Work Paper PGECOLTG175
LED Residential Recessed Downlight
Revision 4

Pacific Gas & Electric Company

Customer Energy Efficiency Department

LED Residential Recessed Downlight

Measure Codes: L1068, L1069, L1070

8/10/2017

At-A-Glance Summary

Applicable Measure Codes:	L1068, L1069, L1070
Measure Description:	LED Downlight kits must be fully integrated (including lamp, driver, and socket adapter), replacing R20, BR20, ER20 incandescent, or R30, BR30, ER30, R40, BR40, or ER40 incandescent or integral CFL lamps in recessed can fixtures.
Energy Impact Common Units:	Retrofit kit.
Base Case Description:	R20, BR20, ER20 incandescent, or R30, BR30, ER30, R40, BR40, or ER40 incandescent or integral CFL lamps in recessed can fixtures Source: PG&E Calculations.
Base Case Energy Consumption:	Various. Refer to .xlsx file attached Source: Based on WRR
Measure Energy Consumption:	Various. Refer to .xlsx file attached
Energy Savings (Base Case – Measure)	Various. Refer to .xlsx file attached
Costs Common Units:	$ per Retrofit kit.
Base Case Equipment Cost ($/unit):	Various. Refer to .xlsx file attached
Measure Equipment Cost ($/unit):	Various. Refer to .xlsx file attached
Measure Incremental Cost ($/unit):	Various. Refer to .xlsx file attached
Effective Useful Life (years):	Varies (max 12 years), ILtg-Com-LED-20000hr 16 years, ILtg-Res-LED-20000hr Source: DEER 2016
Program Type:	ROB
Net-to-Gross Ratios:	
Important Comments:	

NTGR ID	NTGR	Source
Com-Default>2yrs	0.6	DEER 2016
Res-Default>2	0.55	DEER 2016
Res-sAll-mLEDSpcl	0.6	Preliminary Ex Ante database[1]

Document Revision History

Revision #	Date	Description	Author (Company)
Revision 0	11/27/2012	PGECOLTG175 R0	Alina Zohrabian (PG&E)
Revision 0	1/22/2013	PGECOLTG175 R0 Updated Cost section	Jay Martin (EMCOR), reviewed by Alina Zohrabian (PG&E)
Revision 1	5/23/2014	PGECOLTG175 R1 Revised savings values per ED Workpaper Disposition for lighting Retrofit, December 14, 2013. For updated savings values, see file PGECOLTG175 R1.xlsx	Alina Zohrabian (PG&E)
Revision 2	1/1/2016	Updated NTG, annual hours of operation, IE, CDF, EUL, per DEER 2016. Costs have also been updated.	Linda Wan (PG&E)/ Alina Zohrabian (PG&E)/Tai Voong (PG&E)
Revision 3	11/28/2016	-Updated residential interactive effect (IE) factor per DEER 2017. -Saving update for L1070(Revised measure to 13w to reflect lowest end of range as per July 22, 2016 disposition) -Cost updated for L1068 and L1070 due to the disposition	Alina Zohrabian (PG&E)/Mini Damodaran (PG&E)/Tai Voong (PG&E)
Revision 4	8/10/2017	Replaced NTG ID “Res-sAll-MLtgLED-Deemed” which expired 6/30/2017 with “Res-sAll-mLEDSpcl”.	Mini Damodaran (PG&E)

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Section 1. General Measure & Baseline Data

1.1 Product Measure Description & Background

This work paper details the replacement of existing recessed CFL or incandescent fixtures with LED recessed retrofit kits.

Table 1 Product Code and Description

Product Code	Description
L1068	LED Recessed Downlight: Install <10 W LED
L1069	LED Downlight: Install ≥10 W to 12 W LED
L1070	LED Recessed Downlight: Install >12 W to 25 W LED

Program Requirements and Guidelines

The delivery method is the Upstream Lighting Program for residential customers. Multifamily customers can also apply through the downstream multifamily program.

- Rebates are based on a one-for-one replacement of incandescent or CFL fixtures up to 100 watts.
- Customers are responsible for verifying that new fixtures work with existing lighting controls.

Program Restrictions and Guidelines

To qualify for a rebate, the following requirements must be met:

- All new LED retrofit kits must be on the ENERGY STAR qualified products list and be listed with the Department of Energy Lighting Facts Program.
- LED Downlight retrofit kits must be fully integrated (including lamp, driver, and socket adapter), replacing R20, BR20, ER20 incandescent, or R30, BR30, ER30, R40, BR40, or ER40 incandescent or integral CFL lamps in recessed can fixtures.
- LED screw-in lamps are not eligible under these measures.
- The LEDs must meet a minimum luminaire efficacy of 42 lm/W.
- Downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E-283 standard test method[i] to demonstrate no more than 2.0 cfm at 75 Pa pressure difference, and must display a label certifying “airtight” or similar designation which shows accordance with this requirement.
- A product cut sheet must be provided.

Terms and Conditions

The customer must be a residential PG&E electrical customer.

Market Applicability

Single and multi-family installations are eligible. Fixtures with incandescent reflector lamps are mostly used in residential sector, including multifamily.

Table 2 Delivery Method and Applicable Building Types

Delivery Type	Applicable Building Types	Application Type
Upstream	“Com,” “Res”	ROB
Downstream	“MFm”	ROB

1.2 Product Technical Description

Light emitting diode (LED) sources have improved over the past decade, making them an efficient lighting technology. Electricity usage for lighting in the U.S. is projected to be 19% lower in 2020 and 46% lower in 2030 if LED lighting is adopted for general illumination applications.[2] Many LED products are marketed

as incandescent or halogen replacements. The lumen output and efficacy of many LED products are comparable to, or exceed that, of compact fluorescent, halogen, and incandescent sources.[3]

LED products offer many advantages over conventional lighting products, including energy savings, long operating life, reduced radiated heat, minimal light loss, dimmability and controllability, durability, enhanced performance at low temperatures, safety improvements, smaller package size, uniform illumination, mercury reduction, enhanced product appearance, improved color rendition, and lower lumen depreciation.[4]

LED Downlight retrofit kits must be fully integrated (including lamp, driver, and socket adapter), replacing R20, BR20, ER20 incandescent, or R30, BR30, ER30, R40, BR40, or ER40 incandescent or integral CFL lamps in recessed can fixtures. This workpaper bases assumptions on Rounds 12 and 14 of the Commercially Available LED Product Evaluation and Reporting (CALiPER) Program of the U.S. Department of Energy.[5]

1.3 Measure Application Type

The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*, defines the terms as follows:

Table 3 Measure Application Type[6]

Identifies the measure application type in the Measure Implemenation table in DEER2011.

Code	Description	Comment
ER	*Early retirement*	*measure applied while existing equipment still viable, or retrofit of existing equipment*
ROB	*Replace on Burnout*	*measure applied when existing equipment fails or maintenance requires replacement*
NC	*New Construction*	*measure applied during construction design phase as an alternative to a code-compliant standard design*

All the measures within this workpaper are ROB.

1.4 Product Base Case and Measure Case Data

The most common base case wattages are 40, 50, and 95 watts based on the analysis in the previous version. In this workpaper the base case is calculated based on the wattage reduction ratio of 3.42 recommended by Energy Division in December 14, 2013 lighting retrofit disposition. The measure case is the associated LED wattage.

1.4.1 DEER Base Case and Measure Case Information

The Database for Energy Efficient Resources (DEER) 2016 contains measures for LED fixtures using the Wattage Reduction Ratio (WRR) method. The base case wattages use the WRR of 3.42. The measure case is the associated LED wattage.

Hours of Operation

The DEER hours of operation and interactive effects are used for savings calculations.

Net-to-Gross Assumption
The NTG values are from DEER 2016 except for the NTG ID "Res-sAll-MLtgLED-Deemed" expired on 6/30/2017, and are now replaced by "Res-sAll-mLEDSpcl" as per DEER Preliminary Review database's Support table for NTG. The table below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 4 Net-to-Gross Ratios

NTGR ID	Description	Sector	BldgType	Delivery Method	NTGR
Com-Default>2yrs	All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years	Com	Any	Any	0.6
Res-Default>2	All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years	Res	Any	Any	0.55
Res-sAll-mLEDSpcl	All residential specialty LED lamps (other than A-lamp and screw-in reflector)	Res	Any	Any	0.6

Spillage Rate
Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

Installation Rate
The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below:

Table 5 Installation Rate

GSIA ID	Description	Sector	BldgType	ProgDelivID	GSIAValue
Def-GSIA	Default GSIA values	Any	Any	Any	1

Effective Useful Life / Remaining Useful Life:
Although the minimum lamp life in Energy Star is 25,000 hours and most products show a lamp life of 25,000 or 35,000 hours, the Energy Division recommended a lamp life of 20,000 hours. Since the effective useful life (EUL) is dependent on the hours of operation, the EUL varies by building type. The Energy Division also recommended using a maximum value of 12 years for EUL, which is the life of a pin-based CFL fixture in commercial application.

The EUL is calculated using the following equation:

EUL = (Lamp Life (20,0000 hours)) / (Average Operating Hours Per Year)

Table 6 Effective Useful Life/Remaining Useful Life

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
ILtg-Com-LED-20000hr	LED Lamp - Indoor-Commercial	Com	Lighting	Varies (max of 12 years)	Varies
ILtg-Res-LED-20000hr	LED lamp - Indoor - Residential	Res	Lighting	16	5.33

1.4.2 Codes & Standards Requirements Base Case and Measure Information

Title 20: These measures do not fall under Title 20 [2015] of the California Energy Efficiency Regulations.
Title 24: These measures do not fall under Title 24 [2013] Non-Residential Building Energy Efficiency Standards.
Federal Standards: These measures do not fall under Federal DOE Energy Regulations.

1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

Since there is uncertainty regarding manufacturer's claims of LED efficiency, this work paper draws from the Commercially Available LED Product Evaluation and Reporting (CALiPER) Program of the U.S. Department of Energy. The CALiPER reports[3] provide not only objective product testing following the IES LM-79 method[7] and a comparison against manufacturers' published photometric data, but also energy performance data from base case and measure case equipment mounted in insulated recessed cans; this goniophotometric data is valuable as a true reflection of luminaire efficacy *in situ*.

The original edition of this work paper followed the model established by the PG&E "Compact Fluorescent Reflector Lamp" work paper,[8] therefore identifying the American Council for an Energy-Efficient Economy study *Analysis of Standards Options for BR, ER, and R20 Incandescent Lamps*[9] as providing relevant technical, economic, market, and infrastructure standards on current reflector lamp equipment. Other studies cited in the original analysis included SERA's *Revised / Updated EULs Based on Retention and Persistence Studies Results* and KEMA's *Illuminating Current CFL Usage Patterns: Results from a CFL Metering Study*.[10, 11]

In 2009, the market penetration of LED replacements for PAR, BR, and R shaped lamps was 0.2%.[44] Indoor general illumination applications have the potential to save substantial amounts of electricity.

Delta wattage Assumption (ΔW): In CALiPER Rounds 12 and 14, LED downlights were benchmarked against incandescent equivalents. CALiPER Round 14 states, "The [LED] products were between 527 and 803 lumens and are roughly comparable to 60 to 100 W incandescent downlights."[3] The tested LED products ranged in power draw from 10 W, comparable to 60 W incandescent, up to approximately 15 W, comparable to a 100 W incandescent downlight fixture. The base case and measure case fixture wattages for this work paper were established based on the CALiPER results, and conservatively selected as 15 W LED replacing a 95 W incandescent and a 10 W LED replacing a 60 W incandescent. This workpaper also considers the ED's LED integral lamp disposition which suggests that 25% of the base case should be CFL lamps.

The CALiPER Program's photometric testing was considered when employing manufacturer's claims of luminaire efficacy.[12] The CALiPER results correlate the efficacy of integrated LED luminaires to the lumen output and power draw ratings claimed in the manufacturers' specifications; this work paper assumes similar authenticity from other current integrated LED luminaires (complete retrofit) solutions. A relative reduction in lumen output is factored into the measure case selections. Case studies[13] have proven maintained minimum illumination levels, greater uniformity, and customer acceptance with LED replacements; these are assumed as inherent factors of this retrofit.

Categories of replacement fixtures were established due to variation in power consumption and lumen output as reported in the CALiPER results. The categories are labeled as first, second, and third tier in the table below. Fixture efficacy on average is reported as being generally higher in the ENERGY STAR qualified product list as compared to the CALiPER reports. For example, ENERGY STAR reported efficacy was 62 lm/W for the first tier, 55 lm/W for the second tier, and 53 lm/W for the third tier. CALiPER reported efficacy was 27 lm/W for the first tier, 61 lm/W for the second tier, and 47 lm/W for the third tier. To be conservative, the CALiPER reports were used as the basis for determining LED replacements.

Table 7 Comparison of Base Case and Measure Case Efficacy

	Light Source	Category	CALi-PER Round	CALi-PER Refer-ence #	Power (W)	Initial Light Output (lm)	Initial Efficacy (lm/W)	CCT (K)	CRI	Power Factor	Base Case Wattage Range
First Tier											
Base Case	Incandescent	Replacement Lamp (R20) Incandescent	8	09-05	40	227	6	2,516	99	0.99	Up to 40 W
	Incandescent	Replacement Lamp (R16) Incandescent	8	09-08	40	233	6	2,529	100	1	
Average					40	230	6	2,523	100	1.00	
Measure Case	SSL*	Downlight (Track-spot)	12	10-40	9	249	26	2,723	79	0.8	Up to 40 W
	SSL*	Downlight (Track-spot)	12	10-43	9	309	36	3,028	81	0.98	
	SSL	Downlight (Track-spot)	12	10-57	5	136	25	2,996	93	0.53	
	SSL	Downlight (Track-spot)	8	09-33	9	204	22	2,557	83	0.8	
Average					8.0	225	27	2,826	84	0.78	
Second Tier											
Base Case	Incandescent	Replacement Lamp (A-lamp) Incandescent	11	10-31	61	823	14	2,771	100	1	41 W to 65 W
	Incandescent	Replacement Lamp (A-lamp) Incandescent	6	08-49	61	739	12	2,703	100	1	
	Incandescent	Outdoor Wall Incandescent	6	08-59	60	386	6	2,700	99	1	
	Incandescent	Replacement Lamp (A-lamp) Incandescent	5	08-04	55	353	7	2,491	99	1	
	Incandescent	Replacement Lamp (R30) Incandesecent	5	08-13	65	732	11	2,681	99	1	
Average					60.4	607	10	2,669	99	1.0	
Measure Case	SSL	Downlight (6" retrofit)	14	11-64	10	694	69	3,046	84	0.84	41 W to 65 W
	SSL	Downlight (6" retrofit in situ)	14	11-64i	10	689	69			0.84	
	SSL	Downlight (6" retrofit)	14	11-82	11	589	54	3,029	84	0.88	
	SSL	Downlight (6" retrofit in situ)	14	11-82i	11	542	49			0.87	
	SSL	Downlight (6" retrofit)	14	11-98	12	629	53	3,006	83	0.97	
	SSL	Downlight (6" recessed)	12	10-38	10	596	58	2,776	93	0.87	

Table 7 Comparison of Base Case and Measure Case Efficacy

	Light Source	Category	CALi-PER Round	CALi-PER Refer-ence #	Power (W)	Initial Light Output (lm)	Initial Efficacy (lm/W)	CCT (K)	CRI	Power Factor	Base Case Wattage Range
	SSL	Downlight (6" recessed)	12	10-41	12	935	75	2,729	91	0.97	
Average					11	668	61	2917	87	0.9	
Third Tier											
Base Case	Incandescent	Replacement Lamp (A-lamp) Incandescent	12	11-12	99	1,322	13	2,871	100		66 W to 100 W
	Incandescent	Replacement Lamp (A-lamp) Incandescent	12	11-25	90	1,245	14	2,764	100		
Average					94.5	1,284	14	2,818	100		
Measure Case	SSL	Downlight (6" retrofit)	14	11-63	14	576	40	3,174	81	0.94	66 W to 100 W
	SSL	Downlight (6" retrofit in situ)	14	11-63i	14	562	40			0.94	
	SSL	Downlight (6" retrofit)	14	11-73	14	817	58	3,196	78	0.92	
	SSL	Downlight (6" retrofit in situ)	14	11-73i	14	803	57			0.92	
	SSL	Downlight (6" retrofit)	14	11-74	14	614	44	3,007	80	0.95	
	SSL	Downlight (6" retrofit in situ)	14	11-74i	14	563	42			0.96	
	SSL	Downlight (6" retrofit)	14	11-75	15	801	55	3,073	82	0.98	
	SSL	Downlight (6" retrofit in situ)	14	11-75i	15	786	54			0.98	
	SSL	Downlight (6" retrofit)	14	11-76	14	568	41	3,172	82	0.91	
	SSL	Downlight (6" retrofit in situ)	14	11-76i	14	541	40			0.91	
	SSL	Downlight (6" retrofit)	14	11-96	14	619	45	3,083	81	0.98	
	SSL	Downlight (6" retrofit in situ)	14	11-96i	14	591	44			0.98	
	SSL	Downlight (6" retrofit)	14	11-97	14	577	42	2,925	81	0.94	
	SSL	Downlight (6" retrofit)	14	11-103	14	768	55	2,762	80	0.8	
	SSL	Downlight (6" retrofit in situ)	14	11-103i	14	769	55			0.8	
	SSL	Downlight (6" recessed)	14	11-104	17	962	55	2,946	77	0.99	
	SSL	Downlight (4" recessed)	12	10-49	18	874	48	2,967	78	0.98	
	SSL	Downlight (5" recessed)	12	10-50	17	699	41	3,028	82	0.98	

Table 7 Comparison of Base Case and Measure Case Efficacy

	Light Source	Category	CALi-PER Round	CALi-PER Refer-ence #	Power (W)	Initial Light Output (lm)	Initial Efficacy (lm/W)	CCT (K)	CRI	Power Factor	Base Case Wattage Range
	SSL	Downlight (6" recessed)	12	10-53	24	1,072	44	2,995	84	0.98	
Average					**15**	**714**	**47**	**3027**	**80.5**	**0.9**	

*Suitable for first and second tier.

1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

There are no further data or calculations provided for the support of the measures in this work paper.

Section 2. Calculation Methods

2.1 Electric Energy Savings Estimation Methodologies

The energy savings calculation is using the wattage reduction ratio (WRR) of 3.42 on the LED wattages in the measures case. The operating hours and interactive effects for Commercial were taken from DEER 2016 data. The operating hours and interactive effects for Residential were taken from DEER 2017. The energy savings is calculated based on the following formula:

$$Annual\,Energy\,Savings\left[\frac{kWh}{unit}\right] = (\Delta kW/unit) * (Annual\,hours\,of\,operation) * (Energy\,Interactive\,Effects)$$

$$(\Delta kW/unit) = ((Measure\,Case\,Wattage) * (WRR) - (Measure\,Case\,Wattage))$$

The following example calculation demonstrates the annual energy savings, kWh, for the multifamily building type, for the "LED Recessed Downlight: Install <10 W LED" measure:

$$Annual\,Energy\,Savings\left[\frac{kWh}{unit}\right] = (0.008 * 3.42 - 0.008) * (541) * (0.99) = 10.4$$

2.2. Demand Reduction Estimation Methodologies

The lighting demand difference (Watts per unit) is simply the difference between the electric demand of the base unit and the electric demand of the energy efficient unit. The Demand savings is calculated based on the formula below:

$$Demand\,Savings\left[\frac{kW}{unit}\right] = (\Delta kW/unit) * (Lighting\,Coincident\,Demand) * (Demand\,Interactive\,Effects)$$

The following example calculation demonstrates the peak demand reduction, kW, for the multifamily building type, for the "LED Recessed Downlight: Install <10 W LED" measure:

$$Demand\ Savings\left[\frac{kW}{unit}\right] = (0.008 * 3.42 - 0.008) * (0.044) * (1.22) = 0.00104$$

2.3. Gas Energy Savings Estimation Methodologies

The energy savings achieved via a reduction in lighting demand is partially offset by an increase in thermal energy needed for heating. The operating hours and interactive effects for Commercial were taken from DEER 2016 data. The operating hours and interactive effects for Residential were taken from DEER 2017. The gas savings is calculated based on the formula below:

$$Annual Gas\ Savings\left[\frac{Therm}{unit}\right] = (\Delta kW/unit) * (Annual hours of\ operation) * (Gas Interactive\ Effects)$$

The following example calculation demonstrates the natural gas savings, therms, for the multifamily building type, for the "LED Recessed Downlight: Install <10 W LED" measure:

$$Annual Gas\ Savings\left[\frac{Therm}{unit}\right] = (0.008 * 3.42 - 0.008) * (541) * (-0.0213) = -0.223$$

Section 3. Load Shapes

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure's load shape. The measure's load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure's Total Resource Cost (TRC) benefit.

3.1 Base Case Load Shapes

The base case load shape would be expected to follow a typical residential lighting end use load shape.

3.2 Measure Load Shapes

For purposes of the net benefits estimates in the E3 calculator, what is required is the load shape that ideally represents the *difference* between the base equipment and the installed energy efficiency measure. This *difference* load profile is what is called the Measure Load Shape and would be the preferred load shape for use in the net benefits calculations.

The measure load shape for this measure is determined by the E3 calculator based on the applicable residential market sector and the lighting end-use.

Table 8 Building Types and Load Shapes

Building Type	Load Shape	E3 Alternate Building Type
All Commercial Building Types	PGE:DEER:Com:Indoor_CFL_Ltg	NON_RES
All Residential Building Types	PGE:DEER:Indoor_CFL_Ltg	RES

Section 4. Base Case & Measure Costs

A joint effort was made between SCE and PG&E to update base case and measure costs for DEER 2016 affected measures. Please refer to the LED lamp cost workbook for detailed information.

4.1 Base Case(s) Costs

The base case costs are split into 25% CFL and 75% incandescent. CFL costs are taken from the READI Tool v 2.3.0. Costs not available from READI have been interpolated. Incandescent costs are calculated from WO017 workbook. The base case wattages are mapped to individual LED wattages using a table from the Energy Star Calculator.

4.2 Measure Costs

The technique of web scraping was used to gather pricing information from the Home Depot website for measure case costs. First, a small sample of products was examined between different online retailers to determine the need to include items from various retailers and the discrepancy between pricing. Please refer to the Competitive Pricing tab in the cost spreadsheet. Due to the competitive pricing of the same fixture from different retailers, only Home Depot data was examined in detail.

A manual process of examining reasonable cost was conducted by viewing the scatterplot of all costs and its associated rated wattages and categorizing the items into a high, medium, or low cost bin. Note that in some cases where enough data was scraped, only Energy Star lamps and fixtures were considered in the measure case and CA Title 20 compliant lamps and fixtures were considered in the base case.

Item descriptions were also viewed to understand the reasoning of such high costs. It was almost always found that items with high costs were associated with architectural features and/or specialty finishes. As a result, items that fell into the high cost category was not used in the calculations of cost for the work papers because it does not appropriately reflect the approach most consumers would take to implement energy efficiency projects. Refer to the cost spreadsheet for detailed information. Furthermore, the latest EM&V Study from Navigant for LED costs uses the 25th percentile for the median price.

Using the low and medium cost data from Home Depot, the best-fit line or linear regression was used to determine the association between fixture wattages and cost. Please see the cost spreadsheet for the specific linear regression equation generated for the low cost and medium cost. Raw data points are also included in the spreadsheet.

For work paper purposes, the costs are an equal representation of the medium and low cost categories. Therefore, the best representative association is the average of the trend line for medium cost and the trend line of the low cost. This process is not the same as a linear regression determined from the low and medium cost items combined. Due to the quantity in the data sampling, the items associated with the low or medium cost would influence the linear regression. For this reason, the best representative cost comes from the average of the linear regression from the medium cost and the linear regression from the cost. This is how cost is propagated for all the technology categories.

As with base case costs, the measure costs are also reduced by 30% to account for the bulk wholesale pricing discrepancy.

4.3 Incremental & Full Measure Costs

Table 9 Full and Incremental Measure Cost Equations

Installation Type	Incremental Measure Cost	Full Measure Cost	
		1st Baseline	2nd Baseline
ROB	(MEC + MLC) – (BEC + BLC)	(MEC + MLC) – (BEC + BLC)	N/A
NEW/NC			
RET/ER	(MEC + MLC) – (BEC + BLC)	MEC + MLC	(MEC + MLC) – (BEC + BLC)
REF	(MEC + MLC) – (BEC + BLC)	MEC + MLC	N/A
REA	MEC + MLC	MEC + MLC	N/A

MEC = Measure Equipment Cost; MLC = Measure Labor Cost
BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

The labor required installing base case or measure case is equivalent. Therefore, labor cost is not considered in incremental measure costs. For incremental measure costs please refer to the LED fixture cost spreadsheet.

References

[1] http://deeresources.com/index.php/ex-ante-database/best-practices-database

[i] ASTM International. *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen.* ASTM E283 - 04(2012). http://www.astm.org/Standards/E283.htm

[2] Navigant Consulting. *Energy Savings Potential of Solid-State Lighting in General Illumination Applications.* For the U.S. Department of Energy. January 2012. http://www1.eere.energy.gov/buildings/ssl/tech_reports.html

[3] DOE Solid-State Lighting CALiPER Program. *Application Summary Report 14* (March 2012)—downlight retrofit units. http://www1.eere.energy.gov/buildings/ssl/reports.html

[4] Navigant Consulting. *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications.* For the U.S. Department of Energy. January 2011. http://www1.eere.energy.gov/buildings/ssl/tech_reports.html

[5] DOE Solid-State Lighting CALiPER Program. *Round 12 Summary Report* (June 2011)—includes recessed downlight luminaires, track light luminaires, cove lighting luminaires, and other applications.
http://www1.eere.energy.gov/buildings/ssl/reports.html
———. *Application Summary Report 14* (March 2012)—downlight retrofit units.
http://www1.eere.energy.gov/buildings/ssl/reports.html

[6] The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*.

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[8] Pacific Gas and Electric Company. *Compact Fluorescent Reflector Lamp (CFRL)*. Work Paper PGECOLTG103. June 2007.

[9] American Council for an Energy-Efficient Economy. Energy Solutions. *Analysis of Standards Options for BR, ER, and R20 Incandescent Lamps.* For the Pacific Gas and Electric Company. April 28, 2004. http://www.energy.ca.gov/appliances/2004rulemaking/documents/case_studies/CASE_BR_Lamps.pdf

[10] Skumatz Economic Research Associates. *Revised / Updated EULs Based on Retention and Persistence Studies Results.* Revised Report, July 8, 2005.

[11] KEMA. *Illuminating Current CFL Usage Patterns: Results From a CFL Metering Study*. For the San Diego Gas & Electric Company. 2003.

[12] In addition to CALiPER Round 12 (June 2011) and Round 14 (March 2012), every round from Round 1 (March 2007) through Round 9 (October 2009) included downlights. Detailed reports for 58 downlights (as of June 15, 2012) are available at http://www1.eere.energy.gov/buildings/ssl/caliper/default.aspx

[13] DOE GATEWAY Demonstration. *Demonstration Assessment of LED Retrofit Lamps: Malibu, Cal.* (March 2012)
12 W LED PAR 38 lamps replaced 60W halogen PAR 38 flood lamps in an art museum.
———. *Demonstration Assessment of LED Retrofit Lamps: Eugene, Oregon* (September 2011)
12 W LED PAR 38 lamps replaced 90 W PAR 38 130 V narrow flood lamps in an art museum.
———. *Demonstration Assessment of LED Retrofit Lamps: Portland, Oregon* (July 2011)
12 W LED lamps replaced 15 W and 23 W reflectorized CFL track lights used to illuminate artwork.
———. *Demonstration Assessment of LED Retrofit Lamps: San Francisco, Cal.* (Nov. 2010; Updated Jan. 2012)
6 W LED MR-16 and 11 W LED PAR 30 lamps replaced halogen wall-grazing luminaires, track lights, and recessed downlights in a hotel.

———. *Demonstration Assessment of LED Museum Accent Lighting: Chicago, Illinois* (November 2010) An LED track system replaced halogen track luminaires in a science museum.
———. *Demonstration Assessment of LED Residential Downlights and Undercabinet Lights: 2008 Eugene Tour of Homes.* LED lighting was installed in showcase homes.
http://www1.eere.energy.gov/buildings/ssl/gatewaydemos_results.html