Conclusion

The Statewide CASE Team proposes that the Energy Commission adopt energy conservation standards for fluorescent lamps with a CRI of 87 or greater, fluorescent lamps with a length less than 4-feet, and impact-resistant fluorescent lamps. The U.S. DOE's efforts to increase stringency on efficacy standards for GSFLs has resulted in manufacturers producing specialty fluorescent lamps as loophole replacements for GSFLs with low efficacy rather than increasing efficacy of their overall product line. The products that the Statewide CASE Team intends to cover are specifically exempted from federal coverage and thus are eligible for a state-level energy conservation standard. The Statewide CASE Team drew on the past efforts of the U.S. DOE for this analysis and proposes that the standards for federally covered general service lamps be adopted for specific classes of previously excluded lamps.

The standards proposed by the Statewide CASE Team will achieve significant, cost-effective, technically feasible energy savings. The savings after stock turnover are estimated at 892 GWh/year and 141 MW of demand reduction. This proposal will yield savings of 99,558 MTCO2e per year, and a total of 435,150 MTCO2e by 2030. This proposal will lead to significant cost savings for consumers, with $130 million in first-year savings.

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Appendix A: Electricity Rates

The electricity rates used in the analysis presented in this report were derived from projected future prices for residential, commercial, and industrial sectors in the Energy Commission's "Mid-case" projection of the 2018-2030 Demand Forecast (CEC 2018) which used no discount rate and provide prices in 2016 dollars. The sales weighted average of the five largest utilities in California was converted to 2018 dollars using an inflation adjustment of 1.03 (U.S. DOE 2018). See the rates by year below in Table 25.

Table 25: Statewide Sales Weighted Average Residential, Commercial, and Industrial Electricity Rates 2018 – 2030 (PG&E, SCE, SDG&E, LADWP and SMUD - Five Largest Utilities) in 2018 cents/kWh

Year	Residential electricity rate (2018 cents/kWh)	Commercial electricity rate (2018 cents/kWh)	Sector weighted average (2018 cents/kWh)
2017	18.98	16.36	14.77
2018	19.54	16.71	15.09
2019	19.53	16.74	15.10
2020	18.82	16.12	14.57
2021	18.38	15.67	14.19
2022	17.81	15.18	13.77
2023	17.35	14.66	13.30
2024	16.97	14.32	12.99
2025	16.56	13.98	12.66
2026	16.10	13.56	12.29
2027	15.65	13.14	11.92
2028	15.28	12.81	11.62
2029	14.84	12.57	11.35
2030	14.40	12.33	11.09

Appendix B: Load Factors

Table 26: 2013 Electricity Consumption and Peak Demand for the Top Five California Electric Utilities[a]

Sector & End-Use	Coincident Load		Annual Energy		Load Factor[b]
	MW	% of Total	GWh	% of Total	
Residential					
Cooking	581.4	1%	2833.1	1%	56%
Clothes Dryer	759.4	1%	4419.5	2%	66%
Dishwasher	211.1	0%	2237	1%	121%
Freezer	302.4	1%	2132.1	1%	80%
Miscellaneous	2849.3	5%	23139.9	9%	93%
Multi-Family Water Heater	114.2	0%	1189.4	0%	119%
Pool Heater	33.0	0%	155.6	0%	54%
Pool Pump	769.3	1%	3689.7	1%	55%
Refrigerator	1736.4	3%	13996.2	5%	92%
Solar Water Heat - Back-up	0.0	0%	0.2	0%	63%
Solar Water Heat - Pump	0.8	0%	2.3	0%	31%
Spa Heater	64.9	0%	247.6	0%	44%
Spa Pump	261.5	0%	990.4	0%	43%
Single Family Water Heater	196.5	0%	1709.6	1%	99%
Television	807.2	1%	6003	2%	85%
Waterbed Heater	737.0	1%	12003.7	5%	186%
Clothes Washer	122.2	0%	824.6	0%	77%
Air Conditioning	15739.6	28%	8378.51	3%	6%
Space Heating	0.0	0%	3441.46	1%	0%
Commercial					
Other	3344.8	6%	23762.2	9%	81%
Domestic Hot Water	144.5	0%	675.7	0%	53%
Cooking	94.5	0%	721.9	0%	87%
Office Equipment	263.3	0%	1699.2	1%	74%
Refrigeration	888.4	2%	7872.6	3%	101%
Exterior Lighting	40.9	0%	5909.2	2%	1649%
Interior Lighting	4856.2	9%	30686.2	12%	72%
Ventilation	1787.3	3%	10366.1	4%	66%
Air Conditioning	7714.7	14%	15724.95	6%	23%
Space Heating	0.0	0%	2702.77	1%	0%
Subtotal	19134.6	34%	100120.82	38%	60%

Source: California Energy Commission. 2016. Demand Analysis Office. Communications with M. Tian.

[a] The top five California Utilities are Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison Company (SCE), Sacramento Municipal Utility District (SMUD), and Los Angeles Department of Water and Power (LADWP).

[b] Load Factor is the ratio of average annual load to coincident peak load. The load factors for commercial exterior lighting and residential waterbed heaters are very high because their consumption is mainly off-peak.

Appendix C: Pricing Sources

Table 27: Lamp and Ballast Pricing Sources

2-foot Lamps
https://www.1000bulbs.com/product/200218/GREENCREATIVE-28415.html
https://www.1000bulbs.com/product/200103/LEDT-10020.html
https://www.1000bulbs.com/product/116829/HALCO-109804.html
https://www.1000bulbs.com/product/90138/USH-3000261.html
https://www.1000bulbs.com/product/1073/F-17T8841.html
https://www.1000bulbs.com/product/200396/GE-45748.html
https://www.1000bulbs.com/product/137104/PHILIPS-281899.html
https://www.1000bulbs.com/product/6342/F-20T12D.html
https://www.1000bulbs.com/product/4654/F-20T12CW.html
https://www.walmart.com/ip/GE-10213-F20T12-CW-Straight-T12-Fluorescent-Tube-Light-Bulb/123126929
4-foot Lamps
https://www.1000bulbs.com/product/202885/PHILIPS-423889.html
https://www.1000bulbs.com/product/192367/PLT-20008.html
https://www.1000bulbs.com/product/152944/SYLVANIA-24477.html
https://www.grainger.com/product/GE-LIGHTING-48-34-Watts-Linear-Fluorescent-30C506
https://www.uline.com/Product/Detail/S-21222/Light-Bulbs/Fluorescent-Tubes-48-T12-Daylight?pricode=WB0551&gadtype=pla&id=S-21222&gclid=Cj0KCQjwh7zWBRCiARIsAId9b4oT8U6AG9uro3k3q8Hxo8pNchZfXfoNuhFPZaQtXgRBcqHvr_c-kJgaAqAtEALw_wcB&gclsrc=aw.ds
https://www.1000bulbs.com/product/192418/PLT-20055.html
https://www.1000bulbs.com/product/85824/PHILIPS-281550.html
https://www.1000bulbs.com/product/90167/USH-3000101.html
https://www.1000bulbs.com/product/95663/GE-66349.html
https://www.1000bulbs.com/product/152907/SYLVANIA-21781.html
https://www.1000bulbs.com/product/200106/LEDT-10024CS.html
https://www.1000bulbs.com/product/200862/GREENCREATIVE-28407.html
https://www.homedepot.com/p/Philips-32-Watt-Equivalent-T8-LED-Light-Bulb-Daylight-4-ft-10-Pack-472910/303040479
https://www.amazon.com/Sunco-Lighting-Pack-Fluorescent-Replacement/dp/B0163D7CP8

8-foot Lamps
https://www.1000bulbs.com/product/192827/PLT-10850.html
https://www.1000bulbs.com/product/172521/LED-10045.html
https://www.1000bulbs.com/product/201402/LUNERA-10099.html
https://products.currentbyge.com/sites/products.currentbyge.com/files/documents/document_file/LEDL035-GE-LED-Tubes-Type-C-8ft-Sell-Sheet.pdf
https://www.bulbs.com/product/35T8-96-3000-IF-FA8?cm_mmc=GooglePLA-_-Nonbrand-_-909680855-_-shopping&affID=6
https://www.prolighting.com/led-light-bulbs/ledt8lamps/96-led-t8-lamps/kt-led36t8-96p-840-d.html
https://www.1000bulbs.com/category/t8-single-pin-instant-start-linear-fluorescent-tubes/
https://www.1000bulbs.com/product/117842/GE-68870.html
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https://www.1000bulbs.com/product/152930/SYLVANIA-22205.html
https://www.1000bulbs.com/product/154038/GE-12534.html
https://www.1000bulbs.com/product/93406/F-96T8TL850ALTO.html
https://www.1000bulbs.com/product/152897/PHILIPS-372821.html
https://www.lowes.com/pd/SYLVANIA-2-Pack-94-in-Single-Pin-T12-75-Watt-6500-K-Daylight-Fluorescent-Light-Bulb/3203535
https://www.homedepot.com/p/Philips-110-Watt-8-ft-Linear-T12-Fluorescent-Light-Bulb-Cool-White-4100K-High-Output-2-Pack-205443/100612753
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Circline Lamps
https://www.homedepot.com/p/Meridian-22-Watt-Equivalent-Cool-White-T9-Circline-Non-Dimmable-LED-Light-Bulb-13144/302072545
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https://www.shineretrofits.com/neptun-light-led-t9-013w-120v-adim-13w-13-watt-dimmable-t9-circle-lamps-120v-analog-triac-dimming-system.html?utm_source=google&utm_medium=cpc&adpos=1o8&scid=scplpLED-T9-013W-120V-ADIM&sc_intid=LED-T9-013W-120V-ADIM&matchtype=&network=g&device=c&adposition=1o8&keyword=&gclid=CjwKCAjwiPbWBRBtEiwAJakcpPb5pb24SXUIUAlJ92pIRANASZMRdo6xV4sztcbPoKQFT_aXHsdyCBoCeqEQAvD_BwE
https://www.bulbs.com/product/FC8T9-UTILITY-22W-8?RefId=48
https://www.bulbs.com/product/FC8T9-SW?RefId=48

https://www.1000bulbs.com/product/1046/FC-08T9CW.html?gclid=CjwKCAjwlIvXBRBjEiwATWAQIpuC1ZmbNHMcnUmqtFEcCcVsG6jwEEFB6pXwjPaD2gyLi9i_NtIUxRoC6VQQAvD_BwE
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