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

Analysis of Standards Options for Fluorescent Tubes

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1 Executive Summary

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for fluorescent tubes.

Fluorescent tube lamps comprise 77% of all lamps installed in commercial and industrial buildings and 60-70% of the total lighting electricity consumed in these sectors. Although fluorescent technology has evolved considerably over the past 20 years, the market has been slow to adopt more efficient products, primarily due to the long life cycles of fluorescent lamp ballasts and users' familiarity with older products. High performance T8s (also high-lumen, "super" or 3rd generation T8s) have met a lack of awareness, confusion over product classifications, and increased cost over standard T8s. However, since standard T8 technology has become the norm in new construction and California's Title 24 code favors the use of high performance T8s, the existing 1992 federal standard regulating T12 fluorescent lamps has become outdated. Revisions to the federal standard are scheduled to be completed by 2009. California has an opportunity to have a major influence on the federal rulemaking, or to set its own standard should the federal process not move aggressively enough.

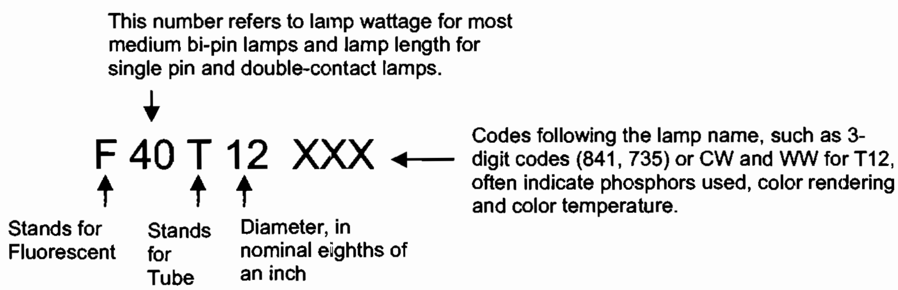
We evaluate standards options for four-foot medium bipin lamps, eight-foot single pin standard output ("slimline") lamps, and eight-foot high-output lamps. Our findings suggest that the energy savings and performance benefits of switching from T12 to extra-efficient T8 products far outweigh the retrofit costs. Even standard-efficiency T8 systems can be upgraded to extra-efficient T8 systems at an average net present value of $3 per unit (assuming half of the replacements are new full-wattage lamp-ballast systems and half are reduced wattage (25W and 28W) lamp-for-lamp replacements.

Based on the dramatic energy savings benefits of extra-efficient T8 systems and the slowly declining market share of T12 lamps in California, we recommend California establish minimum efficacy requirements for T12s and T8s in two phases. In the first phase, all but the most efficient (800-series) T12 lamps would be restricted. A second stage restricting T8s to extra-efficient 800-series lamps would be implemented 2-3 years later. This may be accompanied with the ultimate elimination of virtually all T12 lamps. By the time the existing stock of lamps turns over, annual savings will be over 3,000 GWh, or roughly 9%. Peak demand reduction will be about 1,000 MW (16% savings).

2 Product Description

A fluorescent lamp is a gas-discharge light source consisting of a tube filled with an inert gas (argon or neon) and a small amount of mercury. When voltage is applied to electrodes at each end of the lamp, the mercury generates short-wave ultraviolet light that causes phosphors coating the inner surface of the tube to fluoresce, producing visible light. The lamp requires a ballast to properly maintain the current and regulate the voltage supplied to the lamp.

Fluorescent tubes are classified by lamp length and diameter. The following shows how to interpret the classification scheme used to name most products:



Common lamps are the T12 (1 ½ inches in diameter), the T8 (1 inch), and the T5 (5/8 inch). Both T8 and T12 models are available in two-foot, three-foot, and four-foot general service lamps with medium bi-pin base; four-foot medium bi-pin U-shaped lamps; six-foot and eight-foot single-pin contact lamps (called standard output or "slimline" in some catalogs); and eight-foot high-output (HO) and very high-output (VHO) lamps with a recessed double contact (see figures 1 and 2). Four-foot fluorescent tubes comprise the majority of lamps used in commercial and industrial buildings, as well as a small portion of the residential lighting market. Eight-foot T12 fluorescent lamps represent a small but significant portion of the commercial and industrial market, used primarily in mass market retail, low-bay industrial, and some billboard applications (DOE, 2002).

Figure 1. Schematic of Typical 4-ft T8 and T12 Lamps

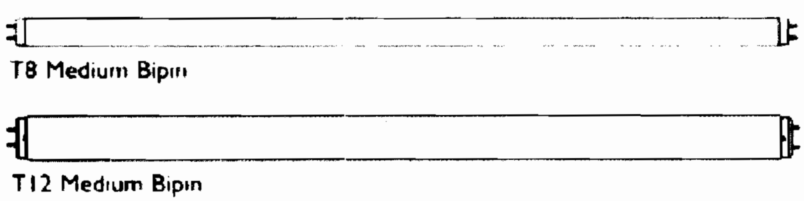


Figure 2. Medium Bipin vs. Standard Single Pin and High Output Lamps

A. Typical 4-ft Lamp: Bi-pin base

B. Standard Output "slimline" Lamp: Single-pin base

C. High Output Lamp: Recessed Double Contact (HO)

Lamp types are differentiated as either full-wattage or reduced-wattage ("energy saving") lamps. The original full-wattage "cool white" (CW) and "warm white" (WW) T12 lamps coated with halophosphate were eliminated in 1992 under federal law. Today, T8 lamps are the norm in commercial new construction, and many T12s are still used, including more advanced lines of full-wattage T12s with tri-phosphor coatings and energy saving T12s that still have the halophosphate coating.

Several parameters determine the light quality and performance of any fluorescent lamp-ballast system, including the lamp's initial light output (in lumens), efficacy (lumens per watt), and lumen maintenance, which is the depreciation of light output over the course of the lamp's life (life ranges from 12,000 to 46,000 hours depending on the lamp, ballast and cycling rate). Two additional parameters are used to indicate light quality: correlated color temperature (CCT) and color rendering index (CRI). CCT (in degrees kelvin, K) is used to measure the perceived "whiteness" of a lamp, ranging from around 3000 K (a warm yellowish light), to over 5000 K (a white-white light). CRI measures the degree of color shift objects undergo under the fluorescent lamp compared to a reference incandescent light source of comparable color temperature. It is measured on a scale of 0–100, with 100 being equal to color rendering of the reference lamp.

Newer lamps are typically identified by a higher rated color rendering index (the 700-series T8 and T12 lamps achieve 70-79 CRI, while 800-series lamps range from 80-89 CRI). These newer lamps yield higher efficacy (initial and maintained) and higher CRI through the use of rare-earth tri-phosphors, typically involve less mercury, and are compatible with more efficient high-frequency electronic ballasts.

Table 1 demonstrates the key performance characteristics that define the major types of T8 and T12 fluorescent lamps. High performance T8 lamps are a class of lamps that have achieved the highest levels of color rendering, lumen output, life, and efficacy. Reduced wattage (30W, 28W and 25W) T8 lamps use similar advanced phosphor blends, but they may introduce ballast compatibility issues, ambient temperature constraints, and other limitations, as discussed further in Section 8.

Table 1. Identifying Characteristics of Major T8 and T12 Fluorescent Lamp Types[a]

	F40T12 700-series	F34T12 Cool White	F32T8 700-Series	F32T8 800-Series	F32T8 800-Series (High-Perf)	28W F32T8	25W F32T8
Color Rendering Index (CRI)	72	62	75–78	81–85	82-86	82-85	85
Lamp Life (hours)	20,000	20,000	15,000–20,000	15,000–20,000	24,000–30,000	18,000–24,000	18,000–24,000
Initial Lumens	3150	2650	2800	2950	3100	2750	2440
Efficacy (Mean Lumens/Watt)	72	68	83	86	92	92	91
Lumen Maintenance (%)	90	87	93	95	95	94	95

Source: Manufacturer catalogs
[a] Table does not include "extra-long life" lamps or high color-temperature lamps (>4500 K).

T5 lamps (and T5 HO lamps) are a new generation of linear fluorescent technology primarily for use in commercial applications. Although they are widely available, they are not a viable retrofit option for existing T12 and T8 fixtures as both T5s and T5HOs are shorter and have different pin bases than T8 and T12 lamps and thus need different sockets and dedicated ballasts. Also T5HO models often require special fixtures to shield work surfaces from their intense brightness when mounted within 12 feet of the floor. For these reasons, T5s and T5HOs are excluded from this analysis.

We also exclude very high-output (VHO) lamps from this standards proposal because they claim a very minor portion of the fluorescent market and are only used in specialized applications.

3 Manufacturing and Distribution Channel Overview

The U.S. lamp market is highly concentrated, with three major manufacturers controlling over 90% of the lamp market. These are General Electric (GE), Osram Sylvania, and Philips Lighting Company. All three compete effectively for all lines of fluorescent tubes. Seven other manufacturers specialize specifically in high-performance T8s.

Nearly two-thirds of all tube fluorescent lamps are purchased by commercial and industrial consumers (building managers and engineers, electric contractors, design professionals) directly from a distributor. Fluorescent lamps are also available through typical residential channels, including home improvement centers, hardware chains, and other mass merchandisers (Vorsatz et al., 1997). Retail sales to residential and some small commercial consumers account for 25% of the annual distribution of fluorescent lamps, according to the National Electrical Manufacturers Association (NEMA). Another 12% are sold to fixture manufacturers (NEMA, 2006).

4 Energy Usage

4.1 Test Methods

4.1.1 Current Test Methods

Federal regulations reference test procedure LM-9-89, for general service fluorescent lamps. This procedure, entitled "Electric and Photometric Measurements of Fluorescent Lamps," is published by the Illuminating Engineering Society of North America and has been revised once since the federal test procedure was established. We recommend California use the most recent revision of this test procedure, IESNA LM–9–99, for their fluorescent lamp standards.

4.1.2 Proposed Test Methods

We propose using the existing IESNA LM-9-99 test procedure without modification.

4.2 Baseline Energy Use Per Product

Baseline energy consumption varies with lamp system wattage and daily operating hours. Lamp system wattage is affected by the rated wattage of the lamp, the type of ballast used (e.g. generic magnetic, generic electronic and extra-efficient electronic), the ballast factor (BF) of the ballast, and the number of lamps in the system. The ballast factor gives the ratio of lamp lumens when operating on a given ballast compared to a 1.0 BF reference ballast. A lower BF means the ballast is driving the lamp at a lower-than-rated power.

Three product classes dominate sales of four-foot fluorescent lamps in all sectors; these are the 32-watt standard 700-series T8 lamp, the 34-watt reduced wattage ("energy saver" (ES)) T12 (primarily, but not solely Cool White (CW)), and the 40-watt 700-series T12. Among the eight-foot lamps, CW energy-saving and 700-series T12s dominate.

Table 2 shows the energy use of our assumed base case, for both four-foot and eight-foot lamps. Our analysis only includes two-lamp fixtures because they represent the majority (57%) of the fluorescent lighting stock (Brook, 2006). It should be noted that lamp wattage will be lower in three- and four-lamp systems, T12 systems operating on electronic ballasts, and T8 systems driven at low ballast factors (<0.85).

Table 2. Baseline Energy Use of Fluorescent Lamps (Typical Commercial 2-Lamp System)

Baseline Lamp	Rated Watts	Rated Mean Lumens	Mean Lumens per Watt	Operating watts (with BF)[a]	Annual Operating Hours[b]	Annual Energy Consumption (kWh/yr)
Four-Foot (Medium Bipin) Lamps						
F32T8 7XX	32	2590	83	29	2,993	87
F34T12 CW	34	2950	68	36	2,993	108
F40T12 7XX	40	2300	72	44	2,993	132
Eight-Foot Standard (Single Pin) Lamps						
F96T8 7XX	59	5190	88	54.5	3,741	204
F96T12 ES CW	60	6110	79	61.5	3,741	230
F96T12 7XX	75	4800	81	79	3,741	296
Eight-Foot High-Output (Double Recessed) Lamps						
F96T12HO ES CW	95	6800	68	103.5	3,741	387
F96T12HO 7XX	110	8150	73	122.5	3,741	458

Source: Manufacturer catalogs unless noted.

[a] Assumes standard ballast factor (0.87-0.88) for generic instant-start electronic ballast for T8 lamps and magnetic rapid-start ballasts for T12s. Single-pin eight-foot T12s are operated on instant-start magnetic ballasts. HO lamps use reference BF ballasts (0.96). Note than energy losses associated with magnetic ballasts result in higher system wattage relative to rated lamp wattage.

[b] Commercial, residential and industrial daily operating hours averaged for four-foot lamps, and commercial- and industrial-sector hours only for lamps greater than four-foot (commercial and industrial only) from DOE, 2002.

4.3 Efficiency Measures

Lamp efficacy is used to measure the energy performance of a lamp, determined by dividing light output by lamp power and expressed in lumens per watt (LPW). In reality, the ballast used to operate the lamp is integral to lamp efficacy. We assume "typical" ballast characteristics in our analysis, but ballast performance is treated in a companion CASE report on fluorescent fixtures. For the lamp itself, efficacy can be rated with respect to initial light output (initial LPW), mean LPW (lumens measured at 40% of rated life), or light output measured after a certain number of operating hours. The current federal standard specifies minimum efficacy levels in initial LPW. We assert that mean LPW is a more useful measure of efficiency because it indicates efficacy over time. However, fluorescent lamps vary in life, making it difficult to compare the efficacies of lamps with different rated lives. As discussed in Section 8.4, a preferred alternative would be to specify efficacy at a specified number of hours (8,000 or 10,000) in order not to impose a bias against extra-long life lamps. More data is needed from lamp manufacturers to incorporate this option into our proposal.

For the four-foot fluorescent market, there are a wide range of efficient full-wattage T8 and T12 products available that offer improved performance over the original 700-series and earlier products through the use of advanced rare-earth phosphor blends, improved fill-gases and better cathodes. The highest-efficiency option is the 3rd generation 800-series T8 lamp. The specific characteristics of these lamps compared to earlier generations of 800-series full-wattage T8s are not clearly defined in the market, but they are typically at least 90 MLPW or higher (on instant-start ballasts), have a light output of at least 3100 initial lumens and 2900 mean lumens, and last roughly 25% longer than earlier T8 lamps, according to the Consortium for Energy Efficiency (CEE, 2006)[1].

4.4 Standards Options Energy Use Per Product

Our objective in considering standards options for linear fluorescent lamps is two fold: a) to accelerate the transition to T8 products by eliminating cheaper, low-efficiency T12 options, and b) to drive the use of higher-efficiency T8 products. In order to allow for a gradual transition away from T12 products, T8 lamps, energy-saving (ES) T12 lamps and full-wattage T12 lamps are treated separately.

Options for raising lamp efficacy standards are based on setting minimum efficacy levels to allow certain advanced "generations" of lamps and restricting others. Table 3 lists the replacement options for each baseline lamp in order of increasing efficacy (mean LPW). For high performance (HP) lamps, we include a low-ballast factor option because this option is standard practice in many retrofits to achieve similar lumen levels. It can not, however, be enforced by the standard. Residential-grade lamps are used with lower ballast factors for fewer hours, so their per-unit energy consumption is not represented by this table.

The least aggressive option is to raise minimum efficacy requirements to allow all but the least efficient products that are currently available, eliminating "cool white" 34W T12s, 700-series 40W T12s and 700-series T8s. A more aggressive option would essentially raise both T8 and T12 efficacies to the most efficient options available: high performance 3rd generation 800-series lamps. For four-foot T8s, this would mean a minimum of 90 mean LPW, consistent with the Consortium for Energy Efficiency (CEE) *High-Performance T8* and *Reduced Wattage T8* Specifications (qualifying products are listed in Appendix A). The most aggressive option for regulating T12s, short of banning them altogether in favor of T8s, would raise minimum efficacy to 75 mean LPW. For eight-foot lamps the equivalent option would raise minimum efficacy to 95 mean LPW for standard output T8s and 81 mean LPW for high output T12s. Because these lamps are not covered under the CEE spec, these levels are based on our own review of available products from the three major lamp manufacturers, provided in Appendix C.

Under the 90 LPW standard for four-foot T8s, retrofit choices would include replacing both lamp and ballast with a high-lumen full-wattage systems, or installing a reduced-wattage lamp. The standard would favor the use of the reduced-wattage T8s in most lamp-for-lamp replacements because they are more cost-effective as long as a ballast replacement is not needed (discussed further in Section 7). However, reduced-wattage T8s have a number of application issues (see Section 8). In the new construction market, high-lumen full-wattage T8s will be favored as they can be used in virtually all applications and will save substantial energy when fixture spacing is increased or a low ballast factor ballast is used.

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[1] For 5000K color temperature lamps, catalog lumens are usually less. For example while high performance F32T8s have 3100 lumens up to 4100K, catalog lumens are usually 3000 for 5000K.

Table 3. Energy Use of Replacement Options (Typical Commercial 2-lamp System)

Design Options (Bold indicates baseline)	Rated Watts	Rated Mean Lumens	Mean Lumens per Watt	Operating watts per lamp (with BF)[a]	Annual Operating Hours[b]	Annual Energy Consumption (kWh/yr)
four-foot (Medium Bipin) Lamps						
F32T8 7XX	**32**	**2615**	**83**	**29**	**3741**	**108**
F32T8 8XX	32	2800	88	28	3741	108
F32T8 8XX HP (std BF)	32	2950	92	26.5	3741	101
F32T8 8XX HP (low BF)	32	2950	92	24	3741	90
F30T8 8XX	30	2685	90	27.5	3741	103
F28T8 8XX	28	2570	92	25.5	3741	95
F25T8 8XX	25	2280	91	23.5	3741	88
F34T12 CW	**34**	**2315**	**68**	**36**	**3741**	**135**
F34T12 7XX	34	2460	74	36	3741	135
F34T12 8XX	34	2770	76	34	3741	135
F34T12 8XX (Elec)	34	2945	76	30	3741	112
F40T12 7XX	**40**	**2845**	**72**	**44**	**3741**	**165**
F40T12 8XX	40	2960	75	36	3741	135
F40T12 8XX (Elec)	40	3250	70	35.5	3741	133
Eight-foot Standard (Single Pin) Lamps						
F96T8 7XX	**59**	**5275**	**89**	**55.0**	**3,741**	**206**
F96T8 8XX	59	5525	94	55.0	3,741	206
F96T8 8XX HP (std BF)[c]	59	5720	97	54.0	3,741	202
F96T8 8XX HP (low BF)[c]	59	5720	97	50.0	3,741	187
F96T8 ES 8XX[d]	55	5430	99	51.0	3,741	191
F96T12 ES CW	**60**	**4825**	**80**	**63.0**	**3,741**	**236**
F96T12 ES 7XX	60	5305	88	63.0	3,741	236
F96T12 ES 8XX	60	5530	92	63.0	3,741	236
F96T12 7XX	**75**	**6020**	**80**	**79.0**	**3,741**	**296**
F96T12 8XX	75	6255	83	79.0	3,741	296
Eight-foot High-Output (Double Recessed) Lamps						
F96T8 HO 7XX	86	7300	85	78.0	3,741	292
F96T8 HO 8XX	86	7600	88	78.0	3,741	292
F96T12HO ES CW	**95**	**6800**	**72**	**101.5**	**3,741**	**380**
F96T12 HO ES 7XX	95	7510	79	101.5	3,741	380
F96T12 HO ES 8XX	95	7700	81	118.5	3,741	443
F96T12HO 7XX	**110**	**8270**	**75**	**118.5**	**3,741**	**443**
F96T12 HO 8XX	110	8540	78	101.5	3,741	380

Source: Manufacturer catalogs unless noted.

[a] Assumes standard ballast factor (0.86-0.89) for generic instant start electronic ballast for T8 lamps and magnetic rapid-start ballasts for T12s. Single-pin eight-foot T12s are operated on instant-start magnetic ballasts. HO lamps use reference BF ballasts (0.96).

[b] Average of commercial and industrial daily operating hours from DOE, 2002.

[c] Available from only one manufacturer.

[d] 50W Energy Savings 8-foot standard output lamps also available.

Two alternatives to the aggressive minimum efficacy requirement for T8s are offered to account for certain technical considerations. In recent years, demand for high color temperature (>4500 K) lamps has increased. Because of design constraints, reaching the lumen output levels required by the CEE specification is difficult for manufacturers of 5000K lamps. Thus a second option for a new T8 standard would be to lower minimum efficacy requirements to 86 mean LPW for lamps greater than 4500K. This efficacy level is based on the highest rated mean light output levels available for high color temperature lamps from all three major manufacturers. Appendix B contains a list of additional cool-color products that would qualify that are not currently included in the CEE qualifying products list (Appendix A).

A second alternative for a T8 lamp standard is to relax the minimum efficacy level to account for claims of inflated efficacy that may hold true among published lumen output levels for high-performance lamps currently on the market. A recent study of 121 800-series or higher T8 lamps (NLPIP, 2006) found that measured efficacies were 3.5% lower on average than those calculated from published mean output levels. This suggests that fewer lamps than reported will be able to meet a new 90 mean LPW standard (or 95 for eight-foot lamps). If further data from manufacturers can corroborate these claims, we may relax the 90 mean LPW standard to 88.

5 Market Saturation and Sales

5.1 Current Market Situation

5.1.1 Baseline Case

The 2002 U.S. Lighting Market Characterization (DOE, 2002) estimates that linear fluorescent lamps comprise 77% of all lamps installed in commercial buildings and account for 60-70% of the total lighting electricity consumed in commercial and industrial facilities. Among these, four-foot lamps (including 2-ft U-shaped lamps) dominate, comprising about 85% of all installed fluorescent lamps. Another 10% are eight-foot lamps, including both standard single pin and high-output types (DOE, 2002).

In California we estimate that there are 286.4 million fluorescent tube lamps installed, including 152 million four-foot T12s, 115 million four-foot T8s, 17 million eight-foot T12s, and 2 million eight-foot T8s. These figures include units installed in commercial, industrial and residential sectors, and they are derived from annual U.S. sales data and average lamp life as shown in Table 5. We estimate California to represent 9.06% of U.S. sales, based on the percentage of national commercial floor area in the Pacific West census region (EIA, 2003) and the portion of the Pacific West population that resides in California (Census Bureau, 2002).

Table 4 provides an alternate inventory of commercial fluorescent lamps conducted for the California Energy Commission (CEC). Because the survey data does not include industrial or residential lamps, our analyses for total state energy use and savings are based on estimates noted above. However, the CEC data are shown as a more accurate estimate of commercial building lighting in the state. For example, the data show that T8 lamps have a higher share of the existing stock (58%) than the national average (40%) (Brook, 2006).

Over the past ten years, market share of T12 technology has declined steadily for four-foot and single-pin "slimline" eight-foot lamps across all lamp-ballast combinations in the commercial sector. According to sales data from the National Electrical Manufacturers Association (NEMA), sales of four-foot T12 lamps have declined 25% since 2001 while T8s now occupy over 60% of sales nationwide (NEMA, 2006). Among eight-foot lamps, T12 sales still dwarf those of T8s, but T12 sales have declined over 20% in favor of eight-foot single-pin and pairs of four-foot T8s. High output lamps have not seen a similar shift away from T12 technology as the other two lamp classes. NEMA reports that 25% of all fluorescent lamp sales are to retail outlets, but their data does not distinguish between T12 and T8, so we assume 75% sold to retail outlets are T12s.

Table 4. Inventory of Fluorescent Lamp Types in California Commercial Buildings

Lamp Type	California Stock (million units)	% of Stock (California)	*% of Stock (National Average)*
Four-foot T12s	33.0	32%	*53%*
Four-foot T8s	59.4	58%	*40%*
Eight-foot T12s	8.5	8%	*6%*
Eight-foot T8s	1.3	1%	*1%*

Source: Brook, 2006; California Commercial End Use Survey

5.1.2 High Efficiency Options

Based on discussions with manufacturers and distributors and by visiting many sites in California, we estimate that the vast majority—around 90%—of T12 lamps sold to commercial consumers are primarily cool white F34T12s, while most of the remaining 10% are 700-series F40T12s. F40T12 lamps (soft white primarily) are more common in the residential sector, accounting for approximately 80% of residential sales.

Among commercial T8 sales, 78% are standard 700- and 800-series lamps used with generic instant-start electronic ballasts (NEMA, 2007). Based on the dramatic difference between state-wide and nation-wide T8 market shares and the promotion of high-performance T8 systems under Title 24, it is likely high-performance T8 lamps enjoy higher market shares in California than the national average. In particular, the sales of improved 800-series lamps has increased over the past few years, although these lamp types are not distinguished in our data. By unofficial manufacturer estimates, it is likely that the ratio of 700-series to 800-series lamps is about 6:1. High-performance lamps represent another 14% of sales as of 2006, and reduced-wattage T8s (30W, 28W and 25W) represent 8% of sales, with more 28W lamps sold representing roughly half of these.

Table 5. California Baseline Stock and Sales, Energy Use and Demand

Lamp Type	Annual Sales			Watts per lamp[c]	Average Lamp Life (Hours)[d]	Annual Operating Hours[e]	Life (Years)	California Stock		% On at Peak[g]	California Energy Use and Demand per Product	
	U.S. (milliions)[a]	California (millions)[b]	Market Share					Units (millions)[f]	Percent of Total		MW	GWh/year
Commercial and Industrial Sector												
Four-foot T8	224.2	20.3	60.4%	29	17,500	3,740	4.7	95.0	33.2%	78%	2,149	10,308
Four-foot F40T12	17.2	1.6	4.6%	44	20,000	3,740	5.4	8.3	2.9%	78%	285	1,367
Four-foot F34T12	154.4	14.0	41.6%	36	20,000	3,740	5.4	74.8	26.1%	78%	2,099	10,069
Eight-foot F96T8	5.2	0.5	1.4%	55	15,000	3,740	4.0	1.9	0.7%	78%	80	383
Eight-foot F96T12	3.4	0.3	0.9%	79	12,000	3,740	3.2	1.0	0.3%	78%	60	289
Eight-foot F96T12 ES	30.3	2.7	8.2%	62	12,000	3,740	3.2	8.8	3.1%	78%	422	2,024
Eight-foot F96T8 HO	0.4	0.0	0.1%	80	18,000	3,740	4.8	0.2	0.06%	78%	11	55
Eight-foot F96T12 HO	2.5	0.2	0.7%	105	12,000	3,740	3.2	0.7	0.3%	78%	61	292
Eight-foot F96T12 HO ES	22.9	2.1	6.2%	116	12,000	3,740	3.2	6.7	2.3%	78%	604	2,897
Consumer Sector (Residential and Light Commercial)												
Four-foot T8	38.0	3.4	6.2%	29	17,500	2,270	7.7	26.5	8.4%	20%	0	1,716
Four-foot F40T12	22.8	2.1	2.1	40	20,000	2,270	8.8	18.2	5.8%	20%	144	1,631
Four-foot F34T12	91.2	8.3	8.3	33	20,000	2,270	8.8	72.8	23.1%	20%	480	5,451
Total	**612.3**	**55.5**	**100%**					**286.4**	**100%**		**6,245**	**36,752**

[a] Table based primarily on 2005 national sales data for four-foot lamps and eight-foot single pin and double-recessed HO lamps from the National Electrical Manufacturers Association (NEMA, 2006). U-shaped lamps are included in four-foot figures. NEMA did not offer a breakdown of sales for 34W vs. 40W T12s. We assumed 34W lamps are 90% of commercial T12 sales and 20% of residential T12 sales.

[b] California sales are 9.06% of U.S. sales based on commercial floor area data from CBECS (EIA, 2003) and 2002 population data from the U.S. Census Bureau.

[c] Operating watts from Table 2. Operating watts of consumer lamps are the average of commercial operating watts and those of a typical residential fixture with a lower, 0.68 ballast factor.

[d] From manufacturer catalogs and averaged for four-foot T8s. Does not include extra-long life lamps.

[e] Daily operating hours averaged for "four-foot lamps" and lamps "greater than four-foot" (commercial and industrial) and all four-foot and miscellaneous applications (consumer), from DOE, 2002.

[f] California existing stock derived by multiplying annual sales by typical lamp life.

[g] Peak coincidence 78% for commercial sector (based on PG&E, 2000) and 20% for consumer sales; specifically, we estimate 10% on at peak in the residential sector (based on 2.2 operating hours/per day for miscellaneous residential fluorescent (DOE, 2002), and a much higher percent on at peak in small commercial buildings.

5.2 Future Market Adoption of High Efficiency Options

According to current trends, T8 sales in the absence of a standard would achieve over 75% market share over the next five years across both commercial and residential sectors. Meanwhile, overall T12 sales could be expected to decline by over 60%, with the majority of this decline occurring in the commercial sector. Based on these trends, we estimate conservatively that 50% of commercial T12-purchasers will switch to T8 systems over the next decade in the absence of a standard. According to sales trends of T8s over the past six years, we estimate a baseline conversion of 30% to high performance systems (both full-wattage and energy-saving T8s) over the next decade, which allows for considerable growth and assumes continued aggressive promotional activities on the part of California utilities.

6 Savings Potential

6.1 Statewide California Energy Savings

Energy savings relative to baseline lamp wattage are calculated in Table 6. The calculations are based on a scenario in which only the maximum efficiency options are allowed for each baseline lamp, as explained in Section 4.4. Note that savings under the T8 standard would not be affected by options that relax standards for lamps over 4500 K or overall to account for potential efficacy inflation in current testing practice, so these options are not considered in the savings analysis.

The savings estimates are based on annual sales data for each existing lamp type (Table 5) excluding a portion of sales to account for those that would adopt high-efficiency options without the standard (Section 5.2). We estimate watts saved per lamp based on a few assumptions regarding which replacement options are adopted under the standards scenario. Of current standard-series T8 users, we assume the proposal would drive half to simply swap their old lamps for improved full-wattage lamps, increasing their light output and saving no wattage (unless they use fewer lamps per fixture, which is not modeled here). The remaining half of users would be split between 28W and 25W reduced-wattage lamp replacements because they are the most economical options (compare under "Present Value of Lifetime Savings" in Table 8. Similarly for T12 users, we assume half will replace their lamps with higher-performing equivalents of the same lamp, (higher light output and no watts saved), while the other half will realize savings either by using reduced wattage lamps if available or by deciding to retrofit their T12 fixtures with T8s before burnout.

For commercial and industrial sectors, 78% of lamps are estimated to be operating during peak daylight hours, from PG&E, 2000 (based on an average of "commercial" and "all other" categories). This load factor is assumed for all eight-foot lamps. For four-foot lamps, a coincidence factor of 62% represents the weighted average of commercial and residential load factors. For consumer sales, 10% coincidence is estimated based on 2.2 average daily operating hours for residential non-compact fluorescent lamps, as reported in DOE, 2002. We doubled this figure to 20% as a conservative estimate to account for small commercial retail sales.

Based on lamp life in Table 5, the entire commercial stock of fluorescent lamps will be replaced within roughly 5 years (4 years for eight-foot lamps). Because of shorter operating hours, turnover in the residential sector is evaluated over a longer, roughly 8-year period. Over the life of existing lamps in both sectors, savings would amount to 3,350 GWh annually and 1,008 MW of peak power. The true savings potential would develop over time as the existing ballast stock turns over, driving more T8 and T12 users to high-performance T8 systems than would be expected under the baseline scenario. If a standards option was chosen that eliminated T12s in a second phase of implementation, that is, if all lamps used were high-performance T8s, we estimate this would result in a total savings of 4,285 GWh and 1,339 MW after lamp stock turns over.

6.2 Other Benefits and Penalties

High performance T8 and T12 lamps typically have higher lumen maintenance (95% at 40% rated life) than standard series T8s (93%) and T12 lamps (85-90%). Extra-efficient T8 systems (and high-lumen T12s operated on electronic ballasts) have markedly longer lifetimes for a fixed "mean lumens" value. Because these systems can maintain high quality light for longer and with more flexibility, they offer increased satisfaction and reduced maintenance costs in both four-foot and eight-foot applications. Longer life also means less mercury and glass used to make the lamps.

The proposed standards options analyzed here have the potential to impact a federal rulemaking now underway for general purpose fluorescent lamps. Details of this process are discussed in Section 8.3.

Table 6. Estimated California Statewide Energy Savings From Baseline With Proposed Standard

Lamp Type	Lamp Sales (millions)	Percent to Convert Without Standard [d]	Watts Saved per Lamp [d]	Percent on at Peak	For First-Year Sales: Coincident Peak Demand Reduction (MW)	For First-Year Sales: Annual Electricity Savings (GWh/yr)	After Entire Stock Turnover: Coincident Peak Demand Reduction (MW)	After Entire Stock Turnover: Annual Electricity Savings (GWh/yr)
Commercial and Industrial Sector								
four-foot T8	20.3	30%	4.8	78%	68	253	316	1,182
four-foot F40T12	1.6	50%	6.0	78%	42	157	224	839
four-foot F34T12	14.0	50%	5.3	78%	4	15	22	82
eight-foot F96T8	0.5	30%	3.5	78%	1	4	5	17
eight-foot F96T12	0.3	50%	11.5	78%	16	59	51	189
eight-foot F96T12 ES	2.7	50%	21.0	78%	3	12	10	38
eight-foot F96T8 HO	0.0	50%	0.0	78%	0	0	0	0
eight-foot F96T12 HO	0.2	50%	25.5	78%	26	99	85	317
eight-foot F96T12 HO ES	2.1	50%	26.9	78%	3	12	10	37
Consumer Sector (Residential and Light Commercial)								
four-foot T8	3.4	10%	0	20%	0	-	0	0
four-foot F40T12	2.1	50%	6.75	20%	28	63	246	557
four-foot F34T12	8.3	50%	4.375	20%	5	10	40	90
Total	**55.5**				**196**	**684**	**1,008**	**3,350**

[c] Assuming 20-year fixture life and 5-year lamp life
[d] Watts saved per lamp is based on assumed distribution of replacement options that are adopted as shown in Table 8, column 8.

7 Economic Analysis

7.1 Incremental Cost

Prices of fluorescent lamps differ considerably depending on the sales channel (retail vs. distributor) and the quantity purchased. Our general lamp and ballast price assumptions are summarized in Table 7. They are based on discussions with distributors and assume purchase by a medium commercial customer buying enough lamps per year to fulfill typical retrofit needs. For replacement options that require a new ballast (Table 8), we factor in the added ballast and labor cost for this replacement and analyze energy savings over the life of the ballast, rather than the lamp.

The incremental costs associated with available replacement options also vary widely depending on the base lamp. Based on current prices, upgrading from a standard-series T8 to a more advanced T8 incurs a 60% increase in the price of the lamp for both four-foot and eight-foot standard-output lamps. For the 34W T12, switching to an extra-efficient T8 can more than double the cost of the lamp, but energy cost savings will far outweigh this increase, as described in Section 7.3. For full-wattage T12s, the incremental cost of switching to a T8 is minimal due to price increases in recent years for full wattage T12s.

For upgrades to existing 2-lamp T8 systems, we analyze the costs and benefits in three scenarios: a lamp-for-lamp replacement, which incurs an incremental cost of $1 at current prices; a lamp and ballast retrofit, which incurs a higher incremental cost of $19.00 for the new ballast and labor; and a new construction scenario, which assumes only the incremental costs of two lamps ($2)[2].

The high incremental cost of high-performance T8 lamps is due to several factors, including the use of more expensive rare-earth phosphors, and the relatively low demand for these products. While production volume is not the only factor driving cost, it is likely that the incremental cost of high-lumen T8s and ballasts would drop dramatically once these products move into the mainstream and away from being "niche" products that carry a premium. Based on confidential conversations with a number of lamp manufacturers, production costs for high-lumen T8s are only about $0.25 higher than standard T8 lamps compared to our estimated $1.00 current incremental cost. Mandating high performance T8s in California, particularly if other states copy California requirements, would increase quantities and would likely have a significant impact on price, especially for full-wattage lamps.

[2] Note that high-lumen upgrades may mean that fewer lamps are needed

Table 7. Lamp and Ballast Cost Analysis

Design Options (Bold indicates baseline)	Price per Lamp[a]	Average Lamp life (hours)[b]	# lamps purchased per 50,000-hr ballast[c]	Ballast Cost
four-foot (Medium Bipin) Lamps				
F32T8 7XX	**$ 1.50**	**17,500**	**6**	**$ 15.00**
F32T8 8XX	$ 2.50	17,500	6	$ 15.00
F32T8 8XX HP (std BF)	$ 2.50	24,000	4	$ 16.00
F32T8 8XX HP (low BF)	$ 2.50	24,000	4	$ 16.00
F30T8 8XX	$ 2.50	17,500	6	$ 15.00
F28T8 8XX	$ 2.50	17,500	6	$ 15.00
F25T8 8XX	$ 3.50	17,500	6	$ 15.00
F34T12 CW	**$ 1.20**	**20,000**	**6**	**$ 15.00**
F34T12 7XX	$ 2.50	20,000	6	$ 15.00
F34T12 8XX	$ 3.00	20,000	6	$ 15.00
F34T12 8XX (Elec)	$ 3.00	20,000	6	$ 16.00
F40T12 7XX	**$ 2.50**	**20,000**	**6**	**$ 15.00**
F40T12 8XX	$ 3.00	20,000	6	$ 15.00
F40T12 8XX (Elec)	$ 3.00	20,000	6	$ 16.00
eight-foot Standard (Single Pin) Lamps				
F96T8 7XX	**$ 5.00**	**15,000**	**8**	**$ 20.00**
F96T8 8XX	$ 7.00	15,000	8	$ 20.00
F96T8 8XX HP (std BF)	$ 7.00	15,000	8	$ 20.00
F96T8 8XX HP (low BF)	$ 7.00	15,000	8	$ 20.00
F96T8 ES 8XX	$ 8.00	15,000	8	$ 20.00
F96T12 ES CW	**$ 3.00**	**12,000**	**8**	**$ 20.00**
F96T12 ES 7XX	$ 8.00	12,000	8	$ 20.00
F96T12 ES 8XX	$ 8.00	12,000	8	$ 20.00
F96T12 7XX	**$ 7.00**	**12,000**	**8**	**$ 20.00**
F96T12 8XX	$ 7.00	12,000	8	$ 20.00
eight-foot High-Output (Double Recessed) Lamps				
F96T8 HO 7XX	$ 9.00	18,000	6	$ 20.00
F96T8 HO 8XX	$ 10.00	18,000	6	$ 20.00
F96T12HO ES CW	**$ 4.00**	**12,000**	**8**	**$ 20.00**
F96T12 HO ES 7XX	$ 9.00	12,000	8	$ 20.00
F96T12 HO ES 8XX	$ 9.00	12,000	8	$ 20.00
F96T12HO 7XX	**$ 8.00**	**12,000**	**8**	**$ 20.00**
F96T12 HO 8XX	$ 8.00	12,000	8	$ 20.00

[a] Stan Walerczyk estimates
[b] Operating hours averaged from lamp catalogs. Does not include extra-long-life lamps
[b] Assumes 2-lamp ballasts. Ballast life from DOE, 2000.

7.2 Design Life

Rated lamp life for linear fluorescent lamps ranges from 12,000 to 42,000 hours at industry standard 3 hour cycles, including long-life products. For most four-foot lamps, 20,000 hours is typical, but some standard T8 lamps commonly last 15,000 hours on an instant start ballast. For our analyses, we assumed an average of 17,500 hours for the life of existing four-foot T8 systems and 20,000 hours for existing T12 systems. Long-life products are not included in the analysis.

For the eight-foot lamps, both standard and high output T12s have a rated lamp life of 12,000 hours. eight-foot T8 lamps in both standard, which some manufacturers call slimline, and HO versions are rated for 15,000 to 24,000 hours, with 18,000 hours being a good average. We convert lives in hours to lives in years based on average annual operating hours in Table 5.

7.3 Lifecycle Cost / Net Benefit

Tables 9 and 10 summarize the projected life cycle cost savings by product for each base-lamp replacement option. Net present value estimates are based on average statewide present value electricity and natural gas prices, supplied by the California Energy Commission.

The ratio of lifecycle benefits to costs from converting from T12 to T8 technology is dramatic. Benefits are greater for full wattage high output lamps, which offer much larger wattage reductions. The high present value of energy savings achieved by T8 products compared to T12s (Table 8) accounts primarily for these benefits, but cost savings will become more pronounced as T12s get further displaced from the market.

For the standard-series T8 lamp, the 25W or 28W reduced wattage F32T8 lamps are highly cost-effective in a retrofit scenario, although the 25W lamp can result in lower light output. High-lumen T8 lamps are the most cost-effective option for new construction and usually so for T12 system upgrades when a ballast replacement is required. As production quantities increase, high-lumen systems are likely to become increasingly attractive compared to reduced-wattage lamp replacement options.

For high-lumen T8s, we analyzed the lifecycle costs in three scenarios relative to a standard T8 system. In a simple lamp-for-lamp replacement, in which a high-lumen T8 is driven by a generic instant-start ballast, no improvement in wattage is achieved, but longer life and higher light output are obtained for a net present value cost of $1 per unit. For a retrofit scenario where both lamp and ballast are replaced, the incremental cost is high, but the savings are sufficient to provide a slight net benefit. The lifecycle benefits are clear in the new construction scenario where the cost of the ballast doesn't figure into the incremental cost.

Table 8. Replacement Options and Economics With Proposed Standard

Lamps[a]	Baseline Lamp	Watts	Total Cost[b]	Replacement Lamp	Watts	Total Cost[c]	Assumed % Switch per Base Case	Watts Saved	Annual Energy Savings (kWh)	Analysis Period (years)[d]	Incremental Cost ($)	Present Value of Lifetime Energy Savings ($)[e]
Commercial and Industrial Sectors												
2 (NC)	F32T8 7XX	58	$ 24.00	32W F32T8 8xx HL	48	$ 26.00	0%	10	37.4	13.4	$ 2.00	$ 57.99
2		58	$ 9.00	32W F32T8 8xx HL	48	$ 28.00	25%	10	37.4	13.4	$ 19.00	$ 57.99
1		29	$ 9.00	32W F32T8 8xx HL	29	$ 10.00	25%	0	0.0	6.4	$ 1.00	$ -
1		29	$ 1.50	30W F32T8	27.5	$ 2.25	0%	2	5.6	4.8	$ 0.75	$ 3.82
1		29	$ 1.50	28W F32T8	25.5	$ 2.50	25%	4	13.1	4.7	$ 1.00	$ 8.90
1		29	$ 1.50	25W F32T8	23.5	$ 3.50	25%	6	20.6	4.7	$ 2.00	$ 13.99
2	F34T12 CW	72	$ 7.20	32W F32T8 8xx HL	48	$ 28.00	50%	24	89.8	13.4	$ 20.80	$ 139.17
1		36	$ 1.20	F34T12 8XX	36	$ 2.50	50%	0	0.0	5.3	$ 1.30	$ -
2	F40T12	88	$ 15.00	32W F32T8 8xx HL	54	$ 28.00	25%	34	127.2	13.4	$ 13.00	$ 197.16
1		44	$ 2.50	F34T12 8XX	36	$ 30.00	25%	8	29.9	13.4	$ 27.50	$ 23.35
1		44	$ 2.50	F40T12 8XX	44	$ 3.00	50%	0	0.0	5.3	$ 0.50	$ -
1	F96T8 7XX	54.5	$ 5.00	F96T8 ES 8XX	51	$ 8.00	100%	4	13.1	4.0	$ 3.00	$ 6.29
2	F96T12 ES CW	123	$ 24.00	F96T8 8XX	100	$ 60.00	100%	23	86.0	13.4	$ 36.00	$ 109.28
2	F96T12 7XX	158	$ 56.00	F96T8 8XX	109	$ 76.00	50%	49	183.3	13.4	$ 20.00	$ 232.82
1		79	$ 7.00	F96T12 ES 8XX	61.5	$ 8.00	50%	18	65.5	3.2	$ 1.00	$ 31.43
2	F96T12 HO ES CW	207	$ 32.00	F96T8HO 8XX	156	$ 74.00	100%	51	190.8	13.4	$ 42.00	$ 242.32
2	F96T12 HO 7XX	245	$ 64.00	F96T8HO 8XX	156	$ 80.00	50%	89	333.0	13.4	$ 16.00	$ 422.87
1		122.5	$ 8.00	F96T12HO ES 8XX	104	$ 9.00	50%	19	69.2	4.8	$ 1.00	$ 47.06
Residential Sector												
2	32W F32T8 7Xx	56	$ 21.00	32W F32T8 8xx HL	48	$ 33.00	0%	8	18.2	22.0	$ 12.00	$ 31.96
1		56	$ 3.50	32W F32T8 8xx HL	56	$ 3.75	100%	0	0.0	22.0	$ 0.25	$ -
2	F34T12 CW or WW	60	$ 13.50	32W F32T8 8xx HL	33	$ 33.00	50%	27	61.3	22.0	$ 19.50	$ 107.87
1		30	$ 2.25	F34T12 8XX	30	$ 2.50	50%	0	0.0	8.8	$ 0.25	$ -
2	F40T12 7XX	70	$ 21.00	32W F32T8 8xx HL	55	$ 33.00	50%	15	34.1	22.0	$ 12.00	$ 59.93
1		35	$ 3.50	F40T12 8XX	35	$ 3.50	25%	0	0.0	8.8	$ -	$ -
1		35	$ 3.50	F34T12 8XX	30	$ 3.50	25%	5	11.4	8.8	$ -	$ 19.98

[a] A 2-lamp analysis indicates a ballast replacement. A 1-lamp analysis is a simple lamp-for-lamp change-out. NC=New Construction. In this case, only the incremental cost of a extra-efficient ballast compared to a generic electronic ballast is included.

[b] Baseline cost for 2-lamp analyses includes 8 sets of lamps per ballast for T12s and eight-foot lamps, 6 sets of lamps per ballast for most four-foot T8s, and 4 sets for high-lumen T8s (Table 6).

[c] Replacement lamp cost for 2-lamp analyses include ½ the cost of the new ballast and installation, assuming the existing ballast is half-way through it's life. Extra-efficient electronic ballast for four-foot T8= $16; Electronic ballast for eight-foot T8=$20. Labor to install = $20 ($60/hour, change 3/hour)

[d] For two-lamp analyses, life is calculated over the life of the 50,000-hour ballast (DOE, 2000). 1-lamp analyses use values from Table 7.

[e] Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2004).

[f] Assumes a low Ballast Factor for lumen equivalence

[g] Viable option, but results in a slightly lower light output.

[h] Viable option, but results in a slightly higher light output.

Table 9. Lifecycle Costs and Benefits for Standards Options

Lamps[a]	Baseline Lamp	Replacement Lamp	Lifecycle Benefit / Cost Ratio	Net present Value ($) Per Unit[c]
Commercial and Industrial Sectors				
2 (NC)	F32T8 7XX	32W F32T8 8xx HP	29.0	$ 56
2		32W F32T8 8xx HP	3.1	$ 39
1		32W F32T8 8xx HP	-	$ (1)
1		30W F32T8	5.1	$ 3
1		28W F32T8	8.9	$ 8
1		25W F32T8	7.0	$ 12
2	F34T12 CW	32W F32T8 8xx HP	6.7	$ 118
1		F34T12 8XX	-	$ (1)
2	F40T12	32W F32T8 8xx HP	15.2	$ 184
1		F34T12 8XX	0.8	$ (4)
1		F40T12 8XX	-	$ (1)
1	F96T8 7XX	F96T8 ES 8XX	2.1	$ 3
2	F96T12 ES CW	F96T8 8XX	3.0	$ 73
2	F96T12 7XX	F96T8 8XX	11.6	$ 213
1		F96T12 ES 8XX	31.4	$ 30
2	F96T12 HO ES CW	F96T8HO 8XX	5.8	$ 200
2	F96T12 HO 7XX	F96T8HO 8XX	26.4	$ 407
1		F96T12HO ES 8XX	-	$ (1)
Residential Sector				
2	32W F32T8 7XX	32W F32T8 8xx HL	2.7	$ 20
1	32W F32T8 7XX	32W F32T8 8xx HL	-	$ (0)
2	F34T12 CW or WW	32W F32T8 8xx HL	5.5	$ 88
1		F34T12 8XX	-	$ (0)
2	F40T12 7XX	32W F32T8 8xx HL	5.0	$ 48
1		F40T12 8XX	N/A	$ -
1		F34T12 8XX	N/A	$ 20

[a] A 2-lamp analysis indicates a ballast replacement and involves the cost of a new ballast. A 1-lamp analysis is a simple lamp-for-lamp change-out. NC=New Construction. In this case, only the incremental cost of a extra-efficient ballast compared to a generic electronic ballast is included.
[b] Total present value benefits divided by total present value costs.
[c] Positive value indicates a reduced total cost of ownership over the life of the appliance

8 Acceptance Issues

8.1 Infrastructure issues

Because the lamps recommended in this standard are already being made by all of the major manufacturers, there are very few products that will need to be newly designed, tested and produced.

8.2 Application Issues

Reduced-wattage lamps are promising low-cost alternatives to high-lumen T8s for reducing overall energy use, but they come with a number of limitations. Compared to an advanced T8 as a retrofit option, reduced-wattage T8s by definition offer no improvement in light levels or rated life compared to an existing T8 system, and they do not necessitate switching to an extra-efficient electronic ballast, which is a more durable way of ensuring savings over the long term. Reduced-wattage T8s also commonly experience starting and/or operating problems (e.g. striations and starting problems) at temperatures below 60°F and with certain older ballasts, which restricts their application. Specifically, these lamps will not operate with generic rapid start, programmed rapid start, or dimmable ballasts. They are not recommended for use with occupancy sensors unless they are used with a ballast that is specifically designed for that purpose. Their incompatibility with some program ballasts also prevents their use with more sophisticated lighting control systems. This lack of flexibility can add confusion to the marketplace and create a drag on the adoption of high-efficiency technologies, despite the clear short-term savings potential and rapid payback associated with these lamps.

8.3 Existing Standards

8.3.1 Federal Standards

The federal government established energy conservation standards for most general service fluorescent lamps under the Energy Conservation and Policy Act of 1992. The law set a minimum efficacy standard, summarized in Table 10, which essentially eliminated the use of cool white full-wattage T12 products. Products with CRI ≥ 82 and very low wattage products (<28 W for four-foot lamps, <52W for eight-foot lamps) are exempt from the standard as are plant lights and some other specialized products. Note the efficacy standard is based on *initial* lumens per watt.

The U.S. Department of Energy (DOE) was directed to revisit the standard in two phases and completed a revised test procedure for fluorescent lamps in May 1997. The department is now scheduled to revise the T12 standards and set new standards for four-foot T8 lamps by 2009. On May 31, 2006, the department released a framework document for this rulemaking for public comment. An ANOPR is scheduled for November, 2007, a NOPR for October, 2008, and the final rule for June, 2009. The new standard will take effect 3 years after the final rule (DOE, 2006).

Table 10. Summary of 1992 Federal Standard for Fluorescent lamps

Lamp Type	Nominal Lamp Wattage	Minimum CRI	Min Average Lamp Efficacy (initial LPW)
Four-foot medium bi-pin	<35W >35W	45 69	75 75
2-ft U-shaped	<35W >35W	45 69	64 68
Eight-foot Slimline	<65W >65W	45 69	80 80
Eight-foot High-Output	<100W >100W	45 69	80 80

Source: DOE, 2006

State standards on four-foot, eight-foot standard and eight-foot HO T12 lamps are preempted by the current federal standard unless a state successfully petitions DOE for exemption from preemption based on a compelling state interest. T8 lamps are not presently regulated by federal law and fall into a gray area on preemption. On the one hand preemption typically does not happen unless there are federal standards, and in the case of T8 lamps there are no federal standards. On the other hand, "general service fluorescent lamps" are listed in federal law as "covered products" and such covered products could be preempted. Several products discussed in the preceding sections are excluded from the definition of "general service fluorescent lamps" including four foot lamps with a rated wattage under 28 Watts and lamps with a color rendering index of 82 or greater.

Given federal preemption on some products and possible preemption on other products, the preferred course is to work with industry to develop consensus new national standards on fluorescent lamps. But if these efforts are unsuccessful, California can regulate some products on its own, may be able to regulate additional products, and could petition DOE for exemption from preemption on any remaining products it wishes to regulate.

8.3.2 Interaction with Title 24 of California's Building Code

The standards discussed in this CASE study are primarily designed to affect existing installations and not new fixtures. For example, we have excluded new fixtures from our savings estimates. Since California's Title 24 primarily affects new construction, including tenant build-outs, interactions with our proposed lamp standards are minimal. However, the proposed standard will significantly increase the use of high performance lamps, making Title 24 limits easier to reach. On the other hand, some designs can pass Title 24 using lamps excluded by our proposed standard and therefore the proposed standard will save some energy beyond that saved by Title 24. Since we excluded new fixtures from our savings analysis, we did not attempt to estimate these savings.

Furthermore, preventing the sale of basic grade T8s in Title 20 would help enforce Title 24 regulations. If 700-series T8s are eliminated, facility managers will be unable to use them as replacement lamps for more efficient 800-series lamps installed under Title 24. The practice of using the cheaper standard 700-series in these applications undermines the energy savings brought about by the building code and brings light levels below those that were intended by design.

8.4 Stakeholder Positions

Although T8 lamps are not explicitly included in the existing federal standard for fluorescent lamps, it is the opinion of manufacturers that T8 lamps are pre-empted by the standard under the four-foot medium bi-pin category of general service fluorescent lamps.

Manufacturers support the objective of increasing the price of T12 lamps and urging conversion to T8 through the standard, but they strongly oppose setting standards for T8 lamps before the T12 market is mostly converted. As stated in our recommendations

(Section 9), we acknowledge that tightening T12 and T8 products simultaneously is problematic and offer a phased approach.

In order not to penalize long-life lamps, manufacturers were in favor of building a standard not on mean efficacy, which is based on lumen output at 40% of life, but rather on efficacy after 8000 hours. We are willing to incorporate this into our proposal once manufacturers supply the data needed.

One manufacturer expressed concern that our analysis misrepresents the performance of T12 systems by not including electronically-ballasted high-lumen 800-series T12 lamps in our analyses. We agree that these systems are available and good replacement options for certain applications, and are thus not outlawed under our proposal. However, a very small percentage of existing T12 systems use electronic ballasts, and upon ballast replacement for *two-lamp systems*, we find that T8s are more economical if lumen levels are to be kept relatively constant, thus these lamps remain excluded from our savings analysis.

Two manufacturers disagreed with claims that the cost of high-performance products would come down substantially with the new standards, which would bring them into the mainstream and increase production volume. We agree that high-lumen lamps will continue to carry some incremental cost because they are more expensive to manufacture. However, in our own research with manufacturer representatives, we have determined that the current cost difference between these high-lumen lamps and standard 700-series lamps may be as much as three times the incremental technical production cost, suggesting that these products are often marked up as "specialty products" status.

9 Recommendations

9.1 Recommended Standards Options

Based on the diminishing market share of T12 lamps in favor of T8s and the dramatic energy savings benefits of high-performance T8 technology, a standard that restricts the least efficient products among both T8s and T12s is warranted. Because high-lumen T8 products are currently available from all major manufacturers and heavily promoted by California utilities, we recommend maximizing savings potential by restricting T8s, full-wattage T12s and energy saver T12s to the most efficient class of products widely available from all major manufacturers. These standards would include no exemptions. The recommended standard is summarized in Table 11, based on values listed in Table 3.

In order to accelerate the transition away from T12 technology, we agree with the view of several manufacturers that implementing T8 and T12 standards simultaneously makes little sense. Doing this would raise the price of both T8 and T12 products, reducing the incentive to make the switch. Therefore, we propose a phased approach wherein T12 lamps would be regulated first, allowing only 800-series products. Roughly three years after enactment, the T8 standard would then take effect, allowing time for the market and industry to adjust. Therefore the savings realized by restricting T8s, or roughly one third of our estimate, would be delayed. Because of the dramatic cost and energy savings benefits, we recommend eliminating T12s altogether in the second phase while tightening up T8 standards.

For the four-foot and eight-foot T8 lamps, we recommend relaxing the minimum efficacy level for high color-temperature lamps for reasons stated in Section 4. We do not recommend relaxing the standard for T8s based on initial evidence suggesting catalog data of high-lumen T8 products may be inflated. Before proposing a standard that accounts for these discrepancies, further data is needed. Manufacturers possess this data, and if 90 LPW cannot be met, they can provide documentation.

Table 11. Recommended Standard

Lamp Type	Lamp Types Effected	Nominal Lamp Wattage	Min Average Lamp Efficacy (MLPW)	
			<4500 K	>4500 K
Four-foot medium bi-pin (Including 2-ft U-shaped)	F32T8/F32T8 ES	<33 W	90	86
	F34T12	33–35 W	77	77
	F40T12	>35 W	76	76
Eight-foot Slimline	F96T8	<60	95	88
	F96T12 ES	60–65 W	90	90
	F96T12	>65 W	82	82
Eight-foot High-Output	F96T8	<90 W	89	89
	F96T12 HO ES	90–100 W	81	81
	F96T12 HO	>100 W	77	77

Note: Under the recommended standards, no U-shaped lamps currently qualify. Manufacturers would have to improve the phosphors in these lamp lines to meet the standard. We did not allow a separate requirement for these lamps because their sales are small. If this issue was critical to manufacturers, we could do so.

9.2 Proposed Changes to the Title 20 Code Language

[To be prepared later]

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11 Appendix A: Consortium for Energy Efficiency Qualifying products list for High-Performance four-foot T8 lamps

Manufacturer	Product Line	Model Code	CCT (K)	Rated Life (hrs) IS	Rated Life (hrs) RS/RPS	Initial Lumens	Mean Lumens	CRI	LM
CRI Lighting	N/A	F32T8/830 XP	3000	24,000	30,000	3100	2950	83	0.94
		F32T8/835 XP	3500	24,000	30,000	3100	2950	83	0.94
		F32T8/841 XP	4100	24,000	30,000	3100	2950	83	0.94
		F32T8/850 XP	5000	24,000	30,000	3100	2950	83	0.94
		F32T8/865 XP	6500	24,000	30,000	3100	2950	83	0.94
General Electric Company	Ecolux High Lumen	F32T8/XL/SPX30/HL/ECO	3000	24000	24000	3100	2915	85	0.94
		F32T8/XL/SPX35/HL/ECO	3500	24000	24000	3100	2915	85	0.94
		F32T8/XL/SPX41/HL/ECO	4100	24000	24000	3100	2915	82	0.94
Halco Lighting	ProLume	F32T8/850/ECO	5000	24000	24000	3050	2900	86	0.95
		F32T8/865/ECO	6500	24000	24000	3050	2900	86	0.95
		F32T8/850/ECO/1C	5000	24000	24000	3050	2900	85	0.95
		F32T8/865/ECO/1C	6500	24000	24000	3050	2900	85	0.95
Howard Industries	N/A	F32T8/830/HL/ECO	3000	24,000	24,000	3100	2950	85	0.95
		F32T8/835/HL/ECO	3500	24,000	24,000	3100	2950	85	0.95
		F32T8/841/HL/ECO	4100	24,000	24,000	3100	2950	85	0.95
Hygrade (also NARVA, Hygrade/Narva, and TriPhase)	High Lumen	F32T8/HL/830	3000	24000	24000	3100	2950	85	0.95
		F32T8/HL/835	6500	24000	24000	3100	2950	85	0.95
		F32T8/HL/841	4100	24000	24000	3100	2950	85	0.95
		F32T8/HL/850	5000	24000	24000	3100	2950	85	0.95
Kumho Electric USA	High Lumen	F32T8/830	3000	24,000	30,000	3100	2950	>81	0.94
		F32T8/835	3500	24,000	30,000	3100	2950	>81	0.94
		F32T8/841	4100	24,000	30,000	3100	2950	>81	0.94
		F32T8/850	5000	24,000	30,000	3100	2950	>81	0.94
		F32T8/865	6500	24,000	30,000	3100	2950	>81	0.94
Maxlite	Premium T8	F32T8/830	3000	24,000	24,000	3100	2900	85	0.94
		F32T8/835	3500	24,000	24,000	3100	2900	85	0.94
		F32T8/841	4100	24,000	24,000	3100	2900	85	0.94
		F32T8/850	5000	24,000	24,000	3100	2900	85	0.94
	T8 XL	F32T8/835XL	3500	24,000	24,000	3200	3020	85	0.94
		F32T8/841XL	4100	24,000	24,000	3200	3020	85	0.94
		F32T8/850XL	5000	24,000	24,000	3200	3020	85	0.94
		F32T8/865XL	6500	24,000	24,000	3200	3020	85	0.94
Osram - Sylvania	Octron XPS	FO32/830/XPS/ECO	3000	24000	36000	3100	2945	85	0.95
		FO32/835/XPS/ECO	3500	24000	36000	3100	2945	85	0.95
		FO32/841/XPS/ECO	4100	24000	36000	3150	2990	85	0.95
Philips Lighting Company	Alto Advantage	F32T8/ADV830/ALTO	3000	20,000	24,000	3100	2950	85	0.95
		F32T8/ADV835/ALTO	3500	20,000	24,000	3100	2950	85	0.95
		F32T8/ADV841/ALTO	4100	20,000	24,000	3100	2950	85	0.95
		F32T8/ADV830/ALTO	3000	30,000	36,000	3150	3000	85	0.97
		F32T8/ADV835/ALTO	3500	30,000	36,000	3150	3000	85	0.97
		F32T8/ADV841/ALTO	4100	30,000	36,000	3150	3000	85	0.97
		F32T8/ADV850/ALTO	5000	30,000	36,000	3050	2935	85	0.97
Premium Quality Lighting, Inc.	SuperiorLife - HiLum	F32T8/835 Super-Brite	3500	24,000	24,000	3100	2950	85	0.95
		F32T8/841 Super-Brite	4100	24,000	24,000	3100	2950	85	0.95
		F32T8 Sky-Brite	5000	24,000	24,000	3100	2950	85	0.95
		F32T8/850 Hi Lumen	5000	24,000	24,000	3100	2950	85	0.95
		F32T8/841 Hi Lumen	4100	24,000	24,000	3100	2950	85	0.95
		F32T8/835 Hi Lumen	3500	24,000	24,000	3100	2950	85	0.95
		F32T8/830 Hi Lumen	3000	24,000	24,000	3100	2950	85	0.95
Radiant Lamp Company a division of Westinghouse Lighting Co	Triten 50 Ultra	F32T8/Triten50/ULTRA/ENV	5000	24,000	24,000	3100	2950	86	0.95
		F32T8/Triten50/ULTRA/ENV							
Technical Consumer Products, Inc.	TCP High Lumen	F32T8/850/HL	5000	24,000	24,000	3100	2915	86	0.94
		F32T8/830/HL	3000	24,000	24,000	3100	2915	85	0.94
		F32T8/835/HL	3500	24,000	24,000	3100	2915	85	0.94
		F32T8/841/HL	4100	24,000	24,000	3100	2915	85	0.94
		F32T8/865/HL	6500	24,000	24,000	3100	2915	85	0.94
SLI Lighting	Terra-Lux High Lumen	F32T8/HL/835	3500	24,000	24,000	3100	2915	85	0.94
		F32T8/HL/841	4100	24,000	24,000	3100	2915	85	0.94

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		F32T8/HL/850	5000	24,000	24,000	3100	2915	85	0.94
Standard Products	XL 31	F32T8/830/XL31	3000	24,000	30,000	3100	2950	85	0.95
		F32T8/835/XL31	3500	24,000	30,000	3100	2950	85	0.95
		F32T8/841/XL31	4100	24,000	30,000	3100	2950	85	0.95
		F32T8/850/XL31	5000	24,000	30,000	3100	2950	85	0.95
USHIO America, Inc.	ULTRA 8 High Lumen	F32T8/841/HL	4100	24,000	30,000	3150	2990	86	0.95
		F32T8/850/HL	5000	24,000	30,000	3150	2990	86	0.95
Westinghouse Lighting Corporation	XL	F32T8/830/XL/ECOMAX	3000	24,000	30,000	3100	2950	86	0.95
		F32T8/835/XL/ECOMAX	3500	24,000	30,000	3100	2950	86	0.95
		F32T8/841/XL/ECOMAX	4100	24,000	30,000	3100	2950	86	0.95

12 Appendix B: Qualifying high-color temperature four-foot T8 products under an 88 mean LPW standard

Manufacturer/Name	Rated Watts	Initial Lumens	Mean Lumens	CCT (K)	Life (3-hr start)	Mean lumens per watt	CRI
Sylvania F032/850/XP/ECO	32	3000	2850	5000	24000	89	85
Phillips F32T8/TL850/PLUS/ALTO	32	2950	2800	5000	30000	88	85
Phillips F32T8/ADV850/ALTO	32	3025	2875	5000	30000	90	85
Phillips F32T8/ADV850/EW/LL/ALTO	28	2625	2470	5000	24000	88	85
Phillips F32T8/ADV850/EW/LL/ALTO	30	2850	2700	5000	24000	90	85
GE F32T8/SP50/UMX/ECO	28	2650	2490	5000	24000	89	80
GE F32T8/XL/SPX50/HL/ECO	32	3000	2820	5000	24000	88	80
Sylvania F032/850/XP/ECO	32	3000	2850	5000	24000	89	85

13 Appendix C: Available Four-Foot T12 Lamps from Major Manufacturers

Note: Does not include products from other manufacturers that would qualify under our proposed standards options.

Manufacturer/Name	Rated Watts	Initial Lumens	Mean Lumens	CCT (K)	Life (3-hr start)	Mean lumens per watt	CRI
Four-Foot T12 Medium Bi-pin Reduced-Wattage (<4500 K)							
GE ecolux utility shoplight	25	1860	1675	4100	12000	67	60
GE ecolux utility shoplight	25	1860	1675	4100	12000	67	60
GE ecolux utility shoplight	25	1860	1675	4100	12000	67	60
GE watt miser plus	32	2650	2400	3500	20000	75	80
GE watt miser plus	32	2650	2400	3500	20000	75	80
GE watt miser plus	32	2500	2200	4100	20000	69	80
GE watt miser moduline	34	2200	2050	4100	14000	60	60
GE watt miser moduline	34	2300	2100	3000	14000	62	52
GE watt miser moduline	34	2300	2100	4100	14000	62	60
GE watt miser moduline	34	2300	2100	4100	14000	62	60
GE watt miser moduline	34	2300	2100	4100	14000	62	60
GE watt miser moduline	34	2350	2150	3000	14000	63	52
GE watt-miser ecolux	34	2650	2280	4100	20000	67	60
GE watt-miser ecolux	34	2650	2280	4100	20000	67	60
GE watt-miser ecolux	34	2650	2280	4100	20000	67	60
GE watt-miser ecolux	34	2700	2320	3000	20000	68	52
GE watt-miser ecolux	34	2700	2320	3000	20000	68	52
GE watt-miser ecolux	34	2825	2430	4200	20000	71	49
GE watt-miser ecolux	34	2750	2475	3000	20000	73	70
GE watt-miser ecolux	34	2750	2475	3000	20000	73	70
GE watt-miser ecolux	34	2750	2475	3500	20000	73	73
GE watt-miser ecolux	34	2750	2475	3500	20000	73	73
GE watt-miser ecolux	34	2750	2475	3500	20000	73	73
GE watt-miser ecolux	34	2750	2475	4100	20000	73	72
GE watt-miser ecolux	34	2750	2475	4100	20000	73	72
GE watt-miser ecolux	34	2900	2610	3000	20000	77	82
GE watt-miser ecolux	34	2900	2610	3500	20000	77	82
GE watt-miser ecolux	34	2900	2610	4100	20000	77	80
Philips U-Bent	34	2400	2050	3000	18000	60	53
Philips U-Bent	34	2400	2050	4100	18000	60	62
Philips U-Bent	34	2350	2050	4100	18000	60	62
Philips U-Bent	34	2425	2125	3000	18000	63	51
Philips U-Bent	34	2500	2150	4200	18000	68	62
Philips Standard RS	34	2650	2300	4100	20000	68	62
Philips Standard RS	34	2650	2300	4100	20000	68	62
Philips Standard RS	34	2650	2300	4100	20000	68	62
Philips U-Bent	34	2700	2350	3000	18000	69	53
Philips U-Bent	34	2760	2500	3000	18000	74	70
Philips U-Bent	34	2760	2500	3500	18000	74	73
Philips U-Bent	34	2760	2500	4100	18000	74	70
Philips RS 800	34	2800	2660	3000	20000	78	82

Philips RS 801	34	2800	2660	3500	20000	78	82
Philips RS 802	34	2800	2660	4100	20000	78	82
Sylvania supersaver RS	34	1925	1656	4100	20000	49	87
Sylvania supersaver RS	34	2600	2235	4200	20000	66	62
Sylvania curvalume RS supersaver	34	2600	2236	4200	18000	66	62
Sylvania curvalume RS supersaver	34	2600	2236	4200	18000	66	62
Sylvania curvalume RS supersaver	34	2600	2236	4200	18000	66	62
Sylvania curvalume RS supersaver	34	2650	2279	3000	18000	67	52
Sylvania curvalume RS supersaver	34	2650	2279	3000	18000	67	52
Sylvania curvalume RS supersaver	34	2650	2279	3000	18000	67	52
Sylvania supersaver RS	34	2650	2279	4200	20000	67	62
Sylvania supersaver RS	34	2650	2279	4200	20000	67	62
Sylvania supersaver RS	34	2650	2279	4200	20000	67	62
Sylvania supersaver RS	34	2650	2279	4200	20000	67	62
Sylvania supersaver RS	34	2650	2279	4200	20000	67	62
Sylvania supersaver RS	34	2750	2355	3000	20000	69	52
Sylvania supersaver RS	34	2750	2365	3000	20000	70	52
Sylvania supersaver RS	34	2750	2365	3450	20000	70	57
Sylvania curvalume RS supersaver	34	2800	2408	4150	18000	71	48
Sylvania supersaver RS	34	2825	2430	4150	20000	71	48
Sylvania supersaver RS	34	2825	2430	4150	20000	71	48
Sylvania curvalume RS supersaver	34	2730	2457	3000	18000	72	70
Sylvania curvalume RS supersaver	34	2730	2457	3500	18000	72	70
Sylvania curvalume RS supersaver	34	2730	2457	4100	18000	72	70
Sylvania supersaver RS	34	2800	2520	3000	20000	74	70
Sylvania supersaver RS	34	2800	2520	3500	20000	74	70
Sylvania supersaver RS	34	2800	2520	3500	20000	74	70
Sylvania supersaver RS	34	2800	2520	3500	20000	74	70
Sylvania supersaver RS	34	2800	2520	3500	20000	74	80
Sylvania supersaver RS	34	2800	2520	4100	20000	74	70
Sylvania supersaver RS	34	2800	2520	4100	20000	74	80
Sylvania supersaver RS	34	2900	2610	3000	20000	77	80
Sylvania supersaver RS	34	2900	2610	3000	20000	77	80
Four-Foot T12 Medium Bi-pin Reduced-Wattage (>4500 K)							
GE watt-miser ecolux	34	1950	1620	6500	20000	48	84
GE watt-miser ecolux	34	2000	1720	5000	20000	51	90
GE watt-miser ecolux	34	2700	2430	5000	20000	71	80
GE watt-miser ecolux	34	2650	2430	6500	20000	71	75
Philips Standard RS	34	2025	1775	6500	20000	52	84
Philips Standard RS	34	2800	2660	5000	20000	78	82
Sylvania Supersaver RS	34	1930	1565	6500	20000	46	88
Sylvania Supersaver RS	34	2650	2279	6500	20000	67	80
Four-Foot T12 Medium Bi-pin Full-Wattage (<4500 K)							
GE ecolux	40	2100	1740	3700	20000	44	90
GE Moduline	40	2725	2400	4100	14000	60	75
GE Moduline	40	2800	2460	3500	14000	62	75
GE Moduline	40	2800	2460	4100	14000	62	75
GE Moduline	40	2800	2460	4100	14000	62	75
GE Moduline	40	2925	2660	3000	14000	67	70
GE Moduline	40	2925	2660	3500	14000	67	73
GE Moduline	40	2925	2660	4100	14000	67	72
GE Moduline	40	3000	2730	3000	14000	68	82

GE Moduline	40	3000	2730	3500	14000	68	82
GE Moduline	40	3050	2780	3000	14000	70	70
GE Moduline	40	3050	2780	3500	14000	70	73
GE Moduline	40	3050	2780	3500	14000	70	73
GE Moduline	40	3050	2780	4100	14000	70	72
GE Moduline	40	3100	2820	3000	14000	71	82
GE Moduline	40	3100	2820	3500	14000	71	82
GE ecolux	40	3150	2860	4100	15000	72	72
GE ecolux	40	3150	2860	4100	15000	72	72
GE ecolux	40	3150	2860	4100	15000	72	72
GE ecolux	40	3200	2910	3500	20000	73	73
GE ecolux	40	3200	2910	4100	20000	73	72
GE ecolux	40	3200	2910	4100	20000	73	72
GE ecolux	40	3250	2950	3000	20000	74	70
GE ecolux long-life	40	3300	2970	3000	24000	74	75
GE ecolux long-life	40	3300	2970	3500	24000	74	75
GE ecolux long-life	40	3300	2970	4100	24000	74	73
GE ecolux	40	3350	3050	4100	20000	76	80
GE ecolux long-life	40	3400	3060	3000	24000	77	82
GE ecolux long-life	40	3400	3060	3500	24000	77	82
GE ecolux long-life	40	3400	3060	4100	24000	77	80
GE ecolux	40	3400	3090	3000	20000	77	70
GE ecolux	40	3400	3090	3000	20000	77	70
GE ecolux	40	3400	3090	3000	20000	77	82
GE ecolux	40	3400	3090	3500	20000	77	82
Philips Standard RS	40	2200	1800	4200	20000	45	89
Philips U-Bent	40	3050	2775	3000	18000	69	70
Philips U-Bent	40	3050	2775	3500	18000	69	73
Philips U-Bent	40	3050	2775	4100	18000	69	70
Philips U-Bent	40	3100	2850	3000	18000	71	85
Philips U-Bent	40	3100	2850	3500	18000	71	85
Philips U-Bent	40	3100	2850	4100	18000	71	85
Phlips RS 800	40	3200	3040	3000	20000	76	82
Phlips RS 800	40	3200	3040	3500	20000	76	82
Phlips RS 800	40	3200	3040	4100	20000	76	82
Phlips RS Ultimate	40	3600	3250	3000	24000	81	85
Phlips RS Ultimate	40	3600	3250	3500	24000	81	85
Phlips RS Ultimate	40	3600	3250	4100	24000	81	85
Sylvania standard RS	40	1480	1273	2750	20000	32	89
Sylvania standard RS	40	2100	1806	3600	20000	45	86
Sylvania curvalume RS supersaver	40	2100	1806	4100	18000	45	87
Sylvania standard RS	40	2150	1849	4100	20000	46	87
Sylvania standard RS	40	2150	1849	4100	20000	46	87
Sylvania curvalume RS supersaver	40	3050	2745	3000	18000	69	70
Sylvania curvalume RS supersaver	40	3050	2745	3500	18000	69	70
Sylvania curvalume RS supersaver	40	3050	2745	4100	18000	69	70
Sylvania standard RS	40	3200	2880	3000	20000	72	70
Sylvania curvalume RS supersaver	40	3200	2880	3000	18000	72	80
Sylvania standard RS	40	3200	2880	3500	20000	72	70
Sylvania standard RS	40	3200	2880	4100	20000	72	70
Sylvania standard RS	40	3200	2880	4100	20000	72	70
Sylvania standard RS	40	3300	2970	3000	20000	74	80

Sylvania standard RS	40	3300	2970	3500	20000	74	80
Sylvania standard RS	40	3300	2970	4100	20000	74	80
Four-Foot T12 Medium Bi-pin Full-Wattage (>4500 K)							
GE ecolux	40	1950	1680	7500	20000	42	92
GE ecolux	40	2250	1870	5000	20000	47	90
GE ecolux	40	2250	1870	5000	20000	47	90
GE ecolux	40	2250	1870	5000	20000	47	90
GE ecolux	40	2250	1870	6500	20000	47	84
GE ecolux	40	3050	2775	6500	20000	69	75
GE ecolux	40	3050	2775	6500	20000	69	75
GE ecolux	40	3050	2775	6500	20000	69	75
GE ecolux	40	3200	2860	5000	20000	72	80
GE ecolux long-life	40	3350	3050	5000	24000	76	80
Philips Standard RS	40	2000	1720	7500	20000	43	95
Philips Standard RS	40	2200	1915	5000	20000	48	92
Philips U-Bent	40	2250	1950	6500	18000	49	84
Philips Standard RS	40	2325	2025	6500	20000	51	84
Phlips RS 800	40	2700	2900	5000	20000	73	82
Phlips RS Ultimate	40	3600	3250	5000	24000	81	85
Sylvania standard RS	40	2180	1770	6500	20000	44	88
Sylvania standard RS	40	2200	1892	5000	20000	47	90
Sylvania standard RS	40	3000	2700	6500	20000	68	80

14 Appendix D: Available eight-foot Lamps from Major Manufacturers

Note: Does not include products from other manufacturers that would qualify under our proposed standards options.

Lamp Type	Manufacturer/Name	Rated Watts	Initial Lumens	Mean Lumens	Mean lumens per watt	CRI
eight-foot Slimline T8						
F96 T8 700	**Phillips F96T8 TL741 ALTO Plus**	**59**	**5700**	**5190**	**88**	**78**
	GE F96T8 700	**59**	**5800**	**5500**	**93**	**78**
F96 T8 800	**Sylvania F096/830/ECO**	**59**	**5900**	**5428**	**92**	**82**
	Phillips F96T8/TL841/PLUS/ALTO	**59**	**5900**	**5490**	**93**	**86**
	Philips F96T8 TL850 (5000K)	**59**	**5780**	**5375**	**91**	**86**
F96 T8 800 high	**GE F96T8/SPX35**	**59**	**5950**	**5650**	**96**	**86**
	Sylvania F096/830/XP/ECO	**59**	**6100**	**5795**	**98**	**85**
eight-foot Slimline T8 Energy Saver						
F96T8 ES 800	**Sylvania F096/830/XP/SS/ECO**	**55**	**5700**	**5415**	**98**	**82**
	GE Xlife Watt-miser ES lamps	**57**	**5800**	**5450**	**96**	**81,83,84**
eight-foot Slimline T12						
F96 T12 700	**Phillips F96T12/SPEC41/ALTO**	**75**	**6425**	**6050**	**81**	**70**
	Phillips F96T12/SPEC41/EW/ALTO	**75**	**5750**	**5400**	**72**	**70**
	GE F96T12/SP41	**75**	**6500**	**6110**	**81**	**72**
	GE F96T12 XL 700	**75**	**6700**	**6180**	**82**	**73, 75**
	Sylvania F96T12/D41/	**75**	**6420**	**5906**	**79**	**70**
F96 T12 800	**Phillips F96T12/841 ALTO**	**75**	**6600**	**6225**	**83**	**85**
	GE F96T12/SPX41	**75**	**6800**	**6390**	**85**	**82, 80**
	GE F96T12/ XL 800	**75**	**6900**	**6370**	**80**	**80**
	Sylvania F96T12/D841	**75**	**6550**	**6157**	**82**	**80**
	Sylvania F96T12/D841/ECO	**75**	**6550**	**6157**	**82**	**80**
eight-foot Slimline T12 Energy Saver						
F96 T12 ES CW	**Sylvania F96T12WWSSECO**	**60**	**5500**	**4840**	**81**	**52**
	GE F96T12CW/WMECO-S	**60**	**5500**	**5060**	**84**	**60**
	Sylvania F96T12CWSSECO	**60**	**5300**	**4664**	**78**	**60**
	Phillips F96T12/CW/EW/ALTO	**60**	**5400**	**4750**	**79**	**62**
F96 T12 ES 700	**Sylvania F96T12D35/SS/ECO**	**60**	**5600**	**5152**	**86**	**70**
	GE F96T12/SP41/WM/U	**60**	**5700**	**5360**	**89**	**72**
F96 T12 ES 800	**Sylvania F96T12D835SS**	**60**	**5800**	**5452**	**91**	**80**
eight-foot High Output T8						
F96 T8 HO 700	**Phillips F96T8 TL741 HO ALTO Plus**	**86**	**7900**	**7100**	**83**	**78**
	GE F96T8/SP41/HO	**86**	**8000**	**7600**	**88**	**78**
	Sylvania F096/741/HO	**86**	**8000**	**7200**	**84**	**75**

	Sylvania F096/741HO/ECO	**86**	**8000**	**7520**	**87**	**78**
F96 T8 HO 800	**Phillips F96T8/TL841/HO/PLUS/ALTO**	**86**	**8200**	**7625**	**89**	**86**
	GE F96T8/SPX35/HO	**86**	**8200**	**7800**	**91**	**86**
	Sylvania F096/835/HO	**86**	**8200**	**7380**	**86**	**84**
	Sylvania F096/835/HO/ECO	**86**	**8200**	**7710**	**90**	**85**
eight-foot High Output T12						
F96 T12 HO 700	**GE F96T12/SP65/HO**	**110**	**8900**	**8010**	**73**	**75**
	GE F96T12/SP41/HO	**110**	**9200**	**8280**	**75**	**72**
F96 T12 HO 800	**Phillips F96T12/841 HO ALTO**	**110**	**9500**	**8550**	**78**	**85**
	GE F96T12/	**110**	**9350**	**8420**	**77**	**82**
	Sylvania F96T12/D841/HO	**110**	**9350**	**8420**	**77**	**80**
	Sylvania	**110**	**9400**	**8648**	**79**	**80**
eight-foot High Output T12 Energy-Saver						
F96 T12 HO ES CW	**Phillips F96T12/HO/EW/ALTO**	**95**	**8000**	**6950**	**73**	**62**
	GE F96T12CWHOWMUPC	**95**	**8000**	**6960**	**73**	**60**
	Sylvania F96T12/CW/HO/SS/ECO	**95**	**8000**	**6480**	**68**	**62**
	Sylvania F96T12WW/HO/SS	**95**	**7700**	**6237**	**66**	**52**
F96 T12 HO ES 700	**GE F96T12 HO ES 700**	**95**	**8350**	**7520**	**79**	**72, 73**
	Phillips F96T12/SPEC41/HO/EW	**95**	**8350**	**7500**	**79**	**70**
	Sylvania F96T12/D41/HO/SS	**95**	**8350**	**7515**	**79**	**70**
F96 T12 HO ES 800	**Phillips F96T12/841HO/EW ALTO**	**95**	**8620**	**7750**	**82**	**85**
	GE F96T12 HO ES 800	**95**	**8500**	**7650**	**81**	**80, 82**