Ex Ante Update for ESPI Uncertain measures
Compact Fluorescent Lamps
19 May 2015

The California Lighting and Appliance Saturation Surveys (CLASS 2012)[1] and the Residential Upstream Lighting Program Evaluation (WO28)[2] research indicate significant revisions to CFL gross, net and lifecycle savings calculations are needed. Some of the critical outcomes of this research include:

- Saturation of CFLs in sockets has increased since the completion of the 2006-2008 program cycle data collection, however at a decreasing rate.
- The saturation increase does not account for the total number of lamps (both program and non-program) sold during the program cycle, which is an indication of a high number of CFL-to-CFL replacements, early removals and burnouts, or a combination of both.
- A primary issue identified by the inclusion of this technology in the ESPI uncertain measure list for 2013-2014 is the portion of CFL-to-CFL that should be considered as part of the gross savings analysis. The fraction of CFL-to-CFL replacements that should be included into the gross savings should not include those which would revert back to an inefficient lighting technology absent the program. The previously recommended and adopted DEER NTG value for upstream screw-in CFLs assumes that approximately 40% of all program CFL lamps would not have been purchased and installed absent the program AND that the sockets where those program lamps were eventually installed would have had an incandescent lamp installed and NOT a non-program CFL.
- If CFL-to-CFL replacements, due to all mechanisms such as early CFL removals and burned-out CFLs, are included in the gross baseline, then it is not necessary to know the breakdown among these categories. The challenge of determining and appropriate EUL remains, but the first year gross savings calculation becomes more straightforward.
- As discussed above, the high CFL-to-CFL replacement level confounds the calculation of life-cycle savings and overall cost-effectiveness because of the implied lower EUL than is currently included in DEER.

Gross Unit Energy Savings

Unit energy savings (UES) values for lighting measures are calculated using ex-ante parameter values applied to a reference method provided in the equations below.

$$UES_{kWh} = (kW_{base} - kW_{msr}) * HOU * IEF_{kWh} \qquad \textit{Equation 1}$$
$$UES_{kW} = (kW_{base} - kW_{msr}) * CDF * IEF_{kW} \qquad \textit{Equation 2}$$
$$UES_{therm} = UES_{kWh} * IEF_{therm} \qquad \textit{Equation 3}$$

Where:

UES_{kWh}: The unit energy consumption savings

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[1] FINAL REPORT, WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012), Prepared for: California Public Utilities Commission, Energy Division 2010-2012 EM&V Work Order 21 – Residential On-site Study, Prepared by: KEMA, Inc., November 24, 2014.

[2] California Upstream and Residential Lighting Impact Evaluation, Work Order 28 (WO28) Final Report, California Public Utility Commission, Energy Division, Prepared by KEMA, Inc., 8/4/2014.

UES_{kW}: The unit energy demand savings

UES_{therm}: The unit energy natural gas savings (always negative for lighting measures)

kW_{base}: The input power of the base fixture, above which the savings are calculated.

kW_{msr}: The input power of the measure fixture.

HOU: The annual hours of use

IEF_{kWh}: The annual HVAC interactive effects factor for energy consumption, expressed as kWh/kWh. This factor represents the additional savings benefits due reduced installed lighting power which results in reduced operation of air conditioning systems.

CDF: The coincident demand factor, which represents the total fraction of lights turned on during the DEER peak demand period

IEF_{kW}: The HVAC peak demand interactive effects factor, expressed as kW/kW. This factor represents the additional demand reduction due to reduced installed lighting power which results in lower overall cooling demand during the DEER peak demand period.

IEF_{therm}: The HVAC natural gas heating interactive effects factor, expressed as therm/kWh. This factor represents the additional natural gas consumptions needed due to reduced installed lighting power, which results in increased operation of natural gas heating equipment.

A wattage reduction ratio (WWR) is defined in terms of the ratio of baseline wattage to measure wattage (kW_{base}/kW_{msr}). The WRR represents the ratio of the typical replaced inefficient wattage to the typical installed CFL wattage. Equations 1, 2 and 3 can be restated in terms of the WRR as[3]:

$$UES_{kWh} = kW_{msr} * (WRR - 1) * HOU * IEF_{kWh} \qquad \textit{Equation 1a}$$
$$UES_{kW} = kW_{msr} * (WRR - 1) * CDF * IEF_{kW} \qquad \textit{Equation 2a}$$
$$UES_{therm} = UES_{kWh} * IEF_{therm} \qquad \textit{Equation 3}$$

Hours of Use and Coincident Demand Factors

The current DEER hours of use for residential CFLs were last revised for DEER2011. The overall HOU and CDF values were developed from field logger data collected under the 2006-2008 program evaluation for a wide range of space, use and socket types, then weighted together to develop a typical usage profile that reasonably represents the entire population of CFL lamps. Once typical usage profiles were fully developed, annual hours of use were calculated based application of those profiles over a full year of operation, and CDFs were developed by identifying the portion of the profile that applies to the DEER peak demand period and calculating the fraction of lights on during that period.

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[3] Refer to "DEER2014-Lighting-IE_and_Adjustment-Factor-Tables-17Feb2014.xlsx", sheet "Example Calcs" available at www.deeresources.com.

The 2006-2008 Upstream Lighting Program (ULP)[4] and WO28 evaluations[5] have confirmed that CFL purchasers tend to install CFLs in their highest usage sockets first. As saturation increases, overall HOU and CDF values for the population of CFLs decreases and approaches the HOU and CDF values for the remaining installed incandescent lamps. Table 1 shows the HOU and CDF from DEER2008 and DEER2011 for interior and exterior CFLs. The table also lists the HOU and CDF values based on the ULP logger data for interior and exterior incandescent lamps. Generally, HOU and CDF values decrease with more recent data and also the between HOU values for CFL and incandescent lamps decreases. However, these trends do not hold for exterior installations. For exterior installations, the CDF values are higher for incandescent lamps than for CFLs, raising concerns with the underlying data as discussed below.

Table 1 Residential CFL Hours of Use and Coincident Demand Factors

INTERIOR						
		CFL			Incandescent	
Year	IOU	Hours of Use		CDF	Hours of Use		CDF
		Annual	Daily	All	Annual	Daily	All
2011	SCE	628	1.72	0.056 - 0.063	452	1.24	0.046 - 0.053
2011	SDG&E	422	1.16	0.021 - 0.027	362	0.99	0.032 - 0.037
2011	PG&E	496	1.36	0.038 - 0.045	377	1.03	0.036 - 0.038
2011	Overall	542	1.49	0.043 - 0.05	407	1.11	0.04 - 0.044
2008	Overall	796	2.18	0.087 - 0.092			
EXTERIOR						
		CFL			Incandescent	
Year	IOU	Hours of Use		CDF	Hours of Use		CDF
		Annual	Daily	All	Annual	Daily	All
2011	SCE	1343	3.68	0.136 - 0.142	740	2.03	0.158 - 0.165
2011	SDG&E	1128	3.09	0.1 - 0.104	649	1.78	0.146 - 0.15
2011	PG&E	1198	3.28	0.117 - 0.124	669	1.83	0.148 - 0.153
2011	Overall	1251	3.43	0.123 - 0.129	695	1.91	0.152 - 0.157
2008	Overall	1132	3.10	0.00			

Lighting logger data collected on-site for the 2006-2008 Small Commercial Contract Group (SmallCom)[6] and the 2010-2012 WO29[7] evaluations were combined with existing DEER data to update the non-residential CFL HOU and CDF values. This work was undertaken to first satisfy the need to update the ESPI uncertain measures but also incorporated into the DEER 2016 update. Table 2 contains a summary of the results of this on-site lighting logger data analysis for non-residential DEER building types. The values used in DEER2014 are compared to the values developed for use in DEER 2015-2016 for both HOU and CDF values. Details on the logger data and the assignments of sites, their space types and

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[4] Final Evaluation Report: Upstream Lighting Program Volume 1 and Volume 2, Prepared by: KEMA, Inc., Prime Contractor: The Cadmus Group, Inc., for the California Public Utilities Commission, Energy Division February 8, 2010.

[5] *Ibid.* 2.

[6] Small Commercial Contract Group Direct Impact Evaluation Report, prepared by Itron, Inc., prepared for California Public Utilities Commission, February 9, 2010.

[7] Nonresidential Downstream Lighting Impact Evaluation Report, Final Report and Final Report Appendices, prepared for California Public Utilities Commission, by Itron, Inc., August 5, 2014.

loggers to the DEER building types and their spaces can be found in the DEER 2016 supporting data for lighting profiles[8].

Table 2 - Summary of Non-Residential CFL Hours-of-Use and Coincident Demand Factors

	Annual Hours of Use		Coincident Demand Factor		Percent Change	
DEER Building Type	DEER2014	DEER2016	DEER2014	DEER2016	HOU	CDF
Assembly	2605	1181	0.53	0.23	-54.7%	-57.4%
Primary School	2272	1226	0.63	0.42	-46.1%	-32.8%
Secondary School	2438	1523	0.72	0.32	-37.5%	-56.2%
Community College	2509	1534	0.80	0.53	-38.9%	-33.9%
University	2313	2118	0.69	0.62	-8.4%	-9.6%
Relocatable Classroom	2623	1086	0.70	0.43	-58.6%	-38.0%
Grocery	4891	4898	0.69	0.78	0.1%	14.0%
Manuf. Light Industrial	3271	2265	0.92	0.51	-30.8%	-44.1%
Manufacturing Bio/Tech	4002	2030	0.85	0.54	-49.3%	-36.6%
Hospital	5365	5366	0.83	0.83	0.0%	0.0%
Nursing Home	4308	3425	0.67	0.49	-20.5%	-28.0%
Hotel	1961	1605	0.23	0.20	-18.2%	-15.8%
Motel	1813	968	0.20	0.08	-46.6%	-58.7%
Office - Large	2788	2038	0.71	0.48	-26.9%	-32.0%
Office - Small	2776	1517	0.69	0.46	-45.4%	-34.2%
Restaurant - Fast Food	4840	3716	0.81	0.67	-23.2%	-17.5%
Restaurant - Sit Down	4831	3676	0.80	0.62	-23.9%	-23.0%
Retail - 3-Story (Dept Store)	3428	1887	0.76	0.61	-45.0%	-19.8%
Retail - Large (Bigbox)	4195	2937	0.83	0.80	-30.0%	-3.2%
Retail - Small	3467	2264	0.88	0.53	-34.7%	-39.5%
Storage Conditioned	3450	2027	0.70	0.49	-41.2%	-29.8%
Storage Unconditioned	3450	1347	0.70	0.24	-60.9%	-66.4%
Refrigerated Warehouse	4792	4709	0.55	0.56	-1.7%	1.7%

Energy simulation of exterior lighting is not needed to estimate savings of exterior lighting measures since there are no HVAC interactive effects. However, annual HOU and CDF values should be, whenever possible, determined from lighting usage profiles that have been developed from field monitored data. Figure 1 includes the estimated profiles for exterior CFL and incandescent lamps, based solely on the field lighting logger data from WO28. The exterior logger data results present a particular problem in that they seem to indicate unexpected operation during daylight hours. The CFL profiles show decreasing "on" fractions during daylight hours, but also show a noticeable "bump" in usage during daylight hours. For incandescent lamps, the primary usage occurs during daylight hours. The ex ante team concluded that the lighting loggers may have been sensing sunlight rather than light from the lamp intended to be metered. For this reason the ex ante team has been previously not published the exterior profiles. Instead, only the annual HOU values have been published and the CDF has always been published as zero, which assumes no exterior lights are on during daylight hours.

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[8] See the "DEER2016 Commercial Indoor Lighting Profiles Development workbook" link under the "Commercial Indoor Lighting Profiles" heading on the DEER2016 page at http://deeresources.com/

Figure 1 - Exterior Usage Profiles by Lamp Type and Year Developed from Field Lighting Logger Data
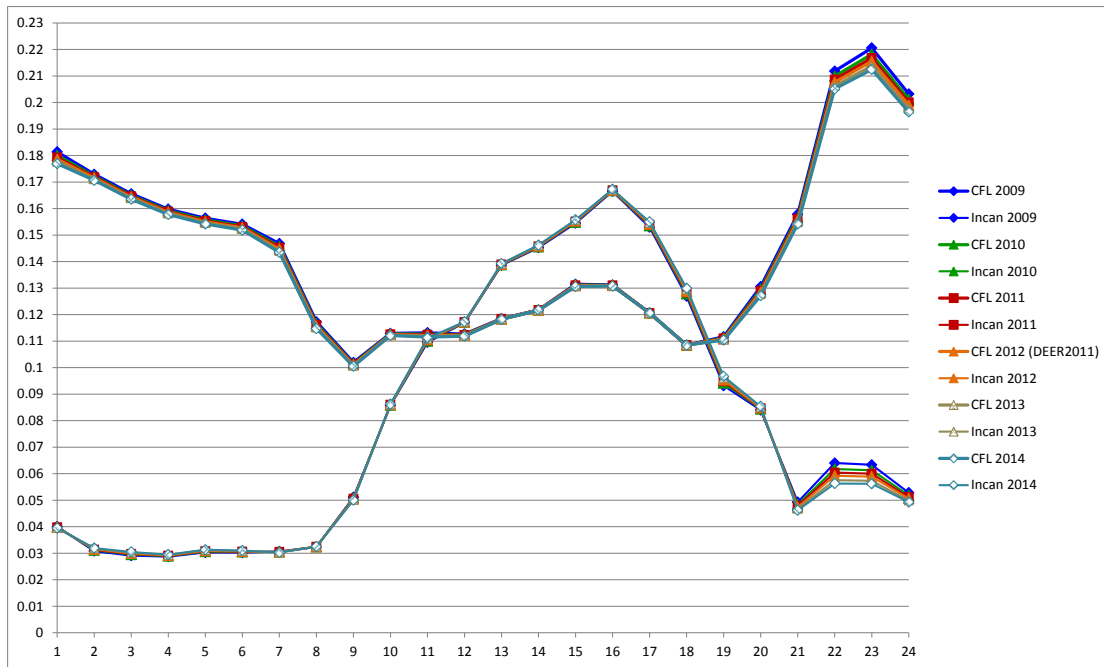
To account for the likely false readings of natural light as artificial light, the ex ante team adjusted each exterior CFL profile so that the lowest fraction on during daylight hours was equal to 10 percent of the highest fraction on during the 24 hour period. An arithmetic "smoothing" relationship was applied so that the profile gradually decreased after sunrise and increased after sunset. The resulting typical annual profiles are shown in Figure 2 and the overall results for HOU and CDF values are shown in Table 3.

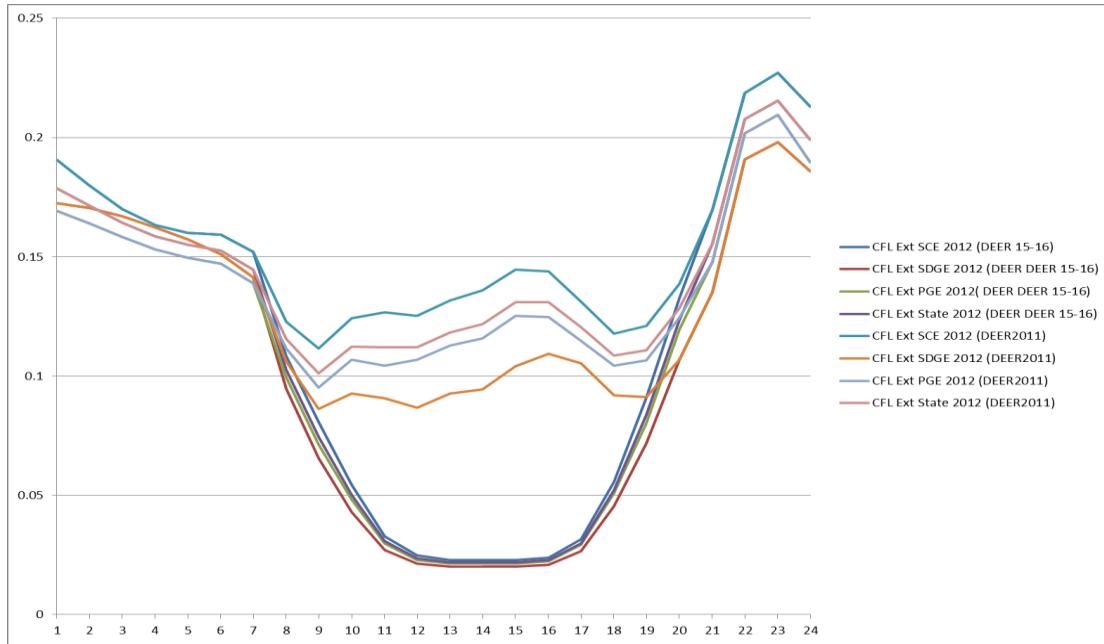**Figure 2- Adjusted Residential Exterior CFL Profiles**

Table 3- 2015-2016 vs 2011 Residential Exterior CFL Hours of Use and Coincident Demand Factors

EXTERIOR CFL 2015-2015 DEER ANALYSIS				
		CFL		
Year	IOU	Hours of Use		CDF
		Annual	Daily	All
2016	SCE	988	2.71	0.022
2016	SDG&E	882	2.42	0.020
2016	PG&E	901	2.47	0.020
2016	Overall	935	2.56	0.021
EXTERIOR CFL 2011 DEER ANALYSIS				
		CFL		
Year	IOU	Hours of Use		CDF
		Annual	Daily	All
2011	SCE	1343	3.68	0.136 - 0.142
2011	SDG&E	1128	3.09	0.1 - 0.104
2011	PG&E	1198	3.28	0.117 - 0.124
2011	Overall	1251	3.43	0.123 - 0.129

Wattage Reduction

The ex ante team current recommendation has included CFL-to-CFL replacements into the gross savings calculation. Table 4 is an excerpt of Table 63 of the WO28 report[9]. The table provides the results of an

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[9] *Ibid.* 2.

installation trajectory analysis and shows a year-over-year increase in CFL installations of about four million. This analysis is based upon the observed CFL installation saturation data from the 06-08 upstream impact evaluation[10] (the observations in 2009) and 2012 CLASS study[11] (observations in 2012), then projected forward into 2013 and 2014. Particular attention should be given to the red highlighted rows in the table. Table 5 extracts the rows from Table 4 relevant to the calculation of the fraction of total CFL purchases that are projected to be CFL-to-CFL replacements. Since there are a total of over 30 million CFLs sold in each year, and about 15 million of those are program incented lamps, yet the increase in socket saturation for CFLs is only about 3 million it is implied that the overwhelming majority of those CFLs are being used to replace existing (thus early removed or burned out) CFLs. If we attribute 100% of the increased CFL saturation to program activities, we still have 80% of program CFLs being CFL-to-CFL replacements. The most recent survey results from WO28 indicate that approximately 40% of CFLs would revert back to an incandescent lamp when the CFL is removed, for whatever reason the removal takes place. This would translate into 52% (40% reversions of 80% CFL-to-CFL replacement plus 20% new saturation) of the program lamps being incandescent replacements. The ex ante team recommends using a 60% incandescent replacement assumption at this time.

The results presented in the WO28 report are based on the previously utilized assumption that gross savings are based on 100% CFL-to-incandescent replacements and that CFL-to-CFL replacements are considered in the determination of the NTG value. The ex ante team recommendation replaces this assumption with the 60% assumption derived above. Using a 100% assumption indicates a regressive baseline, which is contrary to CPUC policy[12]. The ex ante team has recalculated the DEER 2011 wattage reduction ratios to account for 40% of installed CFLs replacing existing CFLs of the same wattage instead of incandescent lamps as shown in Table 6.

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[10] *Ibid.* 4.

[11] *Ibid.* 1.

[12] D.12-05-015 at 351:

   In the cases when there is no regulation, code, or standard that applies, which would normally set the baseline equipment requirements, the baseline must be established using a "standard practice" choice. For purposes of establishing a baseline for energy savings, we interpret the standard practice case as a choice that represents the typical equipment or commonly-used practice, not necessarily predominantly used practice. We understand that the range of common practices may vary depending on many industry- and/or region-specific factors and that, as with other parameters, experts may provide a range of opinions on the interpretation of evidence for standard practice choice. Here again, we expect Commission Staff to use its ex ante review process to establish guidelines on how to determine a standard practice baseline.

   Independent of the baseline selection criteria, we would not expect that new equipment proposed for program incentive support would be simply a like-replacement of the existing equipment in efficiency level, as this would imply either a repair or normal replacement that would not qualify as an energy efficiency upgrade, unless: (1) the proposed equipment exceeds standard practice or code, and (2) there is clear evidence that without support, the efficiency level would fall to the standard practice or code minimum.

Table 4 - Installation Trajectory Analysis (excerpt)

Table 63: Installation Trajectory Analysis – Statewide Sprial and A-Lamp						
Spiral and A-Lamp	2009	2010	2011	2012	2013	2014
Program discounted bulbs	23	23.7	17.2	18.3	15	15
Bulbs going to non-res	1.2	1.7	1.2	1.3	1.1	1.1
Sold in Following year	2.8	2.8	2.1	2.2	1.8	1.8
Total program CFLs	21.9	24.8	18.9	19.1	16.1	15.8
Total Market CFLs bought	31.2	35.4	31.4	31.8	32.3	31.5
CFLs Installed at start of year	77	87.8	99.9	105.7	110.5	114.7
CFLs in storage at start of year	27.9	29.4	31.2	31.8	32.3	32.8
CFLs burning out / breakage	11.6	13.2	15	15.9	16.6	17.2
CFLs early-replacement	7.7	8.8	10	10.6	11.1	11.5
CFLs out of storage	19.3	21.9	25	26.4	27.6	28.7
CFLs left in storage	8.6	7.5	6.2	5.4	4.7	4.1
Net increase in stock	12	13.5	6.4	5.3	4.7	2.8
CFLs to permanent storage	0.4	0.4	0.2	0.2	0.1	0.1
Net Storage	1.2	1.3	0.6	0.5	0.5	0.3
Net installs	10.8	12.1	5.8	4.8	4.2	2.5
Number installed at end of year	87.8	99.9	105.7	110.5	114.7	117.2
Number in Permanent storage at end of year	1.2	1.6	1.8	2	2.1	2.2

Table 5 - CFL-to-CFL Replacements as a percentage of total CFL Purchases

	2009	2010	2011	2012	2013	2014
Total Market CFLs bought	31.2	35.4	31.4	31.8	32.3	31.5
Total program CFLs	21.9	24.8	18.9	19.1	16.1	15.8
Program % of market	70%	70%	60%	60%	50%	50%
Number installed at start of year		87.8	99.9	105.7	110.5	114.7
Replacements as % of installed		25%	25%	25%	25%	25%
CFLs burning out / breakage	11.6	13.2	15	15.9	16.6	17.2
as % of installed		15%	15%	15%	15%	15%
CFLs early-replacements	7.7	8.8	10	10.6	11.1	11.5
as % of installed		10%	10%	10%	10%	10%
Total replaced CFL-to-CFL	19.3	22	25	26.5	27.7	28.7
% CFL-to-CFL of total bought	62%	62%	80%	83%	86%	91%

Table 6 - Revised Residential CFL Wattage Reduction Ratios

Lamp Type	DEER2011 Measure Watts	DEER2011 Base Watts	DEER2011 Ratio	DEER2016 Base Watts (assumes 40% CFL-to-CFL)	DEER2016 Ratio
Interior reflector lamps	16.28	66.62	4.09	46.48	2.86
Interior non-reflector lamps	17.19	59.67	3.47	42.68	2.48
Exterior lamps	17.88	72.72	4.07	50.78	2.84

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Net-to-Gross Ratio

As discussed above, WO28 ex post NTG results assume that all CFL-to-CFL replacements should be considered in the development of NTG rather than the determination of gross savings. WO28 investigated the likelihood that, on burnout, a socket with a CFL would revert to an incandescent lamp. Those sockets that would not revert if program lamps were not available were considered free-riders, and served to reduce the NTG value. The ex ante team recommends that the CFL-to-CFL replacements that would not revert are indication of market transformation and that these purchasers should be included in the gross savings calculation with zero gross savings. Any reallocation of savings from NTG to gross savings, in consideration of CFL-to-CFL replacements will result in reduced gross savings and increased NTG values. The current DEER NTG is 0.54. Moving 40% of CFL-to-CFL replacements means that the NTG needs to be raised by a similar amount. To develop a new NTG value the CPUC adopted 5% market effects adder for all program from 2013 forward must be considered. The calculation above already allocates all saturation increase to the program activity, so there is no remaining gross saturation increase to allocate to the program via the market effects. This would indicate that the NTG value, before the market effects adder, should only be increased by 40% minus the adder. However, the ex-ante team believes 20% (0.01) of that market effect adder should be retained resulting in a recommended NTG value of 0.90 (.54+.40-.04).

Effective Useful Life

The high CFL-to-CFL replacement rate also indicates a reduction in the EUL for residential installations. DEER currently uses a EUL value calculated from the lamp "adjusted" rated life hours divided by the annual DEER HOU for the lamp. Using a typical rated life of 10,000 hours together with the DEER HOU rated life adjustment and the DEER residential interior HOU, the current DEER EUL works out to an approximate CFL burnout rate of 7% or less per year. However, the higher replacement rates from the WO28 analysis indicate a much higher burnout rate of about 25% per year. This is the first time successive large field observation samples of residential CFL saturation rates have been available to perform a estimation of CFL survival rates and thus a projection to observed EUL. The ex ante team prefers the use of field observation to laboratory technical potential to estimate EUL values.

 Table 7 shows the surviving percentages of installed CFLs based on 25%, 18% and 7% annual replacement rates. Using the WO28 model assumption of a total annual replacement rate of 25% would reduce the EUL substantially; the point at which 50% of the original installed measures are still in service, is between two and three years. An 18% annual replacement rate provides a EUL of approximately three and one half years. By contrast a 7% annual replacement rate provides for a EUL slightly over nine years. At this time, the EAR team recommends revising the EUL of residential CFLs to be three and one half (3.5) years. This value represents an annual replacement rate of approximately 18% which is much less than the WO 28 analysis assumes but seems a reasonable compromise between unsupportable past DEER assumption and the rather pessimistic but data supported WO28 assumption.

Table 7 - Years to Reach 50% Survival at Different CFL Replacement Rates

	Replacement Rate		
	WO 28		**DEER2011**
	25%	18%	7%
Year	**Surviving Percent**		
0	100%	100%	100%
1	75%	82%	93%
2	**56%**	67%	86%
3	**42%**	**55%**	80%
4	32%	**45%**	75%
5	24%	37%	70%
6	18%	30%	65%
7	13%	25%	60%
8	10%	20%	56%
9	8%	17%	**52%**
10	6%	14%	**48%**