# "What Will It Cost?" Exploring Energy Efficiency Measure Costs over Time and across Regions

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## ABSTRACT

A utility program considers four key variables when assessing the cost-effectiveness of an energy efficiency measure: energy savings, peak demand savings, measure costs and effective useful life (EUL). Of these four variables, programs typically place the least emphasis on setting and updating measure costs. For this analysis, we explore measure costs by mining program participant data across multiple regions over a four year period. Our analysis focuses on a select group of top retrofit measures in commercial programs, where the incremental cost is equal to the full measure cost. We examine how costs change year-to-year and across different geographic regions. Our analysis found that:

- Regional differences can have a very significant impact on average measure cost ranging from 7% to 51%, with an average of 22%.
- Temporal differences can also have a significant impact ranging from 1% to 24%, with an average of 9%.
- Variables such as project size and changing market conditions can have significant impacts on costs over time.

These observations support our best practice recommendations to base measure cost estimates on the region where the program is located and to update those cost estimates at least every two to three years.

## Introduction

Energy efficiency programs are continually being refined and improved. Each program cycle brings new ideas, measures and plans for reaching more customers and achieving deeper energy savings than the previous year. While this process emphasizes accurately updating reported energy savings, many utilities and program implementers pay less attention to other measure characteristics, namely measure cost. This metric is a major contributor to determining cost-effectiveness and it influences how optimal measure incentive rates are set. In the whirlwind of continuous program improvements, it is not uncommon for programs to use measure costs developed in other regions from past years, even for high-impact measures for which local and more recent data sources may exist. This paper presents the analytical approach to and results from examining data sets from six commercial, prescriptive energy efficiency programs. Our goal was to understand measure cost impacts and trends over time and across regions for several high-impact measures.

There is a very wide range in the level of breadth, detail, and frequency for collecting and updating measure costs. Some regions in the US are more rigorous than others. On one end of the spectrum is California, home of the Database for Energy Efficiency Resources (DEER). DEER houses all of the pertinent information on over 100 measures, with cost and other details on multiple permutations of each measure. There have been four comprehensive measure cost studies in California since 2001, as well as several intermediary updates and revisions. The latest DEER draft measure cost study (Itron, 2014) builds on the work of DEER 2005 and 2008 (Summit Blue, 2005) (Keneipp and Yim, 2009), and uses a variety of data collection and analysis techniques listed below. The Pacific Northwest, through the Regional Technical Forum (RTF), has developed similarly robust techniques for collecting and reporting measure costs (Navigant, 2012). The Northeast completed a two-phase study over several years reporting measure costs for seventeen high-impact measures (Navigant, 2011) (Navigant, 2013). Efficiency Vermont performs periodic queries of its databases when updating certain measure cost estimates reported in Vermont Technical Reference User Manual (Efficiency Vermont, 2013). The Illinois Technical Reference Manual (VEIC, 2013) similarly includes cost data for some high impact measures obtained from a regression analysis of program data collected from 2008-2010 (DNV GL, 2010).

By examining and presenting cost data for select measures across various regions over time, we hope to add perspective on when it may or may not be advantageous to borrow cost data from a neighboring region. We also will show the process and results of using large quantities of actual program data for cost inquiries, as opposed to using other techniques.

## Methodology

### General

The data sources and analysis options commonly cited by rigorous measure cost studies are listed below (Summit Blue 2008)[1]. The bulk of the data presented and discussed in this paper originates from utility program projects. The exceptions are the examples where we compare our results to the results of secondary sources, like DEER. The tables and figures focus on using the arithmetic mean, the median, and the second and third quartiles to show trends over time and across regions.

Cost Data Sources:

- Website data collection
- Point of sales data
- Manufacturers / distributors
- Contractors / design professionals
- On-site data collection at retail sources
- Utility program databases
- Secondary sources (RS Means, TRMs)

Data Analysis Approaches:

- Arithmetic mean
- Regression modeling
- Weighted average
- Custom cost estimates

[1] A through explanation of these sources and analysis options, as well as discussion on the pros and cons for each can be found within the referenced material.

## Data Acquisition, Standardization and Cleanup

In the first phase of this project, we collected, standardized and cleaned the data for six commercial prescriptive programs. Table 1 shows the regions, time frames and number of prescriptive projects in the original data set. We removed any combination projects, such as prescriptive and custom or electric and gas. The names of the programs are withheld to preserve confidentiality. The east region includes one program, which reduces the significance of the temporal and regional comparisons.

Table 1. Approximate number of prescriptive-only projects paid per year within original data set

| Region | States | Program | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| West | Within and west of Rocky Mtns | Program A | 400 | 2,800 | 4,000 | 2,900 |
| | | Program B | 800 | 700 | 900 | 700 |
| Central | In between Rocky Mtns and Applachians | Program C | 2,900 | 5,900 | 9,600 | 5,600 |
| | | Program D | 3,600 | 4,200 | 5,700 | 4,600 |
| | | Program E | 2,600 | 4,800 | 5,600 | 4,800 |
| East | Within and east of the Appalachians | Program F | 3,900 | 3,500 | 1,600 | 700 |

Next, we standardized the data by grouping measure categories, subcategories and names using a common taxonomy and system of units. For example, a "2-lamp 4' T12 to 2-lamp 4' T8" retrofit measure and a "1-lamp 4' T12 to a 1-lamp 4'T8" are both classified as a 4-ft T8 lamp and ballast retrofit, with the first having a unit multiplier of 0.5. In our analysis, we looked at a sample of measures that were relatively easy to compare.

After we mapped the measures to a common set of names and units, we further trimmed the data to remove projects with multiple measure types. This resulted in projects that covered about 30% of the total number of projects and 40% of the total kWh savings. It is common for programs to record a variety of measures for a single project, but most only capture one project cost value for all of these measures. We tested whether dropping multiple-measure projects introduces sampling error since single-measure projects could, on average, be smaller than multiple-measure projects, and therefore cost more per unit. We found that the bias in measure cost when focusing on single-measure projects for the "New T5/T8 Fixture" measure was about half a percent, and estimated the cost bias for the "4-ft T8 Lamp and Ballast Retrofit" measure to be about 2.6%. These biases are small compared to the differences we found when looking at regional and temporal impacts, so we felt that dropping multiple measure projects to be an acceptable and simplifying analytical approach.

After removing multiple measure projects and calculating the cost/unit for each record by dividing the listed project cost by the number of units, we removed the projects with cost/units that were extreme outliers. We used a common statistical approach, where extreme outliers are defined as any data point beyond three times the distance between the end of the first quartile, and the beginning of the fourth quartile from the median.

It is a common practice for the programs sampled in this analysis to collect and record total cost data for the purpose of project capping. Project capping limits the incentive to be no greater than some percentage, usually 50% of the total cost, and 100% of the incremental cost.

These sampled programs typically allow external labor to be included in the total project cost (e.g. labor costs that appear on an invoice). The cost/unit values we present in the next section come from projects which include external labor and those that do not, and thus represent an average cost/unit of those two groups.

## Primary Analysis, Results, and Discussion

### Measure Group 1: New T5/T8 Fixtures and 4-ft T8 Lamp & Ballast Retrofits

Figure 1 shows how the price varies over time and region for two of the most common lighting measures, "New T5/T8 Fixtures" (most often found in high-bay applications, replacing high-intensity discharge fixtures), and "4-ft T8 Lamp and Ballast Retrofits" (commonly found in troffer fixtures in nearly all commercial building types). The grey area represents the middle 50% of observations, the white line represents the sample median, and the data points represent the mean values. The bars around the sample mean are 95% confidence intervals, meaning that there is 95% confidence that the true population mean for that year and region lies within that range.

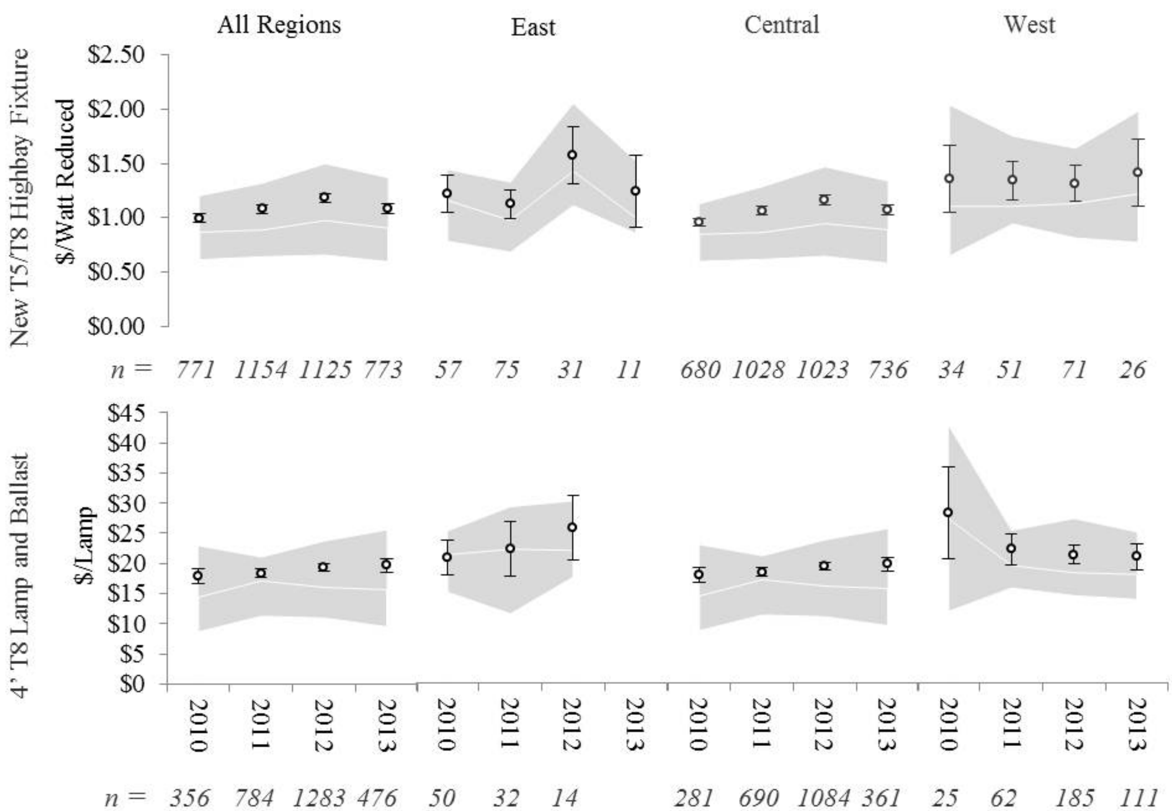


Figure 1. Mean (with 95% confidence bars), median, 2nd and 3rd quartile of cost per unit of two of the most common lighting measures from 2010 to 2013 across different regions of the U.S.

The central region has lower measure costs than the east and west regions. There is also some fluctuation in cost over time, trending slightly upward for both measures, but this temporal signal does not appear to be as strong as the geographic signal. After reviewing this data, the next logical question we asked was, "How significant are the differences between the means from the various regions and years?" Figure 2 shows the range of the differences, depending on whether the data sets (cost data points from a single region within a single year) compared came from different regions only, different years only or from different regions and years. For normalization purposes, the differences are shown in terms of percentage of the overall average cost of $1.10 per Watt reduced for the "New T5/T8 Measure" and $16.08 per lamp for the "4-ft T8 Lamp and Ballast Measure."

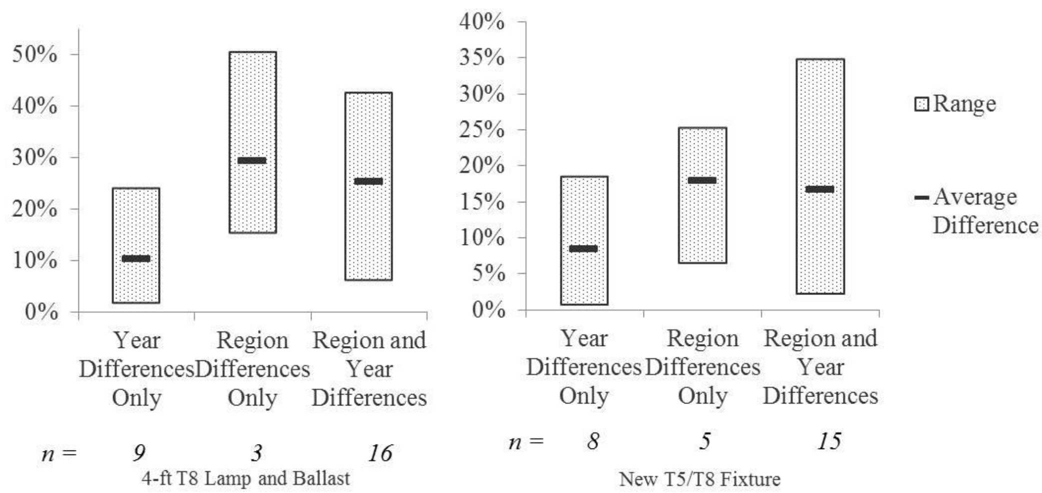


Figure 2. Differences between sample means of the "4-ft T8 Lamp and Ballast" measure and the "New T5/T8 Fixture" measure, where differences are between data sets with 40 or more cost observations, and between cost data from a specific region in a specific year. The *n* is the number of unique comparisons between samples (made up of unique regions and years), not the number of observations within each sample.

Figure 2 further emphasizes that "New T5/T8 Fixture" and "4-ft T8 Lamp and Ballast" measure costs are influenced more heavily by region than by year. If a program were to extrapolate the results from this analysis to estimate what the loss of accuracy might be from using measure cost data for the "New T5/T8 Fixture" from a different region, that loss of accuracy would be between 7 and 25%, or 18% on average. Similarly, the estimate could be off by 1% to 18%, or 8% on average, if using data from a different year within the same region.

We performed standard hypotheses tests on all of the comparisons between samples, and found that nearly half of the comparisons between the means depicted in Figure 1 were significantly different. If we looked at only the comparisons that are significantly different, the average difference is about 6% above the values depicted in Figure 2.

Another observation, less specific to these two linear fluorescent measures, but still clear from Figure 1, is that the sample distribution (i.e. the grey area showing the middle two quartiles) is much wider than the confidence intervals around the mean. This means that a program can have a very accurate estimate on the average cost for any particular measure (useful for program level cost-effectiveness calculations), but a very poor estimate on the cost for an individual project (useful for project level cost-effectiveness calculations). Programs should factor in these ranges because too narrow of a focus on a single average cost can rule out very good projects that people will do if they can find a cost effective way to do it.

## Impact of Project Size on Measure Cost

In addition to geography and time, several other factors drive measure cost, such as who installed the measure, whistles and bells on the particular equipment, the saturation of the technology, and project size. Figures 5a, 5b, and 5c explore how project size affects cost of the "New T5/T8 Fixture" measure.

Figure 3a shows the cost per Watt reduced of the "New T5/T8 Fixture" measure based on the size of the project in terms of total quantity of Watts reduced per project. The x-axis depicts the size of the project in one of four bins (less than 5,000; 5,000-10,000; 10,000 – 30,000; and over 30,000 Watts reduced per project), and the y-axis depicts the cost per Watt reduced. The grey, shaded region represents the middle two quartiles, the white line represents the median, and the circles with the bars represent the mean at 95% confidence intervals. There is a distinct downward trend in terms of cost, and the mean of each bin was significantly different from the mean value of each other bin, with the differences ranging from 7% to 34%. Figure 3b shows the regional variations in project size. Even more interesting is Figure 3c, which shows the variation in project size over time and clearly demonstrates that smaller projects become more prevalent during later years. This confirms that customers, contractors and program implementers aptly focused on completing larger projects earlier, and moved towards completing smaller projects later. These figures demonstrate that the specific characteristics of the market being served by the program (as well as program age) influence average project size, which influences measure cost.

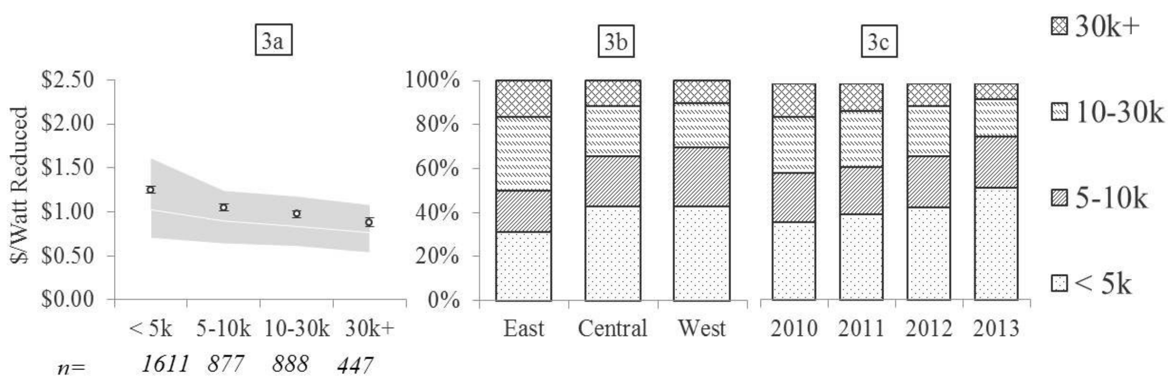


Figure 3a. Cost per Watt reduced for "New T5/T8 Fixture" measure as a function of project size in terms of thousands of Watts reduced per project. Figure 3b. Percentage of New T5/T8 projects that fall into one of four different project size bins (<5,000 Watts reduced per projects to 30,000 or more Watts reduced per project), by region. Figure 3c. Same as Figure 3b, but over time instead of by region.

## Variable Speed Drives

Figure 4 depicts the measure cost of variable speed drives (VSDs) installed on HVAC fans determined from the analysis of the six sample programs, compared to third party sources, including Efficiency Vermont, California's Database for Energy Efficiency Resources and

NEEP/Navigant's 2013 measure cost study. The costs are shown for common fan motor horsepower sizes of 100 HP and less. The median is represented by the white line, which tracks more closely with the other data sources than the mean.

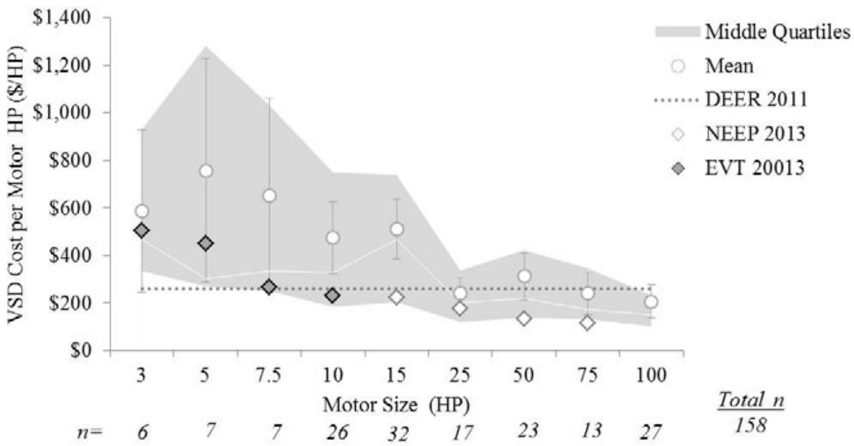


Figure 4. Mean, median, second, and third quartile costs per HP of VSD on HVAC fan by motor size, compared to DEER 2011, Efficiency Vermont (EVT) 2013, and NEEP/Navigant 2013.

## LEDs, Occupancy Sensors, EMS, and Refrigerated Case Lighting

This paper would not be complete without reporting observations from several common measures, least of which being light emitting diodes (LED). There is a lot of recent literature on past and projected LED costs (PNNL, 2014), (Tuenge, 2014), (US DOE, 2013). Figure 5 shows costs for screw-based LED lamps over time in one program in the central US. Each point represents six months of data. Not surprisingly, the costs are decreasing as expected, and in a relatively consistent manner to the recent CALiPER report (PNNL, 2014).

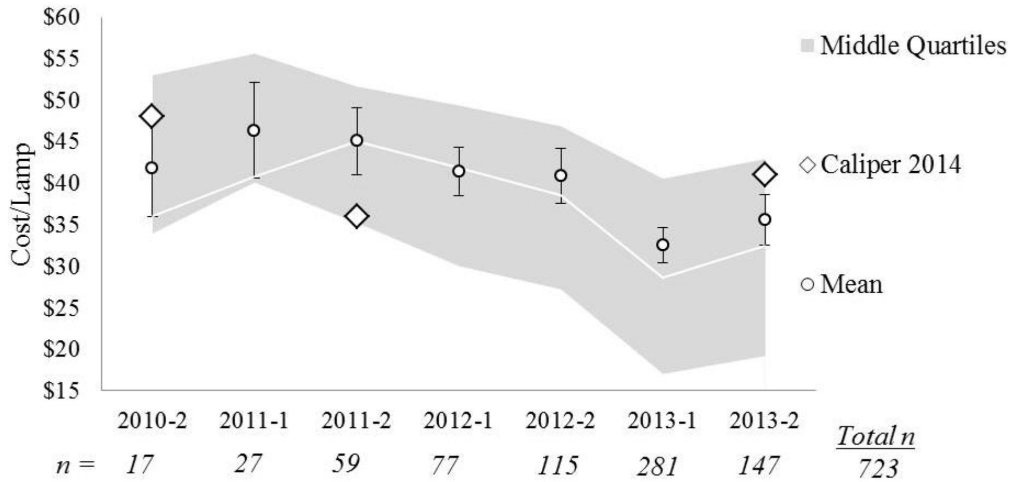


Figure 5. Cost per LED lamp over time in Program D.

Figure 6 reports observations on several other common measures: Lighting Occupancy Sensors, LED Refrigerated Case Lighting and Energy Management Systems (EMS). This figure reports data from all three regions. In Figures 6 and 7, the grey areas represent the middle two quartiles, the white line represents the median, and the circles represent the means with 95% confidence intervals.

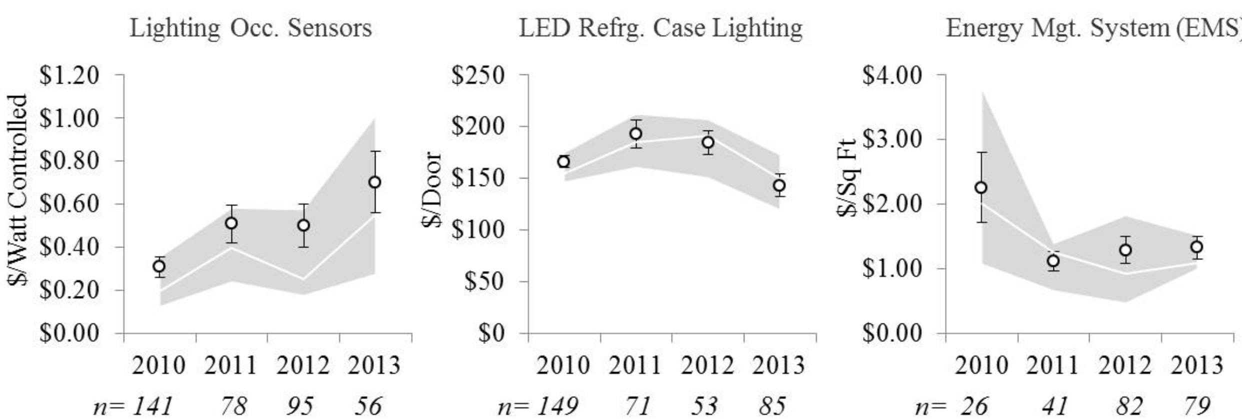


Figure 6. Measure costs of three common measures from 2010 to 2013.

In examining Lighting Occupancy Sensors, our first observation is that the median drops considerably between 2011 and 2012, but the mean and inner quartiles remain the same. For the other measures investigated, the median and mean move in relative unison, but this example reveals that overreliance on any one particular measurement statistic may lead to an incomplete assessment of measure cost. This initial analysis also reveals that Lighting Occupancy Sensors appear to lack any discernible trends. We surmise that this measure is more strongly influenced by project size and the nature of the fixtures where the sensor is being installed. It is possible that lighting occupancy sensors are getting more expensive because lighting control systems are becoming more sophisticated and are being installed on smaller projects.

The LED Refrigerated Case Lighting measure also does not show a consistent trend in measure cost over all four years. Taking a closer look at our data, it appears that the lower unit costs in 2010 are attributable to a large number of projects (51 of the 149 observations) conducted across many locations for one large retail outlet. In future analysis, we would consider grouping projects associated with one large chain together so their reduced costs exert less bias.

For the EMS measure, there is a gradual decrease in measure cost over time, but the trend is less uniform than other measures. Again, we suspect that this measure is less reliant on cost changing over time, but on additional variables such as the scope and complexity of the building and of the new control system. We have also been seeing more chain accounts install this measure over time, which may account for the declining price trend.

## Conclusion

Our analysis shows that measure costs vary significantly by region and over time. It also shows that certain key measures are coming down in costs, while others are increasing. The depth, breadth and frequency for developing costs vary widely across utility programs. By analyzing several years' of data from utility programs in different regions we hope to bolster practices for effectively characterizing measure costs. The first step is to use cost data from the program's region, or make the necessary region-to-region adjustments. The next step is to update this cost data at least every two to three years. These recommendations are based on our observations of six programs that showed considerable regional and temporal factors that influenced measure costs. For two common lighting measures, we saw that costs vary from region to region by as much as 51%, and by as much as 24% within the same region but over a four year time frame.

This analysis demonstrates that incremental measure cost is a dynamic variable that should receive routine and adequate scrutiny during successive program planning cycles. This information and methodology will equip program planners to maintain cost-effective measure/program offerings at the properly-tailored incentive levels and delivery channels.

## References

DEER (Database for Energy Efficiency Resources). 2011 "Work Paper PGECOHVC106 VFDs for HVAC Fans Revision #3". Customer Energy Efficiency Department, Pacific Gas and Electric Company.

Efficiency Vermont. 2013. *Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions.*

Itron (Itron, Inc.), Davis Energy Group, DNV GL, Energy and Resource Solutions, Quantum Energy Services & Technologies, TRC Energy Services, and VACOM Technologies. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Draft Report.* Submitted to California Public Utilities Commission

KEMA. 2010 "ComEd Program Unit Costs". Unpublished Memo to Erinn Monroe, Commonwealth Edison.

Keneipp, F. 2008. *Best Practices for Assessing Measure Costs.* Submitted to Bobbi Wilhelm, Puget Sound Energy.

Keneipp, F. and M. Yim. 2008. *2008 DEER Measure Cost Documentation Revision 3.* Walnut Creek, CA. Summit Blue Consulting, LLC.

Navigant (Navigant Consulting, Inc.). 2011. *Incremental Cost Study Report Final: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets.* Submitted to Northeast Energy Efficiency Partnerships: Evaluation, Measurement and Verification Forum.

Navigant. 2012 *Guidelines for the Development and Maintenance of Incremental Measure Costs and Benefits Estimates.* Prepared for The Regional Technical Forum.

Navigant. 2013. *Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets.* Submitted to Northeast Energy Efficiency Partnerships: Evaluation, Measurement and Verification Forum.

PNNL (Pacific Northwest National Laboratory). 2014. *CALiPER Retail Lamps Study 3*. Prepared for Solid-State Lighting Program, Building Technologies Office, Office of Energy Efficiency and Renewable Energy, US Department of Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_retail-lamps-study3.pdf

Summit Blue (Summit Blue Consulting), and Heschong Mahone Group. 2005. *2005 Measure Cost Study Final Report*. Prepared for Ingrid Bran, PG&E

Tuenge, JR. 2013. *SSL Pricing and Efficacy Trend Analysis for Utility Program Planning*. Prepared for Solid-State Lighting Program, Building Technologies Office, Office of Energy Efficiency and Renewable Energy, US Department of Energy. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_trend-analysis_2013.pdf

U.S. Department of Energy. 2013. *Solid State Lighting Research and Development Multi-Year Program Plan*. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2013_web.pdf

VEIC (Vermont Energy Investment Corporation). 2013. *Illinois Statewide Technical Reference Manual for Energy Efficiency.*