MEMORANDUM

April 2, 2014

To: Redacted

From: Redacted Redacted

Re: Historical Changes in Costs to Light a PG&E Home

INTRODUCTION

As part of its Evaluation, Measurement, and Verification (EM&V) support to Pacific Gas & Electric (PG&E), TRC was engaged to calculate how the cost to light a home in the PG&E service territory has changed compared to twenty years ago. The request was made in response to an inquiry from the California Public Utilities Commission (CPUC):

"As part of my work in the Policy and Planning Division, I am reviewing literature on the cost of energy-saving for a paper on the total cost of services derived from energy. For example, as we know, light bulbs have gotten more expensive as they have changed in technology. At the same time, the amount of energy they consume has declined. And the price customers pay for the electric energy itself has increased. So, counting all three factors, has the cost of the lighting service we consume risen or declined? This question can be asked about almost any energy related subject." -CPUC staff member, in an email to PG&E

This memo summarizes our analysis and findings in response to this request. Detailed calculations, including the inputs used for each calculation, are provided in the Appendix. The workbook with calculations, including a description of all assumptions and the source used for each value, are as a separate Excel workbook.

As described in the Limitations and Recommendations for Improvement section, this project was small in scope. While the results shown below provide reliable ballpark estimates, they could be improved by using data collected more recently, once it becomes publicly available by the California Public Utility Commission (CPUC) and its evaluators, and by spending more time to develop more accurate estimates for some inputs. Thus, PG&E or a contractor could updated the inputs of the attached Excel workbook to develop more accurate estimates.

Methodologies and Data Sources

To ensure that the estimates were reliable, TRC estimated the 20-year change in lighting cost using two different approaches:

- Top down: The average annual household electricity usage for a California household was multiplied by the fraction of electricity used for lighting in a California household[1], and then multiplied by the PG&E electricity rate; and

[1] PG&E specific values were not readily available for either input (i.e., for the total electricity use or the fraction of electricity

- Bottom up: A simple mathematical model was developed for the cost to light a PG&E home, based on the total number of lamps in a home, hours of use, watts per lamp, lamp price, PG&E electricity rate, and other parameters.

The pros and cons of each method are summarized below, along with the data sources used to develop the estimates. In general, we tried to use a single source where possible for each calculation for consistent assumptions. For example, we used the hours of use and the number of lamps in a household from the same study, so that these values would be consistent in assumptions such as whether only sockets were counted or if plugged-in lamps were counted.

Method	Summary	Pros	Cons	Key Data Sources
Top-Down	Multiply average annual household electricity by fraction of electricity used for lighting, and multiply by electricity rate	Fewer assumptions, and faster to estimate	Does not include the price of lamps, and includes embedded assumptions that are unknown	2014 calculation: 2006-08 Upstream Lighting Program Evaluation[2] for lighting fraction, California Residential Appliance Saturation Study[3] and U.S. Energy Information Administration data[4] for annual energy use; 1994 calculation: California Lighting Efficiency Technology baseline report[5] for 1994 calculation
Bottom-up	Develop simple mathematical model of cost to light PG&E home, using number of lamps, hours of use, wattage, lamp price, electricity rate, etc.	Can include price of lamps, and we are more aware of source of numbers and assumptions	More time to calculate, and estimate includes many assumptions	2014 calculation: 2006-08 Upstream Lighting Program Evaluation; Database of Energy Efficiency Resources (DEER)[6] 1994 calculation: California Lighting Efficiency Technology baseline report;

Table 1 – Description of Overall Methodologies and Data Sources

For both methods, TRC obtained the electricity rates for 1993 and 2014 directly from PG&E. The rates provided are the average rates paid by residential customers and include both CARE and non-CARE customers. We adjusted the 1994 electricity rate for inflation using a Bureau of Labor and Statistics calculator[7].

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that is used for lighting), so the average values for a California household were used.

[2] Final Evaluation Report: Upstream Lighting Program. KEMA, prepared for the California Public Utilities Commission, 2010. Vol 1: http://www.energydataweb.com/cpucFiles/18/FinalUpstreamLightingEvaluationReport_2.pdf and vol 2: http://www.calmac.org/publications/FinalUpstreamLightingEvaluationReport_Vol2_CALMAC.pdf

[3] 2009 California Residential Appliance Saturation Study (RASS), Volume 2. KEMA, prepared for California Energy Commission, 2010. http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF

[4] U.S. Energy Information Administration Data, 2012 total kWh residential electricity use per household in California. http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

[5] Lighting Efficiency Technology Report, vol. 1, California Baseline. Heschong Mahone Group, prepared for the California Energy Commission, 1999. http://www.energy.ca.gov/efficiency/lighting/VOLUME01.PDF

[6] DEER 2011 for 13-14 database released May 2012 and cost tables, prepared by JJ Hirsch and Associates, http://www.energy.ca.gov/deer/

[7] U.S. Bureau of Labor and Statistics inflation calculator: http://www.bls.gov/cpi/cpicalc.htm

After calculating the cost to light a PG&E home using both methods, we compared the results.

Results and Discussion

We present results below. In general, lighting electricity and lighting costs for a PG&E household appear to have decreased slightly. The decrease in costs is due to both the decrease in lighting electricity use, and the decrease in inflation-adjusted PG&E electricity rates. The fraction of electricity used by lighting has also dropped.

Because the results are based on various assumptions, and the sources used for these comparisons are different, the results shown here should be viewed as ballpark estimates.

Lighting Electricity Costs

Based on the top down approach, the fraction of total electricity used by lighting has dropped - from 1,704 kWh in 1994 to 1,449 kWh in 2014. This drop is because the fraction of electricity used by lighting has decreased - from 28% in 1994 to 22% in 2014. (The total electricity use has slightly increased in California households.) The inflation-adjusted PG&E electricity rates have dropped slightly. Consequently, based on the top down approach, electricity lighting costs have dropped slightly - from $339 in 1994 to $254 in 2014.

Using the bottom up approach, TRC also found that lighting electricity use has dropped slightly - from 1,681 kWh in 1994 to 1,501 kWh in 2014. This drop is because the fraction of sockets filled by CFLs has increased – from 2% in 1994 to 23% in 2014, so the average wattage per lamp has decreased - from approximately 57 W/ lamp in 1994 to 45 W/ lamp in 2014. The "total lighting hours" (number of lamps multiplied by the hours of use per lamp) has increased slightly – from 80 hours per day in 1994 to 91 hours per day in 2014. But the increase in efficacy outweighed the total lighting hours increase, so the total electricity use has decreased. This, coupled with the drop in inflation-adjusted PG&E electricity rates have caused lighting electricity costs to drop slightly – from $344 in 1994 to $289 in 2014.

The results are summarized and compared in the table below. **Note that the costs below only reflect costs to operate the lamps; these results do not reflect the initial purchase of the lamps or replacement lamp costs.**

Estimated Value	2014	1994	Difference (2014 - 1994)
Top Down Approach: Lighting electricity / year (kWh)	1,449	1,704	(255)
Bottom Up Approach: Lighting electricity / year (kWh)	1,501	1,681	(180)
Electricity rates (2014 $ / kWh)	$0.18	$0.20	($0.02)
Top Down Approach: Lighting electricity costs/year	$254	$339	($85)
Bottom Up Approach: Lighting electricity costs/year	$263	$334	($71)

Table 2 – Lighting Electricity Use and Lighting Electricity Costs, 1994 vs. 2014

The estimates above using the two approaches are similar. However, there are many assumptions included in each approach, so these results should be treated as general estimates.

Initial Cost to Purchase Lamps

Using the bottom up approach, TRC also estimated the initial cost to purchase all lamps for a home (e.g., for new construction). As shown below, the initial cost has increased by $140, from $94 in 1994 to $234 in 2014. This increase is because the fraction of sockets filled by incandescent lamps has decreased by 30% (from 82% in 1994 to

52% in 2014). These have been replaced mostly by an increase in CFLs (from 2% in 1994 to 23% in 2014), followed by an increase in halogens (from 1% in 1994 to 9% in 2014), and a slight increase in non-CFL fluorescents (from 9% in 1994 to 12% in 2014)[8]. All of these technologies (CFLs[9], halogens, and fluorescents) have a higher initial cost than incandescent bulbs.

COSTS (in 2014 $)	2014	1994	Difference (2014 - 1994)
Initial cost to purchase lamps	$234	$94	$140

Table 3 – Initial Cost to purchase lamps, 1994 vs. 2014

Total Operational Costs (Replacement Lamps and Lighting Electricity Costs)

TRC also estimated the cost to replace these lamps upon burn-out, based on their Effective Useful Life (EUL), for the bottom up approach. Results are shown below. We have added the costs to replace lamps to the lighting electricity costs for a total annual operating cost value. As shown below, the cost to replace lamps has increased slightly, from $10 in 1994 to $26 in 2014. This is because, even though customers replace CFLs, halogens, and fluorescents less frequently than incandescent lamps, the initial price of CFLs, halogens, and fluorescents is higher than incandescent bulbs. However the total operating cost has dropped - from $344 in 2014 to $289 in 1994, largely because of the energy savings from CFLs compared to incandescent lamps. The decrease in electricity costs outweighs the increase in replacement lamp costs, so the total operating costs have decreased by $55 – from $344 in 1994 to $289 in 2014.

COSTS (in 2014 $)	2014	1994	Difference (2014 - 1994)
Costs to replace lamps /year	$26	$10	$16
Lighting electricity costs/year	$263	$334	($71)
Total operating (replacement + electricity) costs / year	**$289**	**$344**	**($55)**

Table 4 – Total Annual Operating Costs (Bulb Replacements and Electricity) for 2014 vs. 1994

Using a simple payback estimate, a customer in 2014 would recoup the initial cost of purchasing lamps (estimated at $140 more for 2014 than 1994) due to lower operating costs (estimated at $55 per year less for 2014 than 1994) in roughly 3 years.

Limitations and Recommendations for Improvement

Limitations

This project was small in scope (roughly thirty hours, per PG&E request). More accurate results could be developed with a higher level of effort. Below, we describe some of the improvements that could be made to the calculation given more time. In addition, some of the analysis for the 2014 calculations is based on data from the 2006-08

[8] "Non-CFL fluorescent" bulbs are generally comprised of linear fluorescents. But for accuracy, we describe this category as "Non-CFL fluorescents", because the source documents describe these as "Fluorescents", and present CFL results separately.
[9] For the price of a CFL, TRC included the average PG&E rebate provided in the 2006-08 Upstream Lighting Program.

Upstream Lighting Impact Evaluation. This information is now fairly out of date, but is believed to be the best resource that is publicly available. Better estimates could be developed using more recent data collected by the CPUC's evaluator, once it is published.

Recommendations to Improve Accuracy of Estimates

The following are recommendations for improving the accuracy of these estimates. These are listed roughly in order of our guess as to the significance of the impact on the results. A sensitivity analysis was beyond the scope of this exercise.

- Update 2014 values using more recent data collected from CPUC evaluators or from other sources, once this data is available. There are many examples of possible changes, and we provide a few examples:
    - The number of lamps in the home may have changed, and the total hours of use may have changed.
    - Total electricity use may have changed, and the fraction of electricity used by lighting may have changed, particularly as plug-in loads have increased. If possible, future updates to these calculations should obtain the values for these inputs (total electricity use and fraction used by lighting) from the same source, so that the timeframe for data collection and assumptions used for these values are consistent.
    - LEDs represent a small, but growing number of lamps in California homes. The 2006-08 impact evaluation did not include LEDs, for various reasons, including that very few inside-home products existed at the time of the evaluation. Updated data may show that LEDs have become a more significant part of the market share in 2014.
- Because the hours of use, wattage, and other values vary by room type, a more accurate estimate could be developed by developing a room-by-room estimate.
- Many of the values used are based on California averages, because PG&E specific-values were not readily available. The results would more accurately reflect PG&E territory if PG&E-specific values are used.
- These estimates assumed that the inflation-adjusted price of lamps have not changed. However, old Grainger catalogues or old DEER databases could be used to find more accurate prices of 1994 lamps.
- TRC could not quickly find a value for the price or EUL of halogen lamps in the sources reviewed. Consequently, TRC used our industry knowledge and a quick review of products on-line to develop these values. Halogen lamps represent a diverse group of products. A better understanding of the typical halogen lamp installed in PG&E households, and more accurate estimates for the price and EULs of these lamps, would improve accuracy.

APPENDIX: CALCULATIONS AND DATA SOURCES

Below we present our calculations, and the values used for these calculations. We provide a description of the source of each value or how it was calculated, and any assumptions made for each value, in an attached Excel workbook.

Top Down Approach Calculations

2014 Costs	
Description	**Value**
2008 percent of electricity for lighting, for CA household	22%
2009 total kWh electricity use per CA household	6,296
2012 total kWh electricity use per CA household	6,876
2014 lighting kWh per CA household, using RASS data	1,385
2014 lighting kWh per CA household, using EIA data	1,513
2014 lighting kWh per household	**1,449**
PG&E 100% baseline residential $/kWh, Jan 2014	$0.18
2014 lighting cost, using CPUC data for CA average elec use	$242
2014 lighting cost, using EIA data for CA average elec use	$265
2014 lighting cost	**$254**
1994 Costs	
Description	**Value**
1994 percent of electricity for lighting, for CA household	28%
1994 total kWh electricity use per CA household	6,191
1994 lighting kWh per CA household	**1,704**
PG&E Ave residential $/kWh, 1994	$0.12
PG&E Ave residential $/kWh, 1994, adjusted for inflation to 2014 $	$0.20
1994 lighting cost	**$339**

A summary of the top down approach results is presented below.

COSTS (in 2014 $)	2014	1994	Difference (2014 - 1994)
Lighting electricity / year (kWh)	1,449	1,704	(255)
Electricity rates (2014 $ / kWh)	$0.18	$0.20	($0.02)
Lighting electricity costs/year	$254	$339	($85)

Bottom Up Approach Calculations

2014 COSTS							
Description	**Incandescent**	**CFL**	**Fluorescent (non-CFL)**	**Halogen**	**Socket Empty**	**Unknown**	**Total**
Lamps (%)	52%	23%	12%	9%	3%	1%	100%
Price/ Lamp	$0.65	$1.30	$23	$8	$0	$4	-
EUL	3.7	9.2	15	5	16	7	-
Watts/Lamp	57	17	36	73	2	50	
No. of lamps per home							57
HOU							1.6
lighting elec use (kWh/year)							**1501**
Electricity rates($/kWh)							$0.18
Electricity costs/year							$263
Initial cost							$234
Replacement costs /year							$26
1994 COSTS							
Description	**Incandescent**	**CFL**	**Fluorescent (non-CFL)**	**Halogen**	**HID**	**Other**	**Total**
Lamps (%)	82%	2%	9%	1%	0.1%	6%	100%
Price/ Lamp	$0.44	$1.30	$23	$8	$30	$3	-
EUL	3.7	9.2	15	5	10	5	-
Watts/Lamp	62	19	43	145	72	7	58
No. of lamps per home							34
HOU							2.3
lighting elec use (kWh/year)							**1681**

Electricity rates($/kWh)							$0.12
Inflation adjusted rates (2014 $/kWh)							$0.20
Electricity costs/year							$334
Initial cost							$94
Replacement costs / year							$10

A summary of the bottom up approach results is presented below. The third row, "Lighting electricity costs/year" are comparable to the results of the top down approach. (The top down approach did not include the cost to purchase or replace lamps, so the first two rows of the table below cannot be compared with the top down approach results.)

COSTS (in 2014 $)	**2014**	**1994**	**Difference (2014 - 1994)**
Initial cost to purchase lamps	$234	$94	$140
Costs to replace lamps /year	$26	$10	$16
Lighting electricity costs/year	$263	$334	($71)
Total operating (replacement + electricity) costs / year	**$289**	**$344**	**($55)**

Other calculations:

Comparison	**2014**	**1994**	**Value**	**Calculation**
Simple pay-back for initial costs (years)			3	Initial cost to purchase lamps ($140) / Difference in Total Operating costs ($55/year)
Total lighting hours (hours/day)	91	80	11	No. of lamps per home x HOU
Weighted-Average Wattage (W/lamp)	45	57	**(12)**	Sumproduct (Lamps (%) x Watts / Lamp)