December 17, 2021

Matt Chapman
Director, Waste Management and Prevention Division, Solid Waste Program
Vermont Department of Environmental Conservation (DEC)
One National Life Drive
Montpelier, Vermont 05620

RE: Evidence pertaining to the sale of mercury-containing lamps in Vermont

Dear Director Chapman,

We are writing in response to the November 16, 2021 letter from the National Electrical Manufacturers Association (NEMA). The NEMA letter was in response to your request that they demonstrate compliance with Vermont State Law 10 V.S.A. §7152, as per our earlier October letter to you requesting the same.

First of all, we were pleased to see NEMA concede that (screw-base) compact fluorescent lamps (CFLs) can now be phased out in Vermont. We fully agree with NEMA on this point, that CFLs can and should be banned under existing state law because LEDs, which are mercury-free, are widely available at competitive prices to CFLs, offer users cost savings, and outperform CFLs with respect to efficiency, rated life and many other factors.

However, we do not agree with NEMA's position on the viability of non-mercury energy-efficient lamps replacing linear fluorescent lamps (LFLs). As such, we have prepared the attached assessment in response to the NEMA letter demonstrating that non-mercury LED lamps that serve as a drop-in replacements for linear fluorescent lamps are widely available, often exceed the performance of LFLs, and offer cost savings to residential and commercial customers. Specifically at issue is 10 V.S.A. §7152 (a)(6), which requires that a manufacturer of a mercury-containing lamp shall not sell, offer for sale, or deliver to a retailer for subsequent sale, a mercury-containing lamp unless:

> *"(6) The manufacturer has demonstrated that no alternative non-mercury energy efficient lamp is available that provides the same or better overall performance at a cost equal to or better than the classes of lamps that the manufacturer proposes to sell."*

The NEMA letter fails to demonstrate compliance with the requirements of 10 V.S.A. §7152(a)(6) because: (1) it offers only a superficial price comparison for one type of fluorescent lamp; (2) it omits any cost information for many important categories of fluorescent lamps; and (3) we are concerned NEMA may be fundamentally misinterpreting the requirements of the statute.

1. *Inadequate price review*: NEMA submitted extremely limited price information for only one type of mercury-containing lamp (32-watt 4-foot T8 linear fluorescent lamps (LFLs)). The price information

NEMA submitted for this lamp type was drawn from only one retailer (Grainger.com) and within that retailer's product offering, only a very small subset of those models. This cursory assessment of the price of such a limited number of models does not demonstrate that there are no energy-efficient mercury-free alternatives that provide the same or better performance at an equal or lower cost to Vermonters. Moreover, our preliminary research has revealed the availability of several brands of equivalent LED lamps for the 32-watt T8s presented by NEMA with lower purchase prices. For a more complete assessment of NEMA's pricing assessment, see Attachment A.

2. *Omission of mercury-lamp categories*: NEMA's letter does not offer any information on several other important categories of fluorescent lamps that are currently sold in the State, including:
    - T5 LFLs, including 4 foot lengths;
    - T8 LFLs, including straight 2- , 5- and 8-foot lengths and U-shape;
    - T12 LFLs, including 4- and 8-foot lengths and U-shape; and
    - Pin-based compact fluorescent lamps (CFLs), including 2-pin and 4-pin.

3. *Potential misinterpretation of the statute*: In their letter, NEMA appears to be conflating the term "cost" in 10 V.S.A. §7152(a)(6) with "price". However, everyone knows that cost and price are not the same thing, particularly for lighting products because no one purchases a light bulb simply to put it on a shelf. Rather, a light bulb is purchased to be installed into a socket and used. Therefore, the energy consumed by the light bulb is an intrinsic and inseparable part of the product's "cost" to an end-user. For this reason, the term "cost" in the statute can and should reasonably be interpreted as including both the price paid for the light bulb and the electricity cost.

How DEC interprets the meaning of the word "cost" in the statute will have a significant impact on the lighting market in Vermont. NEMA's apparent interpretation is that price equals cost, and if that definition is followed, it will be difficult for linear lamps and pin-base LED retrofit lamps to compete with fluorescent. However, if the electricity cost associated with the use of the lamps is considered part of the ownership "cost" – getting to the affordability of lighting – then LED is the strong favorite, as it has already achieved least life-cycle cost in virtually all fluorescent lamp applications. The interpretation of the statutory language, and what was originally intended by the authors of the legislation may require careful review.

To address the shortcomings observed in the NEMA letter, we prepared Attachment A to assist DEC's review of mercury-containing lamps in the State. As you will see, the mercury-free (i.e., LED) lighting market has improved dramatically over the last five years in terms of product availability, price, performance and quality. Reflecting the advancements in LED technology, the US Department of Energy stated in 2019 that LEDs "are revolutionizing the lighting market," explaining that they "have surpassed, or matched, all conventional lighting technologies in terms of energy efficiency, lifetime, versatility, and color quality, and, due to their increasing cost competitiveness, LEDs are successfully competing in a wide variety of lighting applications."

Moreover, the European Commission recently conducted a thorough evaluation of the potential for LEDs to replace fluorescent lamps under its Restriction of Hazardous Substances (RoHS) Directive. The Commission decided to ban *all* general-purpose linear fluorescent lamps from the European marketplace within 12-18

months. In its decision, dated December 16,2021, the Commission concluded that "the availability of substitutes has been documented and calculations based on the socioeconomic impact of substitution have shown to result in overall savings and in total environmental, health and consumer safety benefits." It also pointed to studies that found:

- "Reliable mercury-free substitutes are available on the European Union market;"
- "Ample evidence that substituting mercury in the lamp categories covered by the exemption [i.e., double-capped linear fluorescents for general lighting purposes including, but not limited to T5s, T8s and T12s] is scientifically and technically practicable;"
- "The substitution costs would be relatively quickly offset by benefits generated by related energy savings;" and
- "Substituting mercury with LED alternatives in the lamp categories under assessment would avoid placing 2882 kg [i.e., over a ton] of mercury in lamps on the EU market."

Fundamentally, 10 V.S.A. § 7152 (a)(6) states that mercury-containing lamps cannot be sold if mercury-free alternatives are available at the same or better cost and performance. The statute places the burden of proof on suppliers to demonstrate that non-mercury alternatives that meet these criteria do not exist. NEMA's letter fails to meet this obligation; therefore, we are urging the Department to exercise its authority to prohibit the sale of all general-purpose fluorescent lamps, including linear fluorescent and pin-based models unless NEMA or manufacturers can demonstrate that no alternative non-mercury energy efficient lamp is available that provides the same or better overall performance at a cost equal to or better than the classes of lamps that the manufacturer proposes to sell.

Thank you for taking the time to review this submission. Please do not hesitate to get back to us if you have any questions or require further information on any of the points we have raised.

Sincerely yours,

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Executive Director, Vermont Public Interest Research Group

Michael Bender
Executive Director, Mercury Policy Project

Alicia Culver
Executive Director, Responsible Purchasing Network

Brian Fadie
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Senior Manager, CLASP
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Attachment A. Review of Mercury-Free Lighting Alternatives in the State of Vermont

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1 Affordability: Are mercury-free alternatives less costly than fluorescent lamps?

Yes, light-emitting diode (LED) "plug & play" retrofit lamps, which can be inserted directly into existing fluorescent fixtures, are *less costly* than fluorescent lamps operated in those same fixtures. In this section, we discuss how NEMA's letter does not tell the full story of "cost" to consumers and businesses in Vermont. Furthermore, we present our market analysis and cost comparison based on what end-users truly pay to illuminate their homes, institutions and businesses in the State.

1.1 Inadequacy of NEMA's fluorescent lamp pricing analysis

Table 1 presents the prices that NEMA gathered from Grainger.com for 4-foot T8 LFLs and a few replacement linear plug & play (*i.e.*, Type A) LED lamps. It appears that NEMA did not survey all 4-foot T8 products listed on Grainger.com, nor did they consider pricing from any other retailers;- instead they simply asserted that these prices are "indicative of the typical cost differential" for comparable LED and LFL products.

Table 1. NEMA's price assessment of 4-foot linear T8 lamps in their letter dated November 16, 2021

Plug & Play LED General Purpose Linear Light Bulbs (4 ft)

Bulb Shape	Wattage Equiv	Watts	Color Temp.	Lumens	Price
T8	32W LFL	15 W	3,000 K	2,000 lm	$12.56 / each
T8	32W LFL	15 W	3,500 K	2,000 lm	$13.04 / each
T8	32W LFL	15 W	4,000 K	2,100 lm	$12.70 / each

Fluorescent General Purpose Linear Light Bulbs (4 ft)

Bulb Shape	Wattage Equiv	Watts	Color Temp.	Lumens	Price
T8	32W LFL	32 W	3,000 K	2,900 lm	$1.82 / each
T8	32W LFL	32 W	3,500 K	2,915 lm	$6.72 / each
T8	32W LFL	32 W	4,100 K	2,915 lm	$7.14 / each

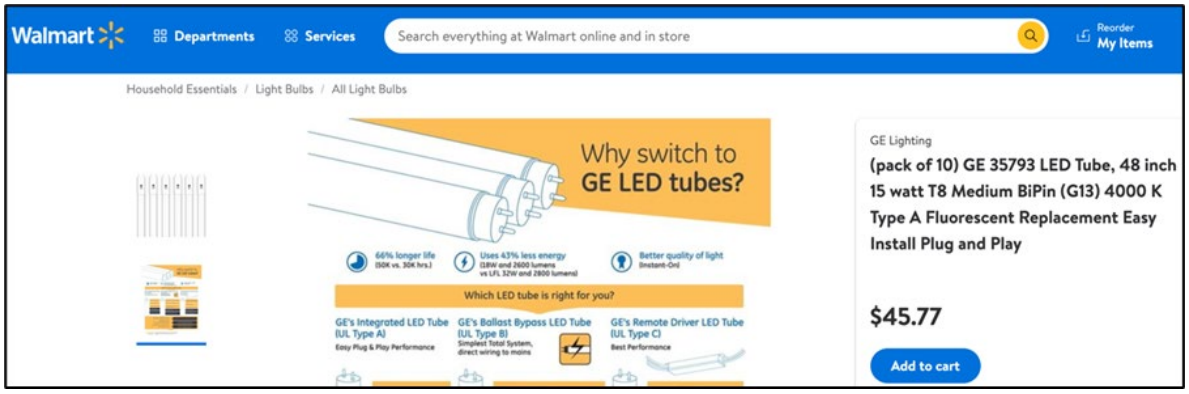
We conducted searches on the websites of retailers that operate in Vermont and were able to identify several 4-foot T8 Plug and Play LED lamps with similar wattages, lumen outputs, and color that had substantially lower prices than those presented by NEMA. In some cases, the prices were found to be lower than the LFL prices NEMA presented in the table above. (Note: While we did not find LED T8 lamps below NEMA's lowest price of $1.82, we determined that $1.82 is not a representative price since all fluorescent T8 lamps listed on the Grainger website under $2 were labeled as clearance items (in red font) for a less well-known brand, Lumapro. See screenshot of Grainger website below from 12/13/2021.

Table 2. Screen Shot of Grainger Website, 4ft T8 32 Watt Linear Fluorescents, December 13, 2021

T8	32W LFL	32 W	5,000 K	2,745 lm	GE CURRENT	2ETV9	$4.55 / each
T8	32W LFL	32 W	3,500 K	2,915 lm	GE CURRENT	3CA62	$7.16 / each
T8	32W LFL	32 W	4,100 K	2,915 lm	GE CURRENT	3CA64	$7.14 / each
T8	32W LFL	32 W	6,500 K	2,725 lm	GE CURRENT	3JJ79	$4.77 / each
T8	32W LFL	32 W	5,000 K	2,950 lm	GE CURRENT	3VK11	$4.59 / each
T8	28W LFL	28 W	6,500 K	2,440 lm	GE CURRENT	40D429	$8.77 / each
T8	32W LFL	32 W	5,000 K	1,600 lm	GE CURRENT	46T405	$6.40 / each
T8	32W LFL	32 W	7,500 K	1,600 lm	GE CURRENT	46T406	$7.20 / each
T8	32W LFL	32 W	3,000 K	2,900 lm	LUMAPRO	48GP54	$1.12 / each
T8	32W LFL	32 W	3,500 K	3,000 lm	LUMAPRO	48GP55	$1.12 / each
T8	32W LFL	32 W	5,000 K	2,900 lm	LUMAPRO	48GP57	$1.12 / each
T8	32W LFL	32 W	6,500 K	2,900 lm	LUMAPRO	48GP58	$1.45 / each

Below, we offer several examples of 4-foot T8 LED lamps from General Electric (GE), a popular brand of LEDs that is featured on the Grainger.com website, and other quality[1] brands from suppliers actively doing business in Vermont:

- Walmart sells GE 15W Plug & Play 4000K LED Linear T8s $4.58/bulb (for a 10-pack), which is much lower than the price ($12.70) that NEMA listed for an equivalent LED lamp on Grainger.com. See screenshot below:



  Walmart also sells a 25-pack of GE 12W Plug & Play LED T8s for $75.99 – or about $3.00/lamp. These DesignLights Consortium (DLC)-listed 4000K LED T8 lamps have an extra long 70,000-hour rated lifetime. (Note: Since, as NEMA mentioned, LFLs are largely purchased by businesses, many LFLs are offered in boxes with 10-25 lamps, which makes these products available at a much lower price than single-lamp boxes.)

- Home Depot offers DLC-listed 4-foot Plug & Play LED T8s (from a company called Simply Conserve) for approximately $5.65/lamp (for a box of 25 17W/2200-lumen 4100K lamps).

[1] This qualifier refers to the fact that all of the lamps in our analysis are listed in the DesignLights Consortium's (DLC) Qualified Product List (QPL). The DLC is a non-profit organization that "collaborate[s] with utilities, energy efficiency programs, manufacturers, lighting designers, building owners, and government entities to create rigorous criteria for lighting performance that keeps up with the pace of technology." It maintains the largest database of LED products in North America that is widely referenced by utilities in their rebate programs. The DLC QPL has set minimum performance specifications that products must meet in order to be listed.

- Northeast Electrical, which has a distribution facility outside of Burlington, VT, sells Sylvania's 17W/2200-lumen 4100K 4-foot SubstiTUBE Value Plug & Play LED T8s for $6.31/lamp. SubstiTUBE LED T8 lamps are available in other color temperatures (e.g., 3000K, 3500K and 5000K).

- Office Depot sells Maxlite's 12W/1800-lumen 4-foot Plug & Play 3500K LED T8s for $6.80/lamp. These lamps are also available in 4000K and 5000K color temperatures.

- Superior Lighting sells its DLC-listed 4100K 15W/2000-lumen 4-foot Plug & Play LED T8 for $3.95/lamp (currently on sale for $2.58/lamp). It also sells equivalent lamps in 3000K, 3500K and 5000K color temperatures for $7.95/lamp.

All the products listed above are on the DLC's Qualified Products List (QPL). We have also identified many other non-DLC-listed residential-grade Plug & Play LED 4-foot T8 lamps with an equal or lower price than the 4-foot fluorescent T8 lamps listed by NEMA. This includes well-known brands such as GE, Philips, Feit Electric and TCP as well as other less-well-known brands. Some of these LED T8s have prices as low as $3.00/lamp.

The figure below plots the three linear fluorescent lamp prices and the three LED lamp prices from NEMA along with the eight LED lamp prices that were gathered by the Responsible Purchasing Network (RPN). The X-axis in this figure represents the listed retail price of one lamp in US dollars (2021).

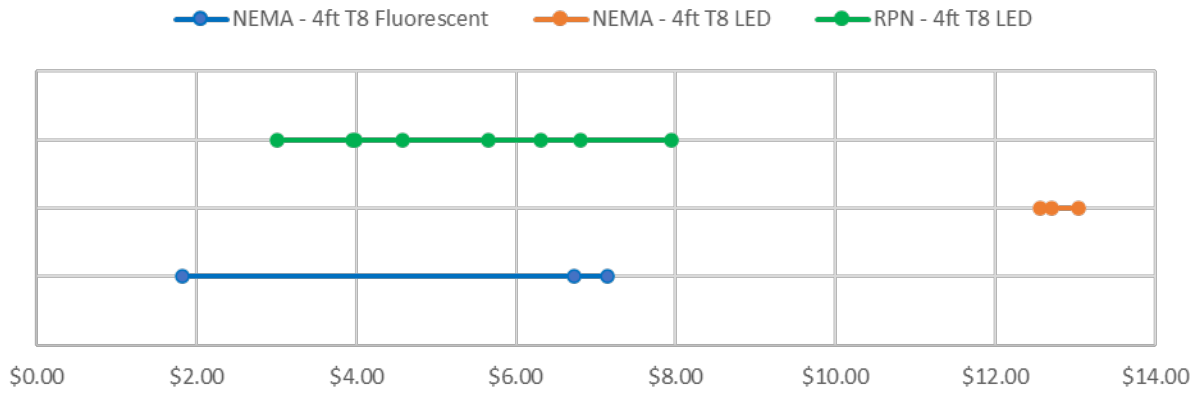


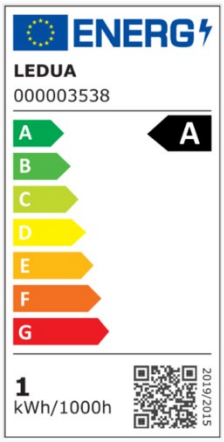
Figure 1. NEMA and RPN Prices Observed for 4-foot T8 Lamps, Fluorescent and LED Retrofits

1.2 "Price" is not the same as "cost"

Vermont 10 V.S.A. §7152 (a)(6) requires that manufacturers of mercury-containing lamps shall not sell, offer for sale, or deliver to a retailer for subsequent sale, a mercury-containing lamp unless:

> *"(6) The manufacturer has demonstrated that no alternative non-mercury energy efficient lamp is available that provides the same or better overall performance at a cost equal to or better than the classes of lamps that the manufacturer proposes to sell."*

As discussed earlier, how the Department interprets the phrase "at a cost equal to or better than" will play a pivotal role in the outcome and the impact of this law. In their submission, NEMA appears to be conflating the term "cost" with "price". They provide a few prices (presented above in section 1.1) for fluorescent and LED 4-foot T8 tubes and conclude that the cost test has been met because they identified some LED replacement lamp prices that were higher than some fluorescent lamp prices. And while our discussion in section 1.1 of this Attachment challenges that finding using LED 4-foot T8 prices from several different retailers operating in Vermont today, we also submit for the Department's consideration that cost and price are not the same thing – particularly for lighting products because no one buys a light bulb simply to own it. Rather, a light bulb is purchased to be installed in a socket and used. Thus, the energy the light bulb uses is part of the "cost" that a consumer has to bear.



Recognizing the fact that running cost is intrinsic to the lamp is precisely the reason that some governments around the world have developed and promulgated energy labelling schemes for lighting products, like the US EPA's Energy Star or the European A to G label. This informs the consumer at the time of purchase whether a particular model is energy-efficient or not, enabling them to make an informed choice about the cost they would be incurring if they choose a particular model. Thus, in our view, because the energy consumed by the light bulb is an intrinsic and inseparable part of the product's "cost" to the user, it is reasonable to interpret the term "cost" in the statute to include both the price paid for the light bulb and the electricity cost.

Furthermore, we note that economists often use the phrase "*first* cost" as a synonym for "price" when discussing a product. However, in 10 V.S.A. §7152 (a)(6), the statute doesn't use the phrase "first cost", rather it simply says "cost" which may indicate a broader interpretation of the cost burden on consumers. If, for example, the legislative drafters had only been concerned with a price comparison of equivalent products, they probably would have written paragraph (a)(6) using the term "price". Instead, by choosing the term "cost", lawmakers may have been allowing for consideration of the true cost of light to Vermonters – i.e., both purchase price and running cost. If 10 V.S.A. §7152 (a)(6) is interpreted in this way, LED technology has already achieved lower cost than fluorescent in virtually all general-purpose lighting applications.

And, with this submission, we demonstrate this fact for 4 ft. T8 LED retrofit tubes. In addition, in section 1.3 below, we also offer some preliminary cost comparison data for 4-foot T5 lamps as well as other lengths of T8 and T12 lamps, and pin-based non-integrally ballasted compact fluorescent lamps

(CFLni). We intend to provide additional research to the Department on these other lamp categories in the coming weeks.

1.3 Mercury-free alternatives are less costly than fluorescent lamps

In this section, we provide a preliminary review of the cost of a range of other popular fluorescent lamp types. In all cases, we found that mercury-free LED retrofit lamps truly represent the lowest cost lighting option in Vermont. In the coming weeks, we will expand this analysis, including collecting more data from retailers, checking models against the DLC QPL database, and conducting additional calculations. However, in the interest of having a timely submission that clearly identifies opportunities for simultaneously saving money and eliminating mercury, we wanted to make the Department aware that LED lamps are available at costs not only equal to – but better than – their mercury-containing fluorescent counterparts for many different shapes and sizes. Indeed, in cases where is a higher initial price for LEDs, the payback periods are often less than one year – please see the table below.

Table 3. Average cost savings and payback periods for drop-in LED retrofit lamps

LED Lamp Type	Sector	Incremental LED Price Compared to Fluorescent (2021$)	Annual Electricity Savings (2021$)	Lifecycle Cost Savings (2021$)	Payback Period (years)
4-foot T12- 40 W	Residential	$2.91	$2.73	$25.45	1.1
	Commercial	$2.91	$13.69	$67.19	0.2
4-foot T12- 34 W	Commercial	$4.09	$9.95	$55.42	0.4
4-foot T8	Residential	$3.31	$1.78	$15.41	1.9
	Commercial	$3.31	$6.01	$35.05	0.6
	Industrial	$3.31	$5.04	$19.13	0.7
4-foot T5	Residential	$4.51	$2.61	$22.93	1.7
	Commercial	$4.51	$7.92	$51.94	0.6
4-foot T5 high output	Commercial	$10.69	$16.46	$106.83	0.6
	Industrial	$10.69	$12.69	$57.83	0.8
8-foot T12	Commercial	$12.77	$23.26	$59.96	0.5
	Industrial	$12.77	$17.15	$28.58	0.7
8-foot T8	Commercial	$13.03	$10.49	$52.02	1.2
	Industrial	$13.03	$8.37	$24.97	1.6
Pin-based LED	Commercial	$3.02	$10.36	$27.38	0.3

Note: This table represents some initial estimates for other popular fluorescent lamp sizes and wattages, considered across different sectors. Electricity prices used are for Vermont, and prices are conservative. When totalling the life-cycle cost savings, the discount rate used was 5%. Source: ASAP, 2021.

2 Availability: Are mercury-free alternatives to fluorescent lamps widely available?

Yes, LED retrofit lamps available on the market today span a broad range of shapes, sizes and base types, levels of light output, compatibility with different types of ballasts, and a wide range of light colors (e.g., cool white and warm white) and functionalities (e.g., dimmability, shatter-proof construction, color-changing ability, etc.). In this section, we show how LED lamps are designed to have the same fit and function as fluorescent lamps, enabling them to be inserted directly into existing fluorescent fixtures. We also provide a table and link to the largest database of LED lighting products in North America, maintained by the DesignLights Consortium (DLC), which lists over 30,000 LED retrofit lighting products offered for sale in the US that can directly replace the most commonly used fluorescent lamps.

2.1 Illustration of LED retrofits for mercury-containing fluorescent lamps

For visualization purposes, Figure 1 below illustrates the most common types of mercury-containing lighting products regulated under 10 V.S.A. § 7152 and the available mercury-free alternatives that can now replace them.

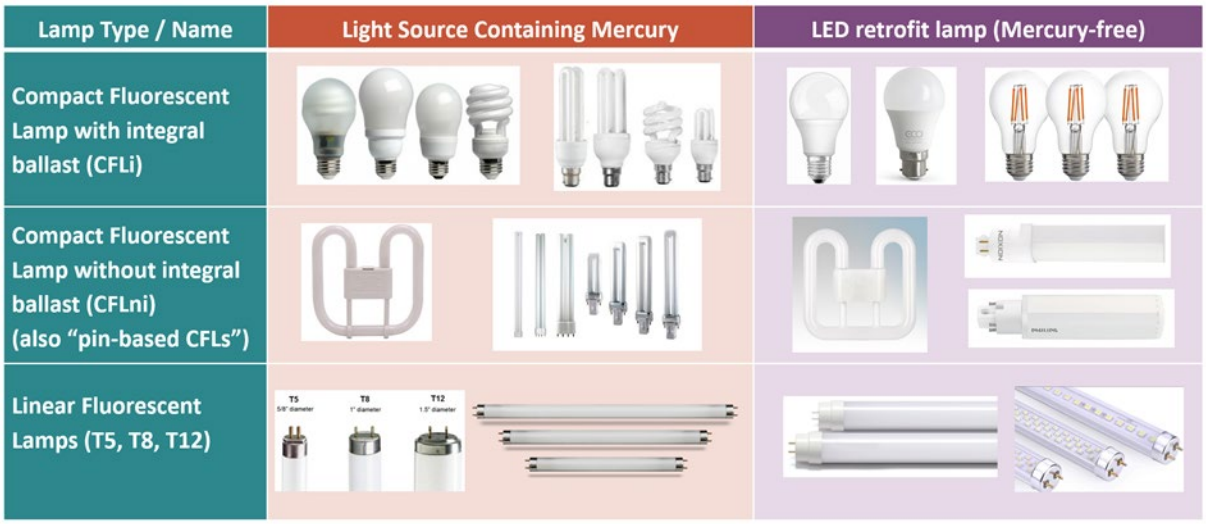


Figure 2. Graphic Illustrating Mercury-containing Fluorescent Lamps and Available LED Alternatives

2.2 DesignLights Consortium's database of available commercial LED retrofits for fluorescent lamps

An important source of information documenting the significant number of high-performance mercury-free LED lamps available for sale in the United States today[2] is the DLC's Qualified Product List (QPL), which currently includes over 30,000 models of LED lamps that can replace most types of fluorescent lamps. Table 1 below displays the number of LED retrofits for common fluorescent lamp types found in the DLC QPL database as of December 2021.

[2] The DesignLights Consortium (DLC) maintains a qualified products list database that lists thousands of LED lamps and luminaires offered on the market in North America. Website: https://qpl.designlights.org/solid-state-lighting

Table 4. LED Availability for Select Common Fluorescent Lamp Types in DLC Database

LED Retrofit Lamp Type	Number of Models in DLC QPL Database[3]
4-foot T5 Linear Lamps	1,616
4-foot T5 High Output Linear Lamps	1,073
2-foot T8 Linear Lamps	3,798
3-foot T8 Linear Lamps	1,041
4-foot T8 Linear Lamps	21,852
8-foot T8 Linear Lamps	983
U-Bend T8 Lamps	1,035
4-pin Compact Fluorescent Lamps	811

We encourage the DEC to explore the DLC database as one convenient source documenting the wide availability of LED retrofits. However, it must be noted while the database is the largest list of verified high-performance LED products in the U.S., it is not an exhaustive list of LED products available in the US market. In order to be listed in the DLC QPL database, a product must meet certain minimum performance requirements, which inevitably not every LED product meets, and the manufacturer must pay a fee for each product listed.

Consequently, there are other LED products available in the US marketplace that are not listed in the DLC database, and the database should be considered one conservative tool for determining availability of good quality LEDs in covered categories. For example, the DLC database does not include LED replacements for 2-pin CFLs, T12 fluorescent lamps, or certain 4-pin CFL base types. In addition, since the DLC QPL is targeting the professional segment of the market, it tends to include commercial-grade LED lamps. Our market research has shown there are a significant number of residential-grade LED linear T8, T5 and T12 lamps as well as pin-based compact lamps available in the market that are not listed in the DLC QPL. One example of a residential product is this 4 ft T8 LED retrofit lamp from Philips Lighting, which has a rated life of 35,000 hours compared to their professional grade model, which is 50,000-hour lamp. Residential-grade LED lamps offer improved efficiency, lamp life and other performance attributes over residential-grade fluorescent lamps.

[3] DLC qualified products list database accessed on December 9, 2021.

3 Acceptance: Do mercury-free LED replacement lamps pass the performance test?

Yes, LED retrofit lamps offer consumers and businesses better quality lighting products that last longer, use less energy, and produce equal or better-quality light than the mercury-containing fluorescent lamps they are designed to replace. 10 V.S.A. § 7152 (a)(6) requires that a non-mercury alternative "provides the same or better overall performance" as mercury-containing lamps. In section 2, we noted that thousands of different models of T8 and T5 linear LED lamps as well as 4-pin compact LED lamps are on the DesignLights Consortium (DLC) Qualified Products List. This list is used by utilities across the US because it includes high-performing LED lamps that meet DLC's rigorous performance requirements (e.g., minimum lumen output and efficacy requirements for each category of LED lamps that it covers).

3.1 Manufacturer's websites advertise equal or better performance than fluorescent lamps

We found that lamp manufacturers, many of whom are NEMA members, often make statements on their websites touting the ability of LEDs to offer equal or better performance than the fluorescent lamps they are designed to replace while also lasting significantly longer. The table below provides some examples of these public-facing statements by lamp manufacturers.

Table 5. Lamp Manufacturer Statements on LED Lamp Performance

Lamp	Product	Manufacturer Statements
T5	Sylvania SubstiTUBE LED T5HO	"SYLVANIA SubstiTUBE LED T5HO lamps are an energy saving alternative, designed to replace traditional fluorescent T5HO lamps. These LED T5HO lamps mimic the look of traditional fluorescent T5 HO lamps, contain no mercury and provide a uniform light distribution with an optimized glass optic design."
T8	Philips MASTER Value LEDtube Universal T8	"And thanks to a high degree of efficiency and long service life, the MASTER Value LEDtube Universal T8 is the ideal alternative to standard fluorescent tubes for all demanding lighting applications. Up to 65% more energy efficient than conventional TL-D (fluorescent) lamps. Up to 3× longer lasting performance than conventional TL-D (fluorescent) lighting tubes."
T12	Feit Electric T12 Plug and Play	"These T12 lamps produce 1800 lumens of 4100K Cool White light while using only 20 watts - up to 50% less energy than a standard fluorescent lamp. Each shatterproof lamp is rated for 35,000 hours / 32 years service life, is RoHS compliant and 100% mercury free. Choose a dependable flicker-free bulb for residential or commercial applications. Installation is simple: No replacement of the ballast or installation of LED driver or removal of old ballast required."

Lamp	Product	Manufacturer Statements
CFL Pin-Based	Sylvania LED Pin-Based Lamps	"Long life of 50,000 hours, lasting up to three times as long as the lamps they replace, minimizes maintenance costs over the life of the lamp. 5-year warranty for worry-free installations. Over temperature protection ensures that lamps will not overheat. Available in 2700K-4100K providing choices to harmonize colors with other technologies in the same application space."

To further illustrate the ability of LEDs to perform the same or better as fluorescent lamps, below is information on four potential performance criteria: light output, efficacy, light quality, and product rated life.

3.2 Linear Lamps (e. g., T5, T8, and T12): Fluorescent vs LED

3.2.1 Light output and efficacy

Today's linear LED lamps (e.g., T5s, T8s, and T12s) offer comparable illumination when installed in a fluorescent fixture while typically using approximately half of the energy (i.e. watts) consumed by linear fluorescent lamps. LEDs are directional light sources, capable of delivering more of the light emitted from the lamp to the room or targeted area. In contrast, fluorescent lamps are diffuse light sources that require optical components in the light fixture to direct light out of fixture. This inefficiency reduces the amount of light emitted from the fluorescent lamp that is delivered to the targeted area. This difference in directionality enables LEDs to deliver the same amount of *useful* light with fewer lumens in many applications. This is one reason a fluorescent lamp that emits 2900 lumens provides the same illumination in a room as a designated equivalent retrofit LED tube that emits 2200 lumens.

An indication of the reason for this equivalency has been demonstrated in Europe by the Swedish Energy Agency. In Sweden, laboratory experts measured the lumen intensity distribution (LID) of a fluorescent luminaire when operating with a 4 ft T8 fluorescent lamp and then operating with two different 4 ft T8 retrofit LED lamps (in the same fixture). The LID graphs are shown below with the fluorescent lamp on the left and two LED retrofits in the middle and on the right. As you can see in the figure, the intensity of the light emitted from the fixture (i.e., the luminous intensity distribution) is virtually identical in all three images. This explains why the market is satisfied with the performance of LED retrofit tubes – even though they emit less light at the tube, the light emitted from the fixtures is the same, and thus the illumination in the home or office is the same.

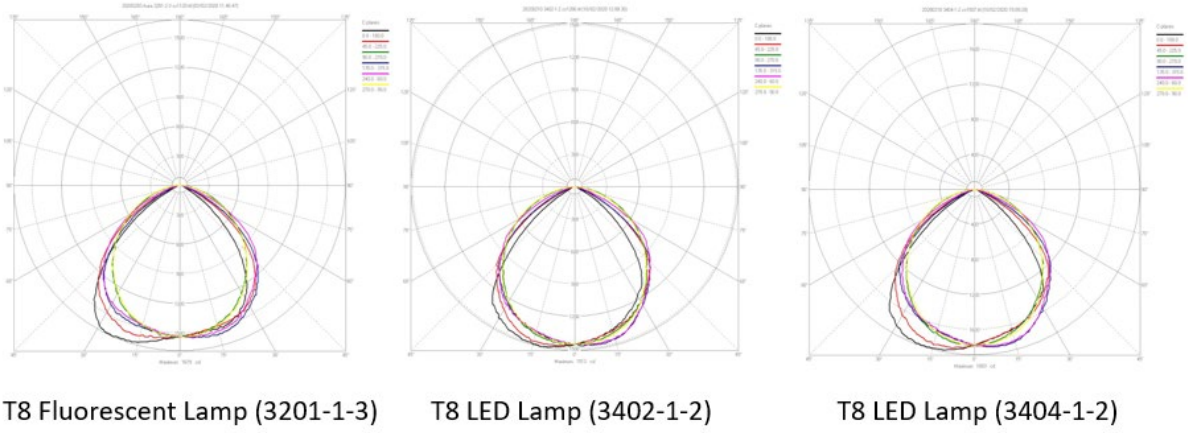


Figure 3. Luminous Intensity Distribution (LID) plots for a fluorescent lamp (left) and two LED lamps (middle, right) operating in the same fluorescent fixture

The Swedish Energy Agency surveyed stakeholders who have replaced fluorescent lamps and reported that, "Experiences from real installations prove the existing alternatives, including retrofit LED tubes….to be clearly satisfying or superior both from a technical (lifetime, maintenance, etc.) and lighting (light distribution, glare, color temperature, safety, comfort, esthetical, etc.) point of view. Even when it comes to the LCC, existing alternatives are many times already attractive."[4] Finally, for those few installations where a full emission pattern (360 degrees) is needed, manufacturers have produced LED tubes that offer a full emission pattern. Example 1. Example 2. Example 3.

The figure below compares the efficacies for fluorescent and LED lamps. An LED uses approximately half the power when operating; in other words, its efficacy is typically double that of the fluorescent lamp it is replacing. And, due to the directional nature of LED lamps, optical losses in the fixture can be reduced, so LED lamps can achieve equivalent illumination out of a fixture with fewer lumens emitted by the lamp. In November 2021, the DesignLights Consortium (DLC) adopted an updated standard (V5.1) requiring all LED tube lamps covered under its standard (i.e., linear and u-shaped T8s and T5s) to have an efficacy of at least 120 lumens/watt.

[4] Source: https://www.clasp.ngo/updates/report-shows-market-readiness-to-eliminate-mercury-based-lighting/

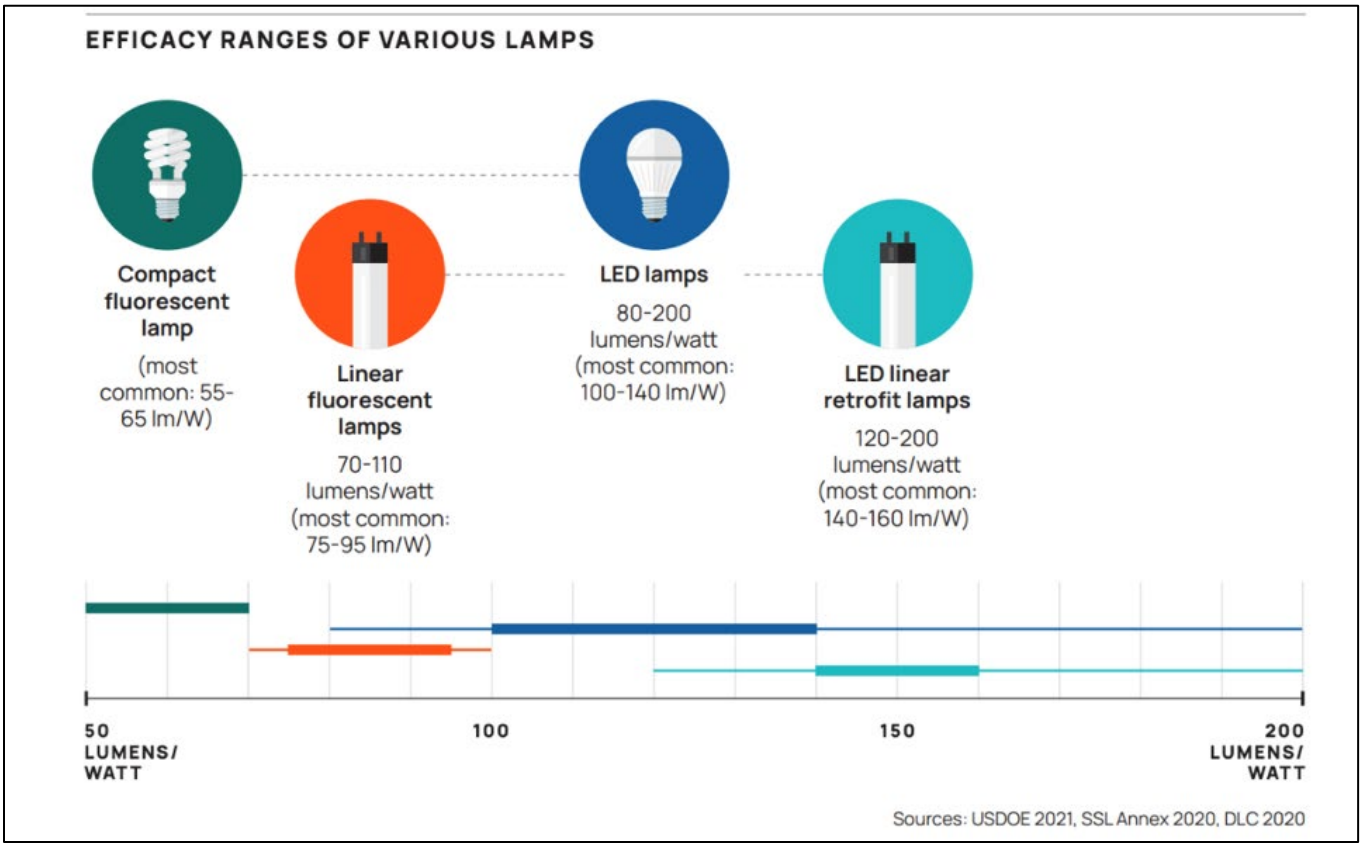


Figure 4. Typical Efficacies of Fluorescent Lamps and LED Retrofit Lamps for the Same Applications

3.2.2 Light Quality

Light color and the ability of a lamp to accurately render color of the surfaces lit are two key characteristics of light quality, referred to as Correlated Color Temperature (CCT) and Color Rendering Index (CRI), respectively.

CCT is a measure of the color 'shade' of white light emitted by a lamp, relating to the color of light emitted, expressed in degrees Kelvin (K). Spectrally, "warm white" shades contain more yellowish/red light content and have at lower temperature, typically around 2700K to 3500K. "Neutral white" shades are around 4000K to 5000K, and "cool white" shades is generally considered to be 5500K or higher. Please see the figure below for an illustration of the light colors and the respective CCT values.

Figure 5. Picture of different CCT Light Colors and their Corresponding CCT value in Kelvin

Our research has shown that for general purpose lighting, where the CCT values are between 3000 and 6500K, there are a wide range of LED tubes available. LEDs are able to produce light in all the same colors that fluorescent lamps can produce.

Table 6. Comparison of Common CCT Ranges for Fluorescent and LED Tubes

Manufacturer	# of Models	CCT Value	Link
Philips/Signify T8 LED lamps	111 products	3000 to 5000K	Link
Philips/Signify, T5 LED lamps	27 products	3000K to 5000K	Link
GE (Currents by GE), T8 and T5 LED Plug & Play Lamps	96 products	3000K to 6500K	Link
Sylvania/LEDvance, T8 LED lamps	74 products	3000 to 6500K	Link
Sylvania/LEDvance, T5 LED lamps	54 products	3000 to 6500K	Link

Color rendering index (CRI) is a measurement of how accurately a light source illuminates the color of objects in the lit space, reported on a scale of 0 to 100. For general purpose lighting, mid-range CRIs are commonly used. The typical CRI for linear fluorescent lamps (including, for example, T8s, T5s and T12s) is 80 to 85, with most reporting a nominal CRI value of 82. Older models sometimes have a CRI in the 70s.

Lamps with a CRI greater than 87 are classified as high-CRI lamps. High-CRI lamps are used largely in applications where it is important to reveal the true color of objects or individuals in the room such as cinematography, museums, retail display of produce, art and jewelry, and neonatal care. Most high-CRI linear fluorescents report CRI of 95 or less, and are used primarily in the types of special-purpose applications described above.

Like fluorescents, many LED replacement lamps have CRIs ranging from 80 to 90. LEDs on the DLC QPL are required to have a CRI of at least 80 and this performance measure is backed up with rigorous testing requirements.

However, we did identify some very high CRI LED products which may be needed for a special application such as a in a television studio or other application where vivid colors are important:

- 90 CRI: TCP 12W Dimmable 48" 5000K 90 CRI Glass T8 LED Bulb, Ballast Compatible
- 90 CRI: Sylvania Lamps, SubstiTUBE® IPS Natural™ LED T8
- 97 CRI: TCP LT818AQ40KBP Q-SOL Type A LED T8 20W

LED retrofit lamps available in the marketplace can match all the same CRI values that are achieved by fluorescent tubes. The CRI value of the LED tubes is just a function of the LEDs that are selected by the product designer, choosing LEDs or a combination of LEDs that have a high CRI or a very high CRI. Thus, we conclude that there are no technical or product availability barriers to LEDs meeting the equal or higher CRI performance levels of linear fluorescent lamps.

3.2.3 Product Life

LED lighting is distinguished from fluorescent light sources by much longer lifetimes. Longer-lived products can provide additional replacement and maintenance (i.e., labor) cost savings, which is especially helpful in hard-to-reach locations. All products on the DLC QPL must meet a minimum lifetime requirement of 50,000 hours and a minimum warranty period of 5 years. The QPL does not include lifetime data for all listed LED products; however, most products with lifetime data report 50,000 hours. If a 50,000 hour lamp is operated for 10 hours per day, this corresponds to over 13 years of lighting service.

Our research has determined that from a product lifetime perspective, T5 LED Plug & Play replacements for fluorescent T5 lamps are reliable substitutes. For example, in the table below, we compare the product lifetimes of a T5 fluorescent lamps, which has a rated life of 30,000 hours, with the lifetimes of an equivalent LED T5 lamps (UL Type A models), which has have a rated life of 50,000 hours. The LED T5s last about 70% longer than the fluorescent T5 lamps they are designed to replace. The warranties offered on these products also reflect the differences in their rated life – 3 years for the fluorescent T5s and 5 years for the LED T5s.

Table 7. Rated Life and Warranty Comparisons for T5 Linear Fluorescent Lamp

T5 Fluorescent Lamp			T5 LED Direct Retrofit		
	Sylvania 20901 – FP28/835/ECO Pentron T5, 46 inches, 28 Watts, 2650 lumens, 3500K[5]	30,000 hours; 3-year warranty		Sylvania/LEDVance 40108 – LED13T5HE/L48/FG /835/SUB SubstiTUBE T5, 46 inches, 13 Watts, 2000 lumens, 3500K, DLC listed[6]	50,000 hours 5-Year warranty

[5] https://www.ledvanceus.com/products/fluorescent/Pages/PENTRON-T5-and-T5HO-Lamps.aspx
[6] https://assets2.ledvanceus.com/media/bin/asset-3506253

From both a rated lifetime and a warranty perspective, our research has found that the T8 LED plug-and-play retrofits for fluorescent T8 lamps are reliable substitutes for fluorescent lamps – they last longer and they have longer warranties. For example, in the table below, we compare the product lifetimes of a 32-watt 4-foot T8 fluorescent lamps from Philips Lighting (a high-lumen model with a have a rated life of 24,000 hours with an equivalent LED T8 lamp (UL Type A model), which has a rated life of 70,000 hours. In this example, the LED lamp lasts over twice as long as the long-life fluorescent T8 and nearly three times as long as the standard-life (high-lumen) fluorescent T8. Similarly, the warranty for the LED T8 is twice as long as the warranty for the long-life T8 and nearly three times as long as the warranty for the standard-life fluorescent T8.

Table 8. Rated Life and Warranty Comparisons for T8 Linear Fluorescent Lamp

T8 Fluorescent Lamp			**T8 LED Direct Retrofit**		
	HIGH-LUMEN MODEL: Philips 280859 – F32T8 ADV841 ALTO – Advantage T8, 4-foot, 32 watts, 3100 lumens, 4100K [7]	24,000 hours, 2.5-year warranty		Philips/Signify 545194 – 15.5T8/MAS/48-840/IF25P/DIM – 4 foot, 15.5 Watts, 2500 lumens, 4100K[8]	70,000 hours, 7-year warranty

[7] https://www.usa.lighting.philips.com/api/assets/v1/file/PhilipsLighting/content/fp927869784203-pss-en_us/927869784203_NA.en_US.PROF.FP.pdf

[8] https://www.usa.lighting.philips.com/prof/led-lamps-and-tubes/led-tubes/t8/929002016404_NA/product