

**L I G H T I N G**

T Y P E B A N D T Y P E C L E D , T U B E

SWLG018-01

C O N T E N T S

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# MEASURE NAME

TYPE B AND TYPE C LED, Tube

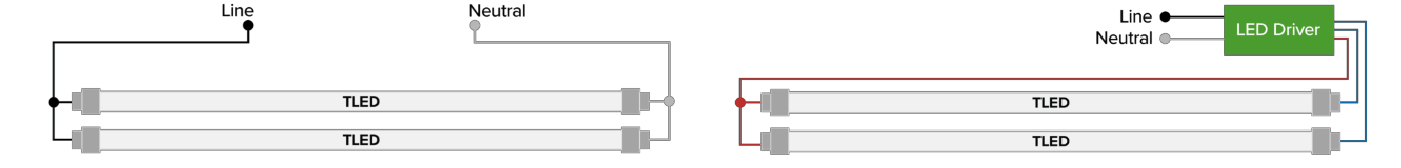
# STATEWIDE MEASURE ID

SWLG018-01

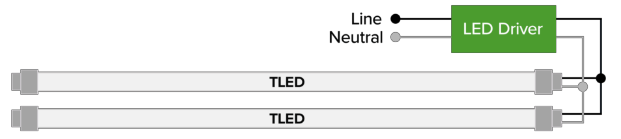
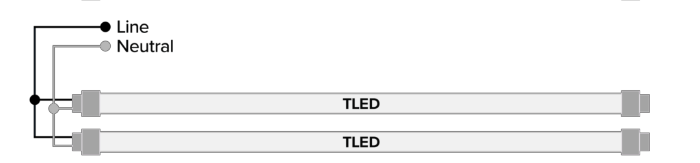
# TECHNOLOGY SUMMARY

Design Lights Consortium (DLC) defines UL Type B lamps, also known as Internal-driver/Line Voltage lamps, as LED “tubes” that “employ lamp holders to connect to the fixture being retrofitted, but do not operate utilizing the existing fluorescent ballast. Thus, they require rewiring the existing fixture to bypass the ballast and send line voltage directly to the lamp holders.”

Similarly, DLC defines UL Type C lamps, also known as External-driver Lamps, as LED “tubes”, that “employ lamp holders to connect to the fixture being retrofitted, do not operate utilizing the existing fluorescent ballast, and require rewiring of the existing fixture to replace the ballast with an external driver. The lamp holders are then wired to receive only the low-voltage electricity that is supplied by that external driver.” The following figures illustrate the UL Type B and C configurations.



*Double-Ended Type B LED Tube Double-Ended Type C LED Tube*



*Single-Ended Type B LED Tube Single-Ended Type C LED Tube*

Type B and C TLED lamps can have single or double-ended configurations and require one or two powered lamp-holders, respectively. Double ended lamps only draw current if both ends of the lamp are plugged in and can be preferred over single-ended ones due to enhanced safety. Some Type B lamps and Type C systems can also be dimmed using dimming technologies such as 0-10V signals and phase cut dimmers.

Retrofit costs can be higher for Type B LEDs and Type C LEDs, compared to maintaining fluorescent linear lamps or retrofitting with Type A LEDs due to increased material and labor costs, as well as potential requirements for new non-shunted lamp holders, in-line fuse kits, or external drivers. However, Type B and C lamps have many benefits due to the removal of the fluorescent ballast, such as longer expected lifetimes, high system efficiencies, and reduced compatibility concerns.

Two U.S. Department of Energy (DOE) CALiPER studies related to LED tubes application and cost effectiveness provide context related to the quickly evolving improvement in LED lamps as well as the analysis related to applications where they are most cost effective.1

# MEASURE CASE DESCRIPTION

The measure case equipment will be high efficacy DLC compliant UL Type B lamps and UL Type C LED lamp and driver systems for specific building /space types. The proposed measure case efficacy is 160 LPW for both Type B and Type C measures. For the purpose of this workpaper, it is proposed that lamp and driver systems with different numbers of lamps be used for the Type C measures because of the impacts of the external LED driver on the measure cost. However, individual lamps will still be used for Type B measures as they do not require an external driver. DLC does not currently approve 1-lamp UL Type C lamp and driver systems, thus that measure is not included here.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Offering ID | Space Type | MAT | Existing Case | Measure Description |
| A | Non-Res | AR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| B | Parking Garages | AR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| C | Common Area | AR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| D | Dwelling Area | AR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| E | Non-Res | AR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| F | Parking Garages | AR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| G | Common Area | AR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| H | Dwelling Area | AR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| I | Non-Res | AR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| J | Parking Garages | AR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| K | Common Area | AR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| L | Dwelling Area | AR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| M | Non-Res | AR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |

1 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Application Summary Report 21: Linear (T8) LED Lamps.* Prepared by the Pacific Northwest National Laboratory (PNNL).

* 1. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.3: Cost-Effectiveness of Linear (T8) LED Lamps.* Prepared by the Pacific Northwest National Laboratory (PNNL).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | Parking Garages | AR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| O | Common Area | AR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| P | Dwelling Area | AR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| Q | Non-Res | NR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| R | Parking Garages | NR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| S | Common Area | NR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| T | Dwelling Area | NR | 4-foot Linear Fluorescent T8 | Efficient 4-foot UL Type B LED T8 Lamp |
| U | Non-Res | NR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| V | Parking Garages | NR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| W | Common Area | NR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| X | Dwelling Area | NR | Fixture with (2) 4-foot Linear Fluorescent T8 | Fixture with (2) Efficient 4-foot UL Type C LED T8 Lamp |
| Y | Non-Res | NR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| Z | Parking Garages | NR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| AA | Common Area | NR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| AB | Dwelling Area | NR | Fixture with (3) 4-foot Linear Fluorescent T8 | Fixture with (3) Efficient 4-foot UL Type C LED T8 Lamp |
| AC | Non-Res | NR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| AD | Parking Garages | NR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| AE | Common Area | NR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |
| AF | Dwelling Area | NR | Fixture with (4) 4-foot Linear Fluorescent T8 | Fixture with (4) Efficient 4-foot UL Type C LED T8 Lamp |

# BASE CASE DESCRIPTION

The existing case baseline is defined as a 4-foot linear fluorescent T8 lamp or fixtures with 2-lamp, 3- lamp, or 4-lamp fluorescent lamp and ballast systems. The base case was determined using the 2018-19

program application data and is considered an existing condition. The analysis of this measure utilizes the existing condition baseline (a 4-foot T8 Linear Fluorescent lamp) to calculate the baseline energy savings.2

The standard practice baseline will be the all LED standard practice baseline with a 133 LPW efficacy as required by Resolution E-50093.

# CODE REQUIREMENTS

State and federal standards that relate to this measure are noted below. *The information provided below is for informational purposes only.*

Applicable State and Federal Codes and Standards

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Date |
| CA Appliance Efficiency Regulations –  Title 20 (2019) | Section 1605 (j) and (k) | January 1, 2019 |
| CA Building Energy Efficiency Standards  – Title 24 (2019) | Section 130.1 Section 141.0(b) | January 1, 2020 |
| Federal Standards | 10 CFR 430.32(m) and (n) | July 14, 2012 |

Title 24 (2019)4

Since UL Type B and Type C measures involve removing and replacing both existing lamps and ballasts with unlike equipment, they are considered alterations. Based on factors such as the amount of luminaires retrofitted and size of building, these measures qualify as either “One-for-One Alterations” (§141.0(b)2Iiii)or “Entire Luminaire Alterations” (§141.0(b)2Ii) and (§141.0(b)2Iii).

Depending on which type of alteration it qualifies as, the comparison of the new LED power to either existing power or to Title 24 lighting power density (LPD) triggers some Title 24 controls requirements including: Multi-level control(§130.1(b))and automatic shutoff controls (§130.1(c)1-8).

Exemption from Code:

The following are exemptions from code for this measure:

* + - §141.09(b)2I Retrofitting <10% of luminaires in an enclosed space does not trigger code. However, verification of this exemption requires knowledge about the total number of luminaires in the space in question.
    - §141.09(b)2I Exemption 6. If the measure involves the retrofit of 50 or less luminaires per floor or tenant space, or in enclosed locations with only one luminaire then it does not trigger code.

2 Southern California Edison (SCE). 2020. “SWLG018-01 TLED Delta Watts Calculation.xlsx.” See “SCE Prog Data” tab.

3 California Public Utilities Commission (CPUC). 2019. *Resolution E-5009*. August 15. Page A-4.

4 California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24).* CEC-400-2018-020-CMF.

Requirements for all alterations:

Regardless of which type of alteration is triggered, the alteration of the system “shall not prevent the operation of existing, unaltered controls, and shall not alter controls to remove functions specified in Section 130.1 (Mandatory Indoor Lighting Controls).” Thus, any existing lighting controls types must remain functional after install.

One-for-One Alterations (§141.0(b)2Iiii):

This measure qualifies for One-for-One alteration if the building or tenant space (in multi-tenant buildings) is ≤5,000 sf and the new TLEDs reduce total luminaire power by 40% or more. These alterations are required to abide by:

* + - §130.1(c)1-8 Auto-Shut-off Control

Entire Luminaire Alterations (§141.0(b)2Ii) and (§141.0(b)2Iii):

This measure qualifies for the Entire Luminaire Alteration when ≥10% of luminaires in a space are retrofitted. Post retrofit controls requirements are determined based on the new system’s comparison to the allowable Lighting Power Density (LPD):

For spaces with ≤80% of allowable LPD the customer must abide by:

* + - §130.1(c)1-8 Auto-Shut-off Control

For spaces with >80% of allowable LPD the customer must abide by:

* + - §130.1(b) Multi-level control
    - §130.1(c)1-8 Auto-Shut-off Control
    - §130.1(d) Primary Daylight Control
    - §110.12(c) Demand Response

Section §141.0(b)2I

*Altered Indoor Lighting Systems. Alterations to indoor lighting systems that include 10% or more of the luminaires serving an enclosed space shall meet the requirements of i, ii, or iii below:*

1. *The alteration shall comply with the indoor lighting power requirements specified in Section 140.6 and the lighting control requirements specified in Table 141.0-F;*
2. *The alteration shall not exceed 80% of the indoor lighting power requirements specified in Section 140.6, and shall comply with the lighting control requirements specified in Table 141.0-F; or*
3. *The alteration shall be a one-for-one luminaire alteration within a building or tenant space of 5,000 square feet or less, the total wattage of the altered luminaires shall be at least 40% lower compared to their total pre-alteration wattage, and the alteration shall comply with the lighting control requirements specified in Table 141.0-F.*

*Alterations to indoor lighting systems shall not prevent the operation of existing, unaltered controls, and shall not alter controls to remove functions specified in Section 130.1.*

*Alterations to lighting wiring are considered alterations to the lighting system. Alterations to indoor lighting systems are not required to separate existing general, floor, wall, display, or ornamental lighting on shared circuits or controls. New or completely replaced lighting circuits shall comply with the control separation requirements of Section 130.1(a)4 and 130.1(c)1D.*

*EXCEPTION 1 to Section 141.0(b)2I. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3.*

*EXCEPTION 2 to Section 141.0(b)2I. Any enclosed space with only one luminaire.*

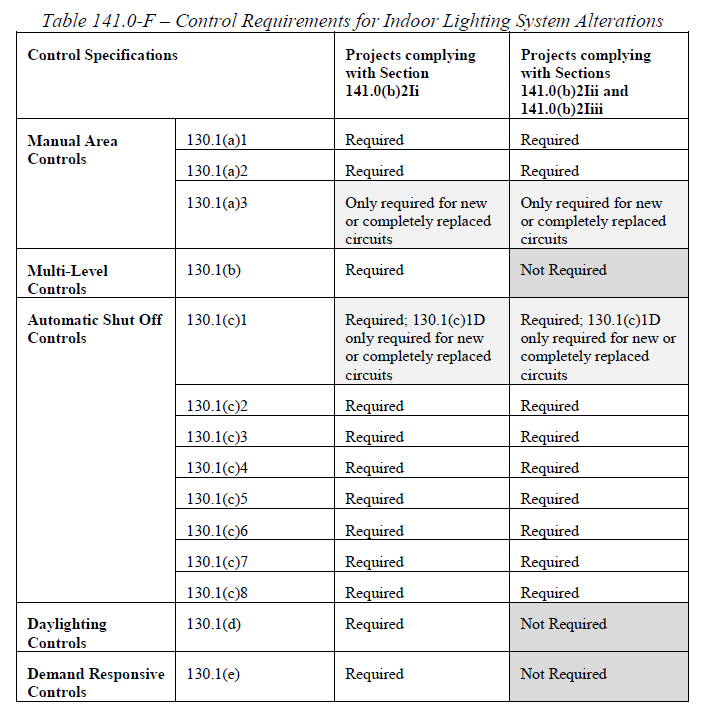
*EXCEPTION 3 to Section 141.0(b)2I. Any alteration that would directly cause the disturbance of asbestos, unless the alteration is made in conjunction with asbestos abatement.*

*EXCEPTION 4 to Section 141.0(b)2I. Acceptance testing requirements of Section 130.4 are not required for alterations where lighting controls are added to control 20 or fewer luminaires.*

*EXCEPTION 5 to Section 141.0(b)2I. Any alteration limited to adding lighting controls or replacing lamps, ballasts, or drivers.*

*EXCEPTION 6 to Section 141.0(b)2I. One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.*

Table 141.0-F – Control Requirements for Indoor Lighting System Alterations



Title 20 (2019)5 includes regulations to fluorescent lamp ballasts, replacement fluorescent lamp ballasts (§ 1605 (j)), and lamps ((§ 1605 (k)).

2012 Federal Standards for General Service Fluorescent Lamps6 issued by the U.S. Department of Energy (DOE) includes energy conservation standards that apply to various linear fluorescent lamp types.

5 California Energy Commission (CEC). 2019. *California Code of Regulations Title 20.*CEC-140-2019-002.

6 Code of Federal Regulations at 10 CFR 430.32(n) and (m).

# NORMALIZING UNIT

The normalizing unit for UL Type B offerings is per lamp. The normalizing unit for UL Type C offerings is per Fixture.

# PROGRAM REQUIREMENTS

*Measure Implementation Eligibility*

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

*Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.*

Implementation Eligibility

|  |  |  |
| --- | --- | --- |
| Measure Application Type | Delivery Type | Sector |
| Accelerated replacement | DnDeemDI | Com |
| Accelerated replacement | DnDeemed | Com |
| Accelerated replacement | DnDeemDI | Ag |
| Accelerated replacement | DnDeemed | Ag |
| Accelerated replacement | DnDeemDI | Ind |
| Accelerated replacement | DnDeemed | Ind |
| Accelerated replacement | DnDeemDI | Res |
| Accelerated replacement | DnDeemed | Res |
| Normal Replacement | DnDeemDI | Com |
| Normal Replacement | DnDeemed | Com |
| Normal Replacement | UpDeemed | Com |
| Normal Replacement | DnDeemDI | Ag |
| Normal Replacement | DnDeemed | Ag |
| Normal Replacement | UpDeemed | Ag |
| Normal Replacement | DnDeemDI | Ind |
| Normal Replacement | DnDeemed | Ind |
| Normal Replacement | UpDeemed | Ind |
| Normal Replacement | DnDeemDI | Res |
| Normal Replacement | DnDeemed | Res |
| Normal Replacement | UpDeemed | Res |

*Preponderance of Evidence Requirements (POE)*

All program administrators and third-party program implementers are required to collect data as stated in the Date Collection Requirements section that will satisfy POE requirements. The data collection requirements are intended to provide establish programmatic evidence and include questions about

existing system functionality, reasons for retrofitting to LED, and potential future plans without provided incentives.

Please note that per resolution E-4818, Accelerated Replacement (AR) and Normal Replacement (NR) measure impact types are allowed in downstream and direct Install (DI) delivery channels. For the upstream delivery channel only Normal Replacement (NR) measure type is allowed.

Eligible Products

Qualified products must meet the following requirements as well as the performance criteria specified below.

* LED tube must be 4-foot and designated as UL Type B, UL Type A+B, or UL Type C. UL Type A+B (dual mode) lamps must be installed in a Type B configuration with the existing ballast removed.
* The lamp must be listed under the Primary Use Category “Internal Driver/Line Voltage (UL Type
  1. Lamps”, “Dual Mode Internal Driver (UL Type A and Type B)”, “2-Lamp External Driver (UL Type
  2. Lamps”, “3-Lamp External Driver (UL Type C) Lamps”, “4-Lamp External Driver (UL Type C) Lamps” on the current Design Lights Consortium qualified product list (<https://www.designlights.org/search/>).
* Must meet a minimum efficacy requirement stated in the workpaper.
* Additional DLC version 5.1 minimum requirements are stated below.
* LED tube must be compatible with the installed system lighting controls. For example, if the lighting system includes dimming controls, the new LED tube must be dimmable and compatible with the installed dimming system.

Program Requirements for LED T8 Lamps

|  |  |  |  |
| --- | --- | --- | --- |
| Performance Metric | DLC Requirement | DLC Tolerance | Minimum Program Requirements |
| System Efficacy | ≥ 120 LPW | -3% | 160 |
| CRI | ≥ 80 | -2 Points | ≥ 80 |
| CCT | 2,200K – 6,500K | n/a | 2,200K – 6,500K |
| Power Factor | ≥ 0.9 | -3% | ≥ 0.9 |
| Total Harmonic Distortion | ≤ 20% | +5% | ≤ 20% |
| Lumen Maintenance | L70 ≥ 50,000 | n/a | L70 ≥ 50,000 |
| Minimum Warranty | 5 Years | n/a | 5 Years |

*Eligible Building Types and Vintages*

This measure is eligible in all commercial and multifamily (common and dwelling areas) and double-wide mobile homes. Parking garages are also eligible.

*Eligible Climate Zones*

This measure is applicable in all California climate zones.

# PROGRAM EXCLUSIONS

This measure does not apply to residential single-family residences. De-lamping is not eligible.

Existing lamps and ballasts must be fully demolished and properly disposed. “Abandon-in-place”

demolition of existing ballasts is not eligible.

# DATA COLLECTION REQUIREMENTS

To ensure that code requirements for lighting power and controls are being met, the following data submission requirements must be met for all delivery types and measure application types.

* Documentation showing that the retrofitted space has achieved a lighting power density that is

<80% of allowable Title 24 LPD for that space type.

* Title 24 compliance documentation verifying the existence of required automated shut-off controls compliant with 2019 Title 24 §130.1(c)1-8 Auto-Shut-off Control.
* Only for AR measures, the Customer must confirm that existing automated control functionality remains intact after install in the POE response.

The following data collection requirements must be met for Accelerated Replacement measures:

The customer must submit responses to the POE questionnaire document associated with these measures7.

Pre-existing data that must be collected includes:

1. Total number of fixtures on site
2. Number of fixtures sampled (must sample at least 10% of the fixtures present)
3. Number of lamps per fixture
4. Fluorescent lamp wattage
5. Disposal method of tube
6. Existing automated controls types in the spaces retrofitted.

# USE CATEGORY

Lighting

# ELECTRIC SAVINGS (kWh)

The calculation of annual electric unit energy savings (UES) of the LED T8 lamp is a function of the difference between the baseline and measure case lamp wattage, hours of operation, and interactive effects.

7 Southern California Edison (SCE). 2020. "SWLG018-01 Type B and C TLED POE Questionaire.docx”

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*UES = unit energy savings (kWh per lamp)*

*∆Watts/unit = (Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp) HOURS = Annual hours of use, by building type/space*

*IE = Interactive Effects, by building type/space*

The inputs to the UES calculation are explained below.

Existing Baseline Case Average Watts per Lamp. The base case average lamp wattage was derived from a weighted average of the base case type lamps (25W, 28W, 30W and 32W). SCE program participation data from 2018-19 on over 160,000 lamps were analyzed; the base case lamp wattage distribution is shown below. Base case wattages were normalized to account for a normal ballast factor of 0.88. For simplicity of the analysis, only 28W and 32W lamps were included in the weighted average as they comprised more than 99% of the baseline.

Existing Baseline Case Wattage Saturation Distribution

|  |  |  |  |
| --- | --- | --- | --- |
| Existing Base Case Wattage (W) | % Saturation  (% used in analysis) | Normalized Base Case Wattage (W) | Source |
| 25 | 0.36% (0%) | 22.0 | Southern California Edison (SCE). 2020. "SWLG018-01 TLED Delta Watts Calculation.xlsx.” |
| 28 | 41.69% (42%) | 24.6 |
| 30 | 0.18% (0%) | 26.4 |
| 32 | 57.77% (58%) | 28.2 |
| Total Weighted Average | | 26.68 |  |

Existing Baseline Case In-Situ Fixture Lumens

A major goal of any lighting measure is to provide similar or improved lighting performance compared to the incumbent technology. One way to compare performance is to compare the total amount of lumens provided to the space for each technology. However, linear fluorescent lamps emit light in all directions, while TLED lamps emit light directionally. While linear fluorescent lamps may emit more total lamp lumens than TLEDs, much of their light is directed away from working surfaces. Furthermore, bare lamp performance is not a preferred metric, as it does not account for the performance of the lamp while enclosed in lighting fixtures (“in-situ” performance).

The US DOE has published several application summaries and detailed reports that can be used to compare the photometric performance of incumbent T8 lamps in fixtures with LED T8 lamps. In these reports, they provide a metric called luminaire efficiency. Luminaire efficiency is the ratio of the total bare

lamp lumens and the total lumens the fixture provides to the space, expressed as a percent.8 The metric can be used to compare the in-situ performance of linear fluorescent lamps to new high efficiency TLEDs. An average of in-situ luminaire efficiencies was calculated for linear fluorescent lamps for nine troffers 9 and two parking/linear pendant fixtures10 from DOE CALiPER reports. Troffer performance was selected to represent the performance of non-parking garage measures, as it is the most common linear fluorescent fixture type.11 Using the saturation weighting from the “Base Case Wattage Saturation Distribution” table above, the weighted average fixture lumens for both types of fixtures was calculated. Most CALiPER reports tested 2-lamp fixtures; thus, this analysis assumes 2-lamp fixtures.

8 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers.* Prepared by the Pacific Northwest National Laboratory (PNNL).

U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers.* Prepared by the Pacific Northwest National Laboratory (PNNL).

U.S. Department of Energy. 2009. “DOE SSL CALiPER Report: Product Test Reference: CALiPER 09-67 2’x4’ Troffer Fluorescent

Benchmark.”

U.S. Department of Energy. 2009. “DOE SSL CALiPER Report: Product Test Reference: CALiPER 09-73 24”x24” Troffer Benchmark

Fluorescent.”

9 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers.* Prepared by the Pacific Northwest National Laboratory (PNNL).

U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers.* Prepared by the Pacific Northwest National Laboratory (PNNL).

U.S. Department of Energy. 2009. “DOE SSL CALiPER Report: Product Test Reference: CALiPER 09-67 2’x4’ Troffer Fluorescent

Benchmark.”

U.S. Department of Energy. 2009. “DOE SSL CALiPER Report: Product Test Reference: CALiPER 09-73 24”x24” Troffer Benchmark

Fluorescent.”

10 U.S. Department of Energy. 2010. “DOE SSL CALiPER Report: Product Test Reference: CALiPER BK 09-108 Parking Structure Fluorescent.”

U.S. Department of Energy (DOE). 2012. "DOE CALiPER Detailed Test Report: CALiPER Reference: 11-79 Linear Pendant."

11 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2013*. CALiPER Exploratory Study: Recessed Troffer Lighting.* Prepared by the Pacific Northwest National Laboratory (PNNL). Revised June 2013.

Existing Case Linear Fluorescent In-Situ Fixture Performance

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | Nominal LF (W) | Lamp Saturation (%) | Lamp Efficacy (LPW)12 | Bare Lamp Lumens  (2-lamp) 13 | Average Fixture Efficiency | Total Fixture Lumens | Weighted Average Fixture Lumens |
| Troffer | 28 | 42% | 90 | 4,386 | 73% | 3,199 | 3,515 |
| 32 | 58% | 89 | 5,134 | 3,744 |
| Parking Fixture | 28 | 42% | 90 | 4,386 | 64% | 2,816 | 3,095 |
| 32 | 58% | 89 | 5,134 | 3,296 |

Standard Practice Case In-Situ Fixture Lumens

Due to the differing lamp characteristics, T8 and TLED fixture efficiencies differ. TLED in-situ fixture efficiencies were compiled from CALiPER data for 22 troffer fixtures.

In-situ parking or linear fixture performance data could not be found for TLEDs from CALiPER. However, the T8 CALiPER reports for the two linear parking fixtures show that over 50% of total lamp lumens are provided in the downward direction (0°-180° zone).14 Due to lack of parking fixture data, the same difference in fixture efficacy that was found for the T8s and TLEDs in troffer fixtures is used to determine the fixture efficiency of TLEDs in parking garage fixtures. Thus, a 9% increase in fixture efficiency is applied to the T8 parking garage fixture efficiency as measured by Caliper studies noted in the section above.

Through an iterative process, using the standard practice 133 LPW TLED, wattages yielding similar fixture lumens to the linear fluorescent existing baseline have been selected. For simplicity, the same TLED wattages is used for both the troffer and parking fixture. The same wattage shows very close in-situ performance for both fixture types.

12 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2014. *CALiPER Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers.* Prepared by the Pacific Northwest National

Laboratory (PNNL).

13 U.S. Department of Energy (DOE), Building Technologies Office of Energy Efficiency & Renewable Energy. 2013*. CALiPER Exploratory Study: Recessed Troffer Lighting.* Prepared by the Pacific Northwest National Laboratory (PNNL). Revised June 2013.

14 U.S. Department of Energy. 2010. *DOE SSL CALiPER Report: Product Test Reference: CALiPER BK 09-108 Parking Structure Fluorescent.*

Standard Practice Baseline LED Standard Practice In-Situ Fixture Performance

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | In-Situ LED (W) | Lamp Saturation Weight (%) | Lamp Efficacy (LPW) | Bare Lamp Lumens (2-lamps) | Fixture Efficiency | Total Fixture Lumens | Weighted Average Fixture Lumens | Percent Difference from T8 (%) |
| Troffer | 15.50 | 42% | 133 | 4,123 | 82% | 3,383 | 3,510 | -0.2% |
| 16.50 | 58% | 133 | 4,389 | 3,601 |
| Parking Fixture | 15.50 | 42% | 133 | 4,123 | 73% | 3,023 | 3,137 | 1.3% |
| 16.50 | 58% | 133 | 4,389 | 3,218 |

Standard Practice Wattage Saturation Distribution

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fixture Type | In-Situ LED (W) | Lamp Saturation Weight (%) | Weighted Average Lamp Wattage (W) | Source |
| Troffer | 15.50 | 42% | 16.08 | Southern California Edison (SCE). 2020. “SWLG018-01 TLED Delta Watts Calculation.xlsx.” |
| 16.50 | 58% |
| Parking Fixture | 15.50 | 42% | 16.08 |
| 16.50 | 58% |

Measure Case In-Situ Fixture Lumens

Similar to the method used to calculate the standard practice lamp wattages, the measure case wattages use the in-situ performance of TLEDs in fixtures to calculate wattages need to achieve similar performance to the base case equipment. The same measure case efficacy of 160 LPW will be used to estimate the measure case savings for both the Type B and Type C measures. Based on exports from the DLC list from the third quarter of 2020, 500 (4%) Type B lamps and 60 (2%) Type C systems can meet this requirement.

Through an iterative process, using a minimum efficacy of 160 LPW, TLED wattages yielding similar fixture lumens to the base case were selected. Since the performance of TLEDs in troffers and parking garage fixtures differ, different measure case wattages per application were selected. DLC reported efficacy for Type C TLED products already includes driver factors. Thus, the calculations for Type C systems will not incorporate additional factors to account for the external LED driver.

For this workpaper, the in-situ fixture efficiency for 2-lamp, 3-lamp and 4-lamp Type C TLED systems will not be assumed to vary. Thus, the savings for the Type C measures will be calculated by multiplying the single lamp savings by the number of lamps per system.

LED In-Situ Fixture Performance

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | In-Situ LED Lamp (W) | Lamp Saturation Weight (%) | Lamp Efficacy (LPW) | Bare Lamp Lumens (2-lamps) | Fixture Efficiency | Total Fixture Lumens | Weighted Average Fixture Lumens | Percent Difference from T8 (%) |
| Troffer | 13.00 | 42% | 160 | 4,160 | 82% | 3,413 | 3,490 | -0.7% |
| 13.50 | 58% | 160 | 4,320 | 3,545 |
| Parking Fixture | 12.50 | 42% | 160 | 4,000 | 73% | 2,933 | 3,069 | -0.8% |
| 13.50 | 58% | 160 | 4,320 | 3,168 |

Measure Case Average Watts. The measure case wattages of lamps selected from the table above for each fixture type were normalized based on the saturation weighting from the SCE Program data.

Measure Case Lamp Wattages

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fixture Type | In-Situ LED Lamp (W) | Lamp Saturation Weight (%) | Weighted Average Lamp Wattage (W) | Source |
| Troffer | 13.00 | 42% | 13.29 | Southern California Edison (SCE). 2020. “SWLG018-01 TLED Delta Watts Calculation.xlsx.” |
| 13.50 | 58% |
| Parking Fixture | 12.50 | 42% | 13.08 |
| 13.50 | 58% |

Measure and Baseline Watts. The total wattage for each case is found by multiplying the existing, standard practice, and measure wattages by the quantity of lamps per measure.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fixture Type | Measure | Existing Baseline Wattage (W) | Standard Practice Baseline Wattage (W) | Measure Wattage (W) | Existing to Measure Reduction (W) | Standard to Measure Reduction (W) |
| Troffer | 4-foot UL Type B LED T8 Lamp | 26.68 | 16.08 | 13.29 | 13.39 | 2.79 |
| Fixture with (2) 4-foot UL Type C LED T8  Lamps | 53.36 | 32.16 | 26.58 | 26.78 | 5.58 |
| Fixture with (3) 4-foot UL Type C LED T8  Lamps | 80.04 | 48.24 | 39.87 | 40.17 | 8.37 |
| Fixture with (4) 4-foot UL Type C LED T8  Lamps | 106.73 | 64.32 | 53.16 | 53.57 | 11.16 |
| Parking Fixture | 4-foot UL Type B LED T8 Lamp | 26.68 | 16.08 | 13.08 | 13.6 | 3.0 |
| Fixture with (2) 4-foot UL Type C LED T8  Lamps | 53.36 | 32.16 | 26.16 | 27.2 | 6.0 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Fixture with (3) 4-foot UL Type C LED T8  Lamps | 80.04 | 48.24 | 39.24 | 40.8 | 9.0 |
|  | Fixture with (4) 4-foot UL Type C LED T8  Lamps | 106.73 | 64.32 | 52.32 | 54.41 | 12.0 |

Demand Difference. The demand difference is the difference between the electric demand of the base case lamp and the electric demand of the measure case lamp.

Interactive Effects Multiplier. Heating, ventilating and air conditioning (HVAC) interactive effects refers to the change in HVAC energy usage due to the installation of energy-savings measures that directly change electric energy use within the conditioned space of a building. Interactive effective multipliers are developed and maintained by the California Public Utilities Commission (CPUC) Energy Division and its team of consultants via building simulation techniques that incorporate results from building site surveys, field measurements, laboratory tests, and facility billing data analysis. Interactive effects multipliers for lighting measures vary by building type, vintage, climate zone, lighting type, and occupancy sensor scenario. The relevant designations to identify the appropriate interactive effects multipliers for LED T8 replacement lamps are provided below.

Interactive Effects Multiplier Designations for LED T8 Replacement Lamps UL Type B and C

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sector | Lighting Type | PA | Building Vintage and HVAC | Source |
| Commercial | Indoor Linear fluorescent lamps (Hardwired) | Any | Existing, Commercial Weighted | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Residential | Indoor Non-CFL lamps and fixtures (Screw-in) | Any | Existing, Residential Weighted | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |

The sources of the input parameters for the electric energy savings calculation are provided below.

LED T8 Replacement Lamps UL Type B and C Electric Energy Savings Parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Annual hours of operation –  commercial | Varies by building type, lighting type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Interactive effects multiplier  - commercial | Varies by climate zone, building type, vintage, lighting type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Annual hours of operation –  residential | Varies by dwelling or common area space for multi- family/double-wide mobile homes | California Public Utilities Commission (CPUC), Energy Division, Ex Ante Team. 2015. "2015 Workpaper Guidance- Lighting Retrofits." Memorandum submitted to the California Energy Efficiency Program Administrators.  January 27. |
| Interactive effects multiplier  - residential | Varies by climate zone, building type, and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |
| Annual hours of operation –  parking garages | 2,613.75 | California Public Utilities Commission (CPUC), Energy Division. 2016. “Disposition for Workpaper SCE13LG123 revision 0.” September 30. |

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Interactive effects multiplier  – parking garages (interactive effects multiplier for unconditioned spaces) | 1.0 | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |

Parking garage annual hours of operation: Parking garage hours of operation represent the equivalent full-load hours (EFLH) and was calculated as the average of the allowed low power usage at 35% power15 and lower-power usage at 20% power.16 The calculated mid-point or average of 20% and 35% is 27.5%, which is within the range allowed for the dimmed-power state by Title24. Calculations for a lamp replacement in a parking garage conforms to the Disposition for Workpapers Covering Exterior LED Lighting Fixtures, issued March 1, 2017.17 (The same hours of use were also calculated for the “PGECOLTG151 R8 Outdoor InterimSolution” workpaper,18 which was subsequently approved by the CPUC Energy Division.)

The resultant LED T8 lamp energy savings vary by market sector and building type, due to operating hours and interactive effects that vary by building type and sector.

Sample Calculation. A sample energy savings calculation is provided below for a 4-foot LED T8 Lamp UL Type B replacing existing case Linear Fluorescent T8 Lamp in a troffer fixture in an Assembly building type, Climate Zone 6, and accelerated replacement installation type.

(26.68 − 13.29) × 1100 × 1.08

��� =

1,000 (𝑊 𝑎��ℎ� ��� )

�𝑊ℎ

��� = 15.91 �𝑊ℎ/��𝑎�

# PEAK ELECTRIC DEMAND REDUCTION (KW)

The calculation of demand reduction impacts (kW) for the LED T8 lamp is a function of the difference between the baseline and measure case lamp wattage (ΔW), a coincident demand factor (CDF) and interactive effects.

15 California Public Utilities Commission (CPUC), Energy Division. 2016. “Disposition for Workpaper SCE13LG123 revision 0.”

September 30.

16 California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2015-037-CMF. Section 130.2(c)3

17 California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition For Workpapers Covering Exterior LED Lighting Fixtures.” March 1.

18 Pacific Gas and Electric Company (PG&E). 2018. *Work Paper PGECOLTG151 LED Outdoor Area and Street Lighting Revision 8*. April 11.

��𝑎� ���𝑎�� ������𝑖�� =

∆ 𝑊 × ��� × ��𝑒𝑙𝑒� 1,000 𝑊/�𝑊

*∆Watts/unit = (Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp) CDF = Coincident demand factor*

*IEelec = Interactive Effects, by building type/space*

See the Electric Savings section for a discussion of the base case and measure case average watts per lamp used to derive the ΔW and the HVAC interactive effects multiplier.

Coincident Demand Factor (CDF). The coincident demand factor (CDF) represents the percentage of the time that all the lights in the building are on at the same time, during the CPUC-defined peak hours. This factor is applied to the demand savings to align the savings with this peak period. This factor varies by building type and climate zone.

The sources for the input parameters for this calculation are specified below.

LED T8 Replacement Lamps UL Type B and C Demand Reduction Parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Lighting coincident demand factor (CDF) – commercial | Varies by building type, vintage, lighting type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Interactive effects - commercial | Varies by climate zone, building type, vintage, lighting type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Lighting coincident demand factor (CDF) – residential | Varies by building type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |
| Interactive effects - residential | Varies by climate zone, building type, and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |
| Lighting coincident demand factor (CDF) – parking garages | Varies by building type, vintage, lighting type and vintage | Parking garage CDF is assumed to be the same as the Non-Res building CDF. |
| Interactive effects multiplier –  parking garages  (interactive effects multiplier for unconditioned spaces) | 1.0 | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |

The resultant LED T8 lamp demand reduction varies by market sector and building type, due to differences in interactive effects.

Sample Calculation. A sample demand reduction calculation is provided below for a 4- foot LED T8 Lamp UL Type B and C replacing Linear Fluorescent T8 Lamp in an Assembly building type, Climate Zone 6, and accelerated replacement installation type.

(26.68 − 13.29) × .226 × 1.23

���𝑎�� ������𝑖�� =

1,000 (𝑊𝑎��)

�𝑊

���𝑎�� ������𝑖�� = 0.00372

�𝑊

��𝑖�

# GAS SAVINGS (THERMS).

The estimated gas savings of a LED T8 lamp are based solely on the estimated change of gas consumption as reflected by a gas HVAC interactive effects multiplier.

��� =

∆𝑊 × ����� × ��𝑔�� 1,000 𝑊ℎ/ �𝑊ℎ

*UES = Unit energy savings (therms per lamp)*

*∆Watts/unit = (Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp) HOURS = Annual hours of use, by building type/space*

*IEgas = HVAC gas interactive effects, by building type/space*

See the Electric Savings section for a discussion of each parameter in the UES calculation. The sources of the input parameters for this calculation are provided below.

LED T8 Replacement Lamps UL Type B and C Gas Energy Savings Parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Annual hours of operation –  commercial | Varies by building type, lighting type and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Gas interactive effects multiplier- commercial | Varies by climate zone, building type, vintage, lighting type, and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv." |
| Annual hours of operation –  residential | Varies by dwelling or common area space for multi-family/double-wide mobile homes | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |
| Gas interactive effects multiplier –  residential | Varies by climate zone, sector, and vintage | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |
| Annual hours of operation – parking garages | 2,613.75 | California Public Utilities Commission (CPUC), Energy Division. 2016. “Disposition for Workpaper SCE13LG123 revision 0.” September 30. |
| Gas interactive effects multiplier –  parking garages | 0.0 | California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition For Workpapers Covering Exterior LED Lighting Fixtures.” March 1. |

Parking garage annual hours of operation: Parking garage hours of operation represent the equivalent full-load hours (EFLH) and was calculated as the average of the allowed low power usage at 35% power19 and lower-power usage at 20% power.20 The calculated mid-point or average of 20% and 35% is 27.5%, which is within the range allowed for the dimmed-power state by Title24. Calculations for a lamp replacement in a parking garage conforms to the Disposition for Workpapers Covering Exterior LED Lighting Fixtures, issued March 1, 2017.21 (The same hours of use were also calculated for the “PGECOLTG151 R8 Outdoor InterimSolution” workpaper,22 which was subsequently approved by the CPUC Energy Division.)

The resultant LED T8 lamp gas energy savings varies by market sector and building type, due to differences in operating hours and interactive effects. Note that the gas interactive effective multipliers

19 California Public Utilities Commission (CPUC), Energy Division. 2016. “Disposition for Workpaper SCE13LG123 revision 0.”

September 30.

20 California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2015-037-CMF. Section 130.2(c)3

21 California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition For Workpapers Covering Exterior LED Lighting Fixtures.” March 1.

22 Pacific Gas and Electric Company (PG&E). 2018. *Work Paper PGECOLTG151 LED Outdoor Area and Street Lighting Revision 8*. April 11.

are negative and reflect the slight increase in gas space heat usage as a result of the installation of this measure.

Sample Calculation. The following is sample gas energy savings calculation (therms) for a 4-foot LED T8 Lamp UL Type B and C replacing Linear Fluorescent T8 Lamp in an Assembly building type, Climate Zone 6, and accelerated replacement installation type.

(26.68 − 13.29)

����𝑎� �𝑎� �𝑎�𝑖��� =

# LIFE CYCLE

1000

× (1100) × (−0.00686) = −0.10105 �ℎ����/��𝑎�

These measures demolish the existing fluorescent lamps and ballasts and only maintain the existing physical components like fixture housing, reflectors, and lens. The new TLED lamps come with their own internal drivers (UL Type B) or external drivers (UL Type C). In similar situations, such as with integral LED lamps (A, PAR, BR, etc.) the EUL of the measure is based on the LED equipment itself. This is unlike the approved EUL of the UL Type A lamps, which is dependent on existing ballast life.

UL Type B and Type C lamps use drivers which perform similarly to full LED fixtures and retrofit kits. In DEER, LED fixtures use 50,000 hours as their EUL basis. Similarly, the minimum qualifying criteria for Design Lights Consortium (DLC) L70 results is 50,000 hours. As these UL Type B and Type C TLEDs use similar drivers and must meet DLC requirements, this workpaper uses a 50,000-hour EUL basis for these measures.

Since this is an accelerated replacement measure (AR), the remaining useful life (RUL) of the existing equipment must be provided. The RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.”23 This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.24

The RUL of the linear fluorescent fixture is derived in two steps: 1) determine the EUL of the fixture, and

2) determine the RUL of the fixture. The EUL of the fixture is equal to the total expected lifetime operating hours divided by the average annual operating hours (effective full-load hours, EFLH) for each building type. Insofar as average hours of operation vary by building type, the EUL of the fixture varies by building type. Note that the EUL is capped at a maximum value of 15 years and therefore the RUL is capped at a maximum value of 5 years.

(�������� 𝐿𝑖���𝑖�� ����𝑎�𝑖�� �����)

��𝐿��𝑙𝑙��� = (��𝑖��𝑖�� ���� ����𝑎�� ����𝑎�𝑖�� ����� ��� 𝑌�𝑎�, ��𝐿 )

1

��𝐿��𝑙𝑙��� = 3 × ��𝐿��𝑙𝑙���

23 California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

24 KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

The inputs and resultant EUL and RUL of LED T8 UL Type B and Type C lamps are presented below.

Effective Useful Life and Remaining Useful Life Inputs

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Source ID | Value | Source |
| EUL (Years), Non-Res | ILtg-Com-LED- 50000hr | 50,000 hour basis. EUL varies based on building type. Max 12 years | California Public Utilities Commission (CPUC), Energy Division. 2014. “DEER2014-EUL-table- update\_2014-02-05.xlsx.” |
| EUL (Years), Res | ILtg-Res-LED- 50000hr+12yr | 50,000 hour basis. EUL varies based on building type. Max 12 years | California Public Utilities Commission (CPUC), Energy Division. 2014. “DEER2014-EUL-table- update\_2014-02-05.xlsx.” |
| RUL (Years), Non-Res fluorescent fixture | ILtg-Lfluor-Elec | 70,000 hour basis. EUL varies based on building type. Max of 15 years. RUL = 1/3 EUL, max of 5 years | The source for this data/information is unknown. |
| RUL (Years), Res fluorescent fixture | LtgFixture-Default | 70,000 hour basis. EUL varies based on building type. Max of 15 years. RUL = 1/3 EUL, max of 5 years | The source for this data/information is unknown. |
| Hours of Use | N/A | Varies by building type | California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Com-InLtg.csv."  California Public Utilities Commission (CPUC). 2020. "SupportTable\_2020-Res-InLtg.csv." |

# BASE CASE MATERIAL COST ($/UNIT)

The standard practice baseline material cost was derived from online price data collected via web scraping from various online retailers such as 1000 bulbs, BeesLighting, Amazon, Bulbs.com, Top Bulbs, Pro Lighting, and Grainger websites in the second and third quarter of 2020. The average cost of the collected Type B, Dual Mode, and Type C LED T8 lamps with efficacies near the standard practice case LED efficacy (130 to 136 LPW) is used for the material cost. 25

For Type C lamp systems, LED driver costing was also found using the same methodology as described in the measure case cost section. LED driver efficiencies were not readily found to affect costs; thus, the same LED driver costs are used for the base and measure case Type C TLED systems.

For consistency, standard practice equipment costs for the same system type (Type B or Type C) is used for the incremental cost analysis.

# MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material cost was derived from online price data collected via web scraping from various online retailers such as 1000 bulbs, BeesLighting, Amazon, Bulbs.com, Top Bulbs, Pro Lighting, and Grainger websites in the second and third quarter of 2020. The average cost of the collected Type B, Dual

25 Southern California Edison (SCE). 2020. “SWLG018-01 Cost Calculations.xlsx.”

Mode, and Type C LED T8 lamps with efficacies greater than or equal to the measure case LED efficacy (160 LPW) is used for the material cost. 26

For Type C lamp systems, LED driver costs were also derived from online price data collected via web searching from online retailers such as 1000 bulbs, BeesLighting, Grainger, and LEDT8Bulb. Average costs for drivers suited for operating two and four lamps were found and applied to the Type C material costs. The 3-lamp Type C measures use the same driver costs as the 4-lamp measures.

# BASE CASE LABOR COST ($/UNIT)

For consistency, standard practice labor costs for the same system type (Type B or Type C) is used for the incremental cost analysis. The base case installation labor cost for both the Type B and Type C systems is assumed to equal the measure case installation labor cost. See Measure Case Labor Cost.

# MEASURE CASE LABOR COST ($/UNIT)

Different labor requirements exist for the installation of Type B and Type C T8 LEDs. RSMeans 2020 labor hours were used to calculate installation costs for each type of install.27 The RSMeans 2020 hourly labor rate of $74.95 for a commercial electrician28 is used to calculate the labor cost for this measure based on the labor hours presented below.

The labor required to perform a Type B lamp install includes the removal of the existing fluorescent lamps and ballasts, rewiring of the main line voltage to the lamp holders, and installation of the new LED Lamps. This measure is normalized on a per lamp basis, but the existing fixtures may have more than one lamp connected to a single ballast. Thus, the total quantity of lamps and ballasts from SCE’s 2018-2019 program data was used to find a weighted average ballast per lamp. This was used to normalize the estimated hours for ballast removal per lamp installed29.

Normalized Ballasts quantity per Lamp

|  |  |
| --- | --- |
| Equipment | Value |
| Total Ballasts | 65,165 |
| Total Linear Fluorescent Lamps | 163,060 |
| Total Ballast per Lamp | 0.40 |

26 Southern California Edison (SCE). 2020. “SWLG018-01 Cost Calculations.xlsx.”

27 Southern California Edison (SCE). 2020. “SWLG018-01 Cost Calculations.xlsx.”

28 RSMeans Labor Rates, 2020. [https://www.rsmeansonline.com/References/LABORRATE/2-](https://www.rsmeansonline.com/References/LABORRATE/2-Year%202020%20Labor%20Rates/Open%20Shop%20Labor%20Rates.PDF)  [Year%202020%20Labor%20Rates/Open%20Shop%20Labor%20Rates.PDF](https://www.rsmeansonline.com/References/LABORRATE/2-Year%202020%20Labor%20Rates/Open%20Shop%20Labor%20Rates.PDF)

29 Southern California Edison (SCE). 2020. “SWLG018-01 Cost Calculations.xlsx.”

UL Type B Labor Hours

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Labor Description | RSMeans Description | Raw Labor Hours | Normalizing Factor per lamp | Labor Hours |
| Remove existing T8 Ballast | Ballast, fluorescent fixture, electrical demolition, remove | 0.33 | 0.40 | 0.13 |
| Install Type B TLED Lamp | 3500K LED advantage T8 18 W 1600LM 4ft linear 2 BD frosted | 0.12 | 1 | 0.12 |
|  | Total: Type B TLED Hours |  |  | 0.25 |

The labor required to perform a Type C system install includes the removal of the existing fluorescent lamps and ballasts, installation of the new LED driver, and installation of the new LED Lamps. No specific labor item for TLED drivers exists in RSMeans, however, installation requirements are very similar to linear fluorescent ballasts. Thus, labor hours for the replacement of a fluorescent ballast is used to estimate the hours for the LED driver. Labor costs for the installation of new LED lamps is calculated based on the quantity of lamps in the system30.

UL Type C Labor Hours

|  |  |  |
| --- | --- | --- |
| Labor Description | RSMeans Description | Labor Hours |
| Remove existing T8 ballast and replace with LED Driver | Electrical facilities maintenance, remove and replace or maintain, ballast, electronic type, for 2 tubes | 1 |
| Install Type C TLED Lamp | 3500K LED advantage T8 18 W 1600LM 4ft linear 2 BD frosted | 0.12 |
|  | Total: 2-lamp Type C TLED Hours | 1.23 |
|  | Total: 3-lamp Type C TLED Hours | 1.35 |
|  | Total: 4-lamp Type C TLED Hours | 1.46 |

# NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The default NTG values are based upon the average of

all NTG ratios for all evaluated 2006 – 2008 residential and commercial programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. These sector average NTGs are applicable to all energy efficiency measures that have been offered through residential and commercial sector programs for more than two years and for which impact evaluation results are not available.

Accelerated replacement measures will use default NTG values. Normal replacement measures use an all LED baseline, thus those measures will use NTGs from Resolution E-4952 for LED measures assuming all LED baselines. 31

30 Southern California Edison (SCE). 2020. “SWLG018-01 Cost Calculations.xlsx.”

31 California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Page A-34 – A-35.

Net-to-Gross Ratios

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| NonRes-In-Ltg-LEDFixt  (Non-Res Sectors, NR Measures) | 0.91 | California Public Utilities Commission (CPUC). 2018. Resolution E- 4952. October 11. Page A-34 – A-35. |
| Res-InCmn-Ltg-LEDFixt (Res Sector, NR Measures) | 0.91 | California Public Utilities Commission (CPUC). 2018. Resolution E- 4952. October 11. Page A-34 – A-35. |
| Agric-Default>2yrs  (Ag Sector, AR Measures) | 0.6 | Itron, Inc. 2011. DEER Database 2011 Update Documentation. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3. |
| Com-Default>2yrs  (Com Sector, AR Measures) | 0.6 | Itron, Inc. 2011. DEER Database 2011 Update Documentation. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3. |
| Ind-Default>2yrs  (Ind Sector, AR Measures) | 0.6 | Itron, Inc. 2011. DEER Database 2011 Update Documentation. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3. |
| Res-Default>2  (Res Sector, AR Measures) | 0.55 | Itron, Inc. 2011. DEER Database 2011 Update Documentation. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3. |

# GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This “default” GSIA rate for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rate

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| GSIA - default | 1.0 | California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31. |

# NON-ENERGY IMPACTS

The non-energy impacts of this measure have not been quantified.

# DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods based upon the Database for Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

|  |  |
| --- | --- |
| DEER Item | Comment / Used for Workpaper |
| Modified DEER methodology | No |
| Scaled DEER measure | Yes |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |

|  |  |
| --- | --- |
| DEER Item | Comment / Used for Workpaper |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | No |
| DEER Version | Non-DEER |
| Reason for Deviation from DEER | DEER does not contain this type of measure |
| DEER Measure IDs Used | n/a |
| NTG | Source: DEER.  The NTG of 0.91 is associate with NTG ID: NonRes-In-Ltg-LEDFixt The NTG of 0.91 is associate with NTG ID: Res-InCmn-Ltg-LEDFixt The NTG of 0.60 is associate with NTG ID: Agric-Default>2yrs The NTG of 0.60 is associate with NTG ID: Com-Default>2yrs  The NTG of 0.60 is associate with NTG ID: Ind-Default>2yrs The NTG of 0.55 is associate with NTG ID: Res-Default>2 |
| GSIA | Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA* |
| EUL/RUL | Source: DEER2014. EUL ID: *ILtg-Com-LED-50000hr* is associated with50,000/HOU or the max of EUL value.  Source: DEER2014. EUL ID: *ILtg-Res-LED-50000hr+12yr* is associated with50,000/HOU or the max of EUL value.  Source: DEER2014. EUL ID: *LtgFixture-Elec* is associated with (70,000/HOU)/3 or the max of RUL value. |

# REVISION HISTORY

Measure Characterization Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision Number | Revision Complete Date | Primary Author, Title, Organization | Revision Summary and Rationale for Revision |
| 01 | 10/5/2020 | Lake Casco, PE TRC | First draft of workpaper |
| 01 | 12/4/2020 | Ajay Wadhera, SCE | Changed Normalizing Units for UL Type C offerings from “Lamp” to “Fixture”. Please refer to Normalizing Units section in the narrative of this document.  Changes made in EAD tables, Data Spec sheet, and Delta Watts Calculations sheet as well to reflect correct Norm Units. |
| 01 | 08/09/2021 | Ajay Wadhera, SCE | Changed E3MeaElecEndUseShape from “DEER:Indoor\_Non-CFL\_Ltg” to “  DEER:Indoor\_CFL\_Ltg” in EAD table. |