**State of Illinois**

**Energy Efficiency**

**Technical Reference Manual**

**[LED Screw-Based Omnidirectional Lamps]**

**Section #]**

**[Measure Code]**

**Mary Sutter, Opinion Dynamics Corporation**

**11/11/13**

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Table Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **MM/DD/YY** | **Author,Company** | **Summary of Changes** |
| 0 | 11/11/13 | Mary Sutter, Opinion Dynamics | Creation of new measure for screw based omnidirectional LED lamps within the residential and multi-family sector |
|  |  |  |  |

# Summary

Version 2 of the Illinois TRM includes information about screw-based omnidirectional LEDs within the commercial sector, but not the residential sector. With the growth of this measure expected in the future, addition of a residential specific measure covering this type of LED is proposed. This work paper has taken information from version 2 of the Illinois TRM for residential CFLs and commercial LEDs to create this document. Additionally, because the next version of the TRM is due out after deadlines for application of EISA baselines in 2013 and 2014, the language and examples around how to handle savings before 2014 has been removed. However, in some cases this measure may last slightly past the EISA 2020 cut off and the work paper retains information around how to handle lifecycle savings after 2020.

## Measure Components Affected

Note that the boxes checked reflect changes from either the residential CFL or commercial LED measures.

###### Description

###### Definition of Efficient Equipment

###### Definition of Baseline Equipment

###### Deemed Lifetime of Efficient Equipment

###### Deemed Measure Cost

###### Deemed O&M Cost Adjustments

###### Loadshape

###### Coincidence Factor

###### Net To Gross Ratio

Algorithm

###### Calculation of Energy Savings

###### Electric Energy Savings

###### Summer Coincident Peak Demand Savings

###### Natural Gas Savings

###### Water Impact Descriptions and Calculation

###### Deemed O&M Cost Adjustment Calculation

**Measure code**

## Algorithm and Input Components Affected

### Algorithm / Input 1

Efficient watts for LED is used, baseline wattage of halogens remain identical to CFLs

### Algorithm / Input 2

NA

## Rationale for the Change

New Measure

### Methodology

Applied inputs based on either the residential CFL or commercial LEDs measure, depending on which is appropriate

### Sample Size

NA

### Other Rationale

NA

## Please Specify the Proposed Change

Table Summary of Proposed Change

|  |  |  |  |
| --- | --- | --- | --- |
| **ITEM** | **ORIGINAL SPECIFICATION** | **PROPOSED SPECIFICATION** | **CITATION FOR PROPOSED SPECIFICATION** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Author (Company) and Date

Mary Sutter, Opinion Dynamics, 11/11/13.

# Components of TRM Measure Characterizations

### LED Screw Based Omnidirectional Bulbs

###### Description

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g. A-Type lamps) lamps within the residential and multifamily sectors.

This measure was developed to be applicable to the following program types:  TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

###### Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be Energy Star labeled.

###### Definition of Baseline Equipment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) will require all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014. Since measures installed under this TRM all occur after 2014, baseline equipment are the values after EISA. These are shown in the baseline table below.

###### Deemed Lifetime of Efficient Equipment

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year. For the residential and multi-family sector, this changes based on where the lamp is used and varies from 4.2 years (multi-family common areas) to 26 years (residential home).

###### Deemed Measure Cost

Wherever possible, actual incremental costs should be used. Refer to reference table “Residential LED component Cost & Lifetime” for defaults.

###### Deemed O&M Cost Adjustments

Refer to reference table “Residential LED component Cost & Lifetime.”

###### Loadshape

|  |
| --- |
| Loadshape R06 – Residential Indoor Lighting |
| Loadshape R07 – Residential Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor is assumed to be 9.5%[[1]](#footnote-1) for Residential and in-unit Multi Family bulbs and 75%[[2]](#footnote-2) for Multi Family common area bulbs.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((Wattsbase-WattsEE)/1000) \* Hours \*WHFe\*ISR

Where:

Wattsbase = Input wattage of the existing system. Reference the “LED New and Baseline Assumptions” table for default values.

WattsEE = = Actual wattage of LED purchased / installed

For ENERGY STAR rated Omnidirectional Lamps - ENERGY STAR Minimum Luminous Efficacy = 50Lm/W for <10W lamps and 55Lm/W for >=10W lamps.

**LED New and Baseline Assumptions Table**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Nominal wattage of lamp to be replaced  (Wattsbase) | Minimum initial light output of LED lamp (lumens) | LED Wattage  (WattsEE) | Delta Watts | Post EISA 2020 requirement (45Lm/W) | Effective date for post EISA 2020 assumption | Delta Watts (post EISA 2020) |
| 25 | 200 | 4.0 | 21.0 | 25 | Exempt | 21.0 |
| 29 | 325 | 6.5 | 22.5 | 7.2 | June 2020 | 0.7 |
| 29 | 450 | 9.0 | 20.0 | 10 | June 2020 | 1.0 |
| 43 | 800 | 14.5 | 28.5 | 17.8 | June 2020 | 3.3 |
| 53 | 1,100 | 20.0 | 33.0 | 24.4 | June 2020 | 4.4 |
| 72 | 1,600 | 29.1 | 42.9 | 35.6 | June 2020 | 6.5 |
| 72 | 2,000 | 36.4 | 35.6 | 44.4 | June 2020 | 8.0 |
| 150 | 2,600 | 47.3 | 102.7 | 150 | Exempt | 102.7 |

ISR = In Service Rate, the percentage of units rebated that are actually in service.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Program** | **Weighted Average 1st year In Service Rate (ISR)** | **2nd year Installations** | **3rd year Installations** | **Final Lifetime In Service Rate** |
| Retail (Time of Sale) or Efficiency Kits | 69.5%[[3]](#footnote-3) | 15.4% | 13.1% | 98.0%[[4]](#footnote-4) |
| Direct Install | 96.9%[[5]](#footnote-5) |  |  |  |

Hours = Average hours of use per year

|  |  |
| --- | --- |
| **Installation Location** | **Hours** |
| Residential and in-unit Multi Family | 938 [[6]](#footnote-6) |
| Multi Family Common Areas | 5,950 [[7]](#footnote-7) |
| Exterior | 1,825 [[8]](#footnote-8) |
| Unknown | 1,000 [[9]](#footnote-9) |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

|  |  |
| --- | --- |
| Bulb Location | WHFe |
| Interior single family or unknown location | 1.06 [[10]](#footnote-10) |
| Multi family in unit | 1.04 [[11]](#footnote-11) |
| Multi family common area | 1.04 [[12]](#footnote-12) |
| Exterior or uncooled location | 1.0 |

**Mid Life Baseline Adjustment**

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <300 and 2600+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2014, the full savings (as calculated above in the Algorithm) should be claimed for the first six years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

| Nominal wattage of lamp to be replaced  (Wattsbase) | Minimum initial light output of LED lamp (lumens) | Delta Watts (post EISA 2012-2014) | Adjustment made from date | Mid Life adjustment (made from June 2020) from first year savings | Delta Watts (post EISA 2020) |
| --- | --- | --- | --- | --- | --- |
| 25 | 200 | 21.0 | Exempt | Exempt | 21.0 |
| 35 | 325 | 22.5 | June 2020 | 2.5% | 0.7 |
| 40 | 450 | 20.0 | June 2020 | 3.2% | 1.0 |
| 60 | 800 | 27.6 | June 2020 | 7.3% | 3.3 |
| 75 | 1,100 | 33.0 | June 2020 | 8.0% | 4.4 |
| 100 | 1,600 | 42.9 | June 2020 | 9.2% | 6.5 |
| 125 | 2,000 | 35.6 | June 2020 | 9.0% | 8.0 |
| 150 | 2,600 | 102.7 | Exempt | Exempt | 102.7 |

For example, an 8W LED lamp, 450 lumens, is installed in the interior of a home in 2014. The customer purchased the lamp through an upstream program:

ΔkWH = ((29-8/1000)\*938\*1.06\*.695

= 14.5 kWh

For the bulbs installed in this first year, this value should be claimed for six years, i.e. June 2014 – May 2020, but from May 2020 until the end of the measure life for that same bulb, savings should be reduced to (14.5 \* 0.032 =) 0.46 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

###### Deferred Installs

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

Using the example from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through an upstream program in 2014.

ΔkWH1st year installs = ((29-8/1000)\*938\*1.06\*.695

= 14.5 kWh

ΔkWH2nd year installs = ((29-8/1000)\*938\*1.06\*.154

= 3.2 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

ΔkWH3rd year installs = ((29-8/1000)\*938\*1.06\*.131

= 2.7 kWh

###### Heating Penalty

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

∆kWh[[13]](#footnote-13) = - (((WattsBase - WattsEE) / 1000) \* ISR \* Hours \* HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[[14]](#footnote-14) for interior or unknown location

= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[[15]](#footnote-15):

|  |  |  |  |
| --- | --- | --- | --- |
| **System Type** | **Age of Equipment** | **HSPF Estimate** | **ηHeat**  **(COP Estimate)** |
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| After 2006 | 7.7 | 2.26 |
| Resistance | N/A | N/A | 1.00 |

Using the same 8 W LED that is installed in home with 2.0 COP Heat Pump (i.e., the heat pump was installed prior to 2006):

∆kWh1st year = - (((29-8) / 1000) \* 0.695 \* 938 \* 0.49) / 2.0

= - 3.4 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

###### Summer Coincident Peak Demand Savings

∆kW = ((WattsBase - WattsEE) / 1 000) \* ISR \* WHFd \* CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

|  |  |
| --- | --- |
| **Bulb Location** | **WHFd** |
| Interior single family or unknown location | 1.11[[16]](#footnote-16) |
| Multi family in unit | 1.07[[17]](#footnote-17) |
| Multi family common area | 1.07 [[18]](#footnote-18) |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure.

|  |  |
| --- | --- |
| **Bulb Location** | **CF** |
| Interior single family or unknown location | 9.5% [[19]](#footnote-19) |
| Multi family in unit | 9.5% [[20]](#footnote-20) |
| Multi family common area | 75% [[21]](#footnote-21) |

Other factors as defined above

For the same 8 W LED that is installed in a single family interior location in 2014, the demand savings are:

ΔkW = ((29-8) / 1000) \* 0.695\* 1.11 \* 0.095

= 0.0015 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Std Inc.** | **EISA Compliant Halogen** | **LED-A** |
| 2014 | $0.34 | $1.25 | $13.81 |
| 2015 | $0.34 | $0.90 | $10.86 |
| 2016 | $0.34 | $0.80 | $8.60 |
| 2017 | $0.34 | $0.70 | $7.74 |
| 2018 | $0.34 | $0.60 | $6.96 |
| 2019 | $0.34 | $0.60 | $6.27 |
| 2020 & after | $0.34 | N/A | $5.64 |

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

|  |  |  |  |
| --- | --- | --- | --- |
| Installation Location | Omnidirectional LED Measure Hours (A) | Hours of Use per year (B) | Measure Life in Years (A/B) |
| Residential and in-unit Multi Family | 25,000 | 938 [[22]](#footnote-22) | 26.7 |
| Multi Family Common Areas | 25,000 | 5,950 [[23]](#footnote-23) | 4.2 |
| Exterior | 25,000 | 1,825 [[24]](#footnote-24) | 13.4 |
| Unknown | 25,000 | 1,000 [[25]](#footnote-25) | 25 |

The NPV for replacement lamps and annual levelized replacement costs using the statewide real discount rate of 5.23% are presented below:

| **Location** | **Lumen Level** | **NPV of replacement costs for the period** | | **Levelized annual replacement cost savings** | |
| --- | --- | --- | --- | --- | --- |
| **June 2014 - May 2020** | **June 2020- May 2025** | **June 2014 - May 2020** | **June 2020- May 2025** |
| Residential and in-unit Multi Family | Lumens <310 or >2600 (incandescent lamps) | $1.86 | $1.55 | $1.22 | $1.16 |
| Lumens ≥ 310 and ≤ 2600 (halogen lamps) | $4.30 | $2.42 | $1.19 | $1.16 |
| Multi Family Common Areas | Lumens <310 or >2600 (incandescent lamps | $11.61 | $8.70 | $1.22 | $1.16 |
| Lumens ≥ 310 and ≤ 2600 (halogen lamps) | $27.28 | $15.36 | $1.19 | $1.16 |
| Exterior | Lumens <310 or >2600 (incandescent lamps) | $3.56 | $2.67 | $1.22 | $1.16 |
| Lumens ≥ 310 and ≤ 2600 (halogen lamps) | $8.37 | $4.71 | $1.19 | $1.16 |
| Unknown | Lumens <310 or >2600 (incandescent lamps) | $1.95 | $1.46 | $1.22 | $1.16 |
| Lumens ≥ 310 and ≤ 2600 (halogen lamps) | $4.58 | $2.58 | $1.19 | $1.16 |

Note incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For these lamps there is no baseline shift and so the assumption is a baseline replacement cost of $0.34 for each replacement cycle. For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[[26]](#footnote-26) The replacement cycle is based on the location of the lamp and varies based on the hours of use for that location. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

## Net to Gross Ratio

No research has occurred to date that is specific to a NTGR for LEDs. Recommend use of 0.80 until a better value is determined.

# Stakeholder Comments

## Author (Company) and Date

1. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. “ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols” <http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf>

   “Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team” <http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf> [↑](#footnote-ref-1)
2. Coincidence factor is based on healthcare/clinic value (used as proxy for multi family common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois. [↑](#footnote-ref-2)
3. 1st year in service rate is based upon review of PY1-3 evaluations from ComEd and Ameren (see ‘IL RES Lighting ISR.xls’ for more information. The average first year ISR for each utility was calculated weighted by the number of bulbs in the each year’s survey. This was then weighted by annual sales to give a statewide assumption. [↑](#footnote-ref-3)
4. The 98% Lifetime ISR assumption is based upon review of two evaluations:

   ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. [↑](#footnote-ref-4)
5. Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010. <http://www.icc.illinois.gov/downloads/public/edocket/287090.pdf>. [↑](#footnote-ref-5)
6. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

   <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-6)
7. Multi family common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. [↑](#footnote-ref-7)
8. Based on secondary research conducted as part of the PY3 ComEd Residential Lighting Program evaluation. <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-8)
9. Assumes 7% exterior lighting, based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-9)
10. The value is estimated at 1.06 (calculated as 1 + (0.66\*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 \* SEER2) + (1.12 \* SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey; <http://www.eia.gov/consumption/residential/data/2009/xls/HC7.9%20Air%20Conditioning%20in%20Midwest%20Region.xls> ) [↑](#footnote-ref-10)
11. As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average); <http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls> [↑](#footnote-ref-11)
12. Ibid. [↑](#footnote-ref-12)
13. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-13)
14. This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes. [↑](#footnote-ref-14)
15. These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. [↑](#footnote-ref-15)
16. The value is estimated at 1.11 (calculated as 1 + (0.66 \* 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load. [↑](#footnote-ref-16)
17. As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average); <http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls>. [↑](#footnote-ref-17)
18. Ibid [↑](#footnote-ref-18)
19. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. “ComEd Residential Energy Star Lighting Program Metering Study: Overview of Study Protocols” <http://www.icc.illinois.gov/downloads/public/edocket/303835.pdf>

    “Memo RE: Lighting Logger Study Results – Version 2, Date: May 27, 2011, To: David Nichols and ComEd Residential Lighting Interested Parties, From: Amy Buege and Jeremy Eddy; Navigant Evaluation Team” <http://www.icc.illinois.gov/downloads/public/edocket/303834.pdf> [↑](#footnote-ref-19)
20. Ibid. [↑](#footnote-ref-20)
21. Coincidence factor is based on healthcare/clinic value (used as proxy for multi family common area lighting with similar hours of use) developed using Equest models for various building types averaged across 5 climate zones for Illinois for the following building types. [↑](#footnote-ref-21)
22. Based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation.

    <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-22)
23. Multi family common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. [↑](#footnote-ref-23)
24. Based on secondary research conducted as part of the PY3 ComEd Residential Lighting Program evaluation. <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-24)
25. Assumes 7% exterior lighting, based on lighting logger study conducted as part of the PY3 ComEd Residential Lighting Program evaluation. <http://www.icc.illinois.gov/downloads/public/edocket/323818.pdf> [↑](#footnote-ref-25)
26. The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent. [↑](#footnote-ref-26)