Energy Efficiency Program Costs, Program Size, and Market Penetration

Draft Working Paper

By

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1. Introduction

Utility sponsored[2] energy efficiency programs have been implemented in varying degrees for over 20 years across numerous customer segments. Demand response programs, however, have been around for decades beginning with interruptible or off-peak type rate offerings that existed in the 1940's and expanded to include cycling of end-use equipment and more sophisticated dynamic pricing structures.

Besides the fact that the implementation of energy efficiency and demand response programs involves significant complexity in marketing, communication, and cost-effectiveness analysis, information on the costs to implement are very difficult to unravel due to the multi-year life of measures in the portfolio of programs. The major source of historical data on costs and impacts is the Energy Information Administration (EIA) which is part of the Department of Energy. Using Form 861, the EIA has been collecting cost and load impact data, among other items, for energy efficiency and demand response efforts for all utility service areas in the United States since 1990.

This paper focuses only on the costs and load impacts associated with implementation of energy efficiency (EE) programs. Investigation of demand response costs is reserved for future

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[2] For purposes here, utility sponsored includes programs implemented by third parties, including third party administration efforts.

study. The energy efficiency cost and impact information available on the EIA web site includes current year direct program spending, indirect spending (e.g., administrative costs not directly associated with a program), current year energy efficiency MWH and MW impacts, as well as cumulative MWH and MW impacts for each utility service area for the period over which the EIA has been collecting the data[3]. However, the cost and impact data represent totals for the portfolio of energy efficiency programs. Values at the individual program level are not available from the EIA data. For the year 2012, the EIA data on direct plus incentive expenditures for the 50 states plus District of Columbia totaled $4.4 billion. Through this level of spending, the current year retail energy impacts were 21,478,470 MWH which results in a first year[4] cost of $0.205 per kWh. Furthermore, the cumulative[5] EE load impacts reported total 138,524,613 MWH. These on-going cumulative impacts represent the sum of the historical impacts achieved by the programs as reported to EIA.

The issue here is the cost. The value of $.205/kWh represents the total program spending per kWh in one year to gain a stream of kWh savings over the life of the installed measures. If one knew the life of the measures being implemented as well as the relevant discount rate, one could calculate a levelized cost in order to compute a levelized cost per kWh, a commonly used metric for comparing costs across supply-side and demand-side options. For example, for the $0.205/KWh first year costs cited above, if the discount rate were 8% and the measure life averaged to five years, the levelized cost per kWh converts to 5.1 cents/kWh.

To benchmark current costs and project future costs, there are three issues with this analysis. One, the discount rate and relevant measure life are unknown. Changes to either or both

[3] EIA stated in the past that the cumulative impacts should represent total impacts since 1992. However, this may change in the future as the EIA has indicated it wants to incorporate measure life into these load impact estimates.
[4] First year cost is defined as the total program spending divided by the load impacts achieved in the first year of program implementation.
[5] For clarity, cumulative load impacts, defined as Annual by the EIA, represents the sum of the incremental load impacts.

significantly impact the resulting cost estimate. Two, the number represents an average. The cost for a specific program can vary substantially from this average estimate. And three, the level of historical penetration of EE in any one utility service area can be quite different from the average. In some utility service areas, the cumulative impacts can be large, exceeding 10% of retail sales. In other service areas, the cumulative impacts have been minor, less than 1%. Using an average cost estimate from the EIA data ignores all of the utility specific details that could affect cost. This raises a critical question. As the cumulative market penetration of EE rises, does the cost to achieve further incremental energy efficiency impacts rise or fall or stay the same? One typically expects the marketing cost to attract the early adopters to be somewhat elevated due to the cost of the startup. Then, as the program size expands, there can be some marketing economies of scale driving down the unit cost. But, as the cumulative market penetration rises, the marketing cost per unit to attract additional interest could be expected to rise.

This paper takes a new look at the EIA data in an effort to glean how the level of market penetration could affect unit implementation costs. By examining how the cost of implementing EE programs changes across the states, one can begin to gain insight on the incremental cost of EE through analysis of areas where the market penetration is low versus where it is high.

The following sections provide:

- Brief review of past studies of energy efficiency that reported implementation costs,
- Discussion of the modeling approach,
- Review of issues related to the use of the EIA data,
- Presentation of the modeling results, and
- Summary of the results along with comments on applicability and implications for future research.

2. Past Studies

A large volume of literature has been devoted to studies on energy efficiency and the costs associated with program implementation. Study categories include those that summarize costs and impacts based on other reports (meta-studies) and those that conduct a bottom-up analysis of end-use efficiency. The studies provide estimates of the market potential and the levelized cost to implement energy efficiency. The levelized cost estimates represent an average expected cost for implementing a program or measure or portfolio of programs.

Generally, the focus of these studies has been on market size and cost in a macro perspective, though a few examine the costs associated with individual programs or measures. As the spending on energy efficiency escalates due to energy efficiency portfolio standards (EERS) or potentially new EPA rules[6] requiring energy efficiency impacts of 1.5% of retail sales each year, the cost-effectiveness of energy efficiency programs and measures could change as the market penetration of energy efficiency increases. The research to-date has not provided any insight or guidance on this issue.

The American Council for an Energy Efficient Economy (ACEEE) has produced numerous reports, studies, and meta-studies on energy efficiency market size and cost-effectiveness[7]. The ACEEE reports tend to focus on the estimates of program costs per kWh. In addition to estimating the size of the potential, ACEEE compiled information on unit cost estimates from reports by state utility commissions as well as individual utility reports. While these reports provide a significant

[6] See Section 111d on energy efficiency in the U.S. EPA's GHG Abatement Measures in Docket ID No. EPA-HQ-OAR-2013-0602.

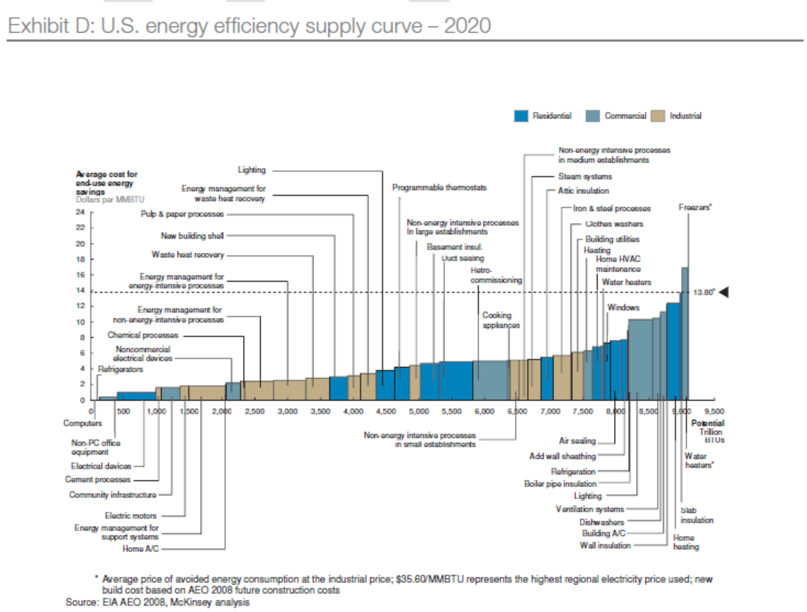
[7] See Chittum (2011), Eldridge et. al. (2010), Elliott et. al. (2007), Friedrich et.al. (2009), Kushler (2004), Laitner et. al. (2012), Nadel and Herndon (2014), Neubauer et. al. (2009), Neubauer and Neal (2012), Neubauer and Elliott et. al. (2009), Shipley and Elliott (2006), and Takahashi and Nichols (2008).

volume of cost related information, none of the reports investigate or estimate how the unit costs might vary as the cumulative market penetration increases.

The Electric Power Research Institute investigated the market potential for EE in two relatively recent reports[8]. These reports also examined program cost-effectiveness as well as market size. But again, neither of these reports provided insight on how the unit costs might vary as the cumulative market penetration increases.

McKinsey & Company also produced a report[9] on EE potential in 2009. In addition to providing estimates of market potential, McKinsey presented a graphical view of the EE supply curve as shown in Figure 1. The chart cleverly combines energy efficiency market potential for each end-use with the average annualized cost to implement the efficiency improvement on a dollars per MMBTU basis. The width of the bars represents the market potential while the height depicts the unit costs.

Figure 1



8 See Electric Power Research Institute (2014) and Rohrmund et. al. (2008).
9 See McKinsey & Company (2007) and (2009). See the Executive Summary page 6.

While the chart demonstrates that unit costs will increase as the market potential for the portfolio of programs is achieved, the report does not provide guidance on how the costs vary as the cumulative market penetration changes for each measure.

Several other studies[10] presented estimates of the market potential and/or the unit costs for energy efficiency. However, these studies also do not examine how the unit costs may change as the cumulative market penetration increases.

Four additional studies investigated the presence of economies of scale in the implementation of energy efficiency programs[11]. Two of these[12] essentially relied on the same research results. Both studies reported declines in the unit costs with increases in incremental first year energy saving (as measured by percent of retail sales). However, neither study considered the impact of cumulative market penetration in unit costs. A very recent report[13] published by Lawrence-Berkeley National Laboratory that found a slight decline in the levelized unit cost curve as participation increases for a specific program, appliance recycling. However, the report indicates that this relationship was not statistically significant for any other program studied. While the study claims that cost efficiency exists for this one program, the report does not indicate whether the unit cost estimates could have been influenced by the size of the different markets or whether or not unit costs decline as cumulative market penetration increases.

The fourth study[14] is the first identified to pose the question as to the existence of increasing returns to scale with diminishing marginal returns. In other words, the researchers contend that the unit costs of implementing energy efficiency programs will decline with increases

[10] See Barbose et. al. (2009), Brown et. al. (2010), Cappers and Goldman (2009), Chandler and Brown (2009), Energy Center of Wisconsin (2009), Forefront Economics et. al. (2012), Forefront Economics and H. Gil Peach and Associates (2012), GDS Associates (2006), GDS Associates (2007), Itron, Inc. et. al. (2006), La Capra Associates, Inc. et. al. (2006), McKinsey & Company (2007), Nadel and Herndon (2014), Midwest Energy Alliance (2006), Western Governors' Association (2006), Wilson (2009), and U.S. Department of Energy (2007).
[11] See Billingsley et. al. (2014), Hurley et. al. (2008), Plunkett et. al. (2012), and Takahashi and Nichols (2008).
[12] See reference number Hurley et. al. (2008) and Takahashi and Nichols (2008).
[13] See Billingsley et. al. (2014).
[14] See Plunkett et. al. (2012).

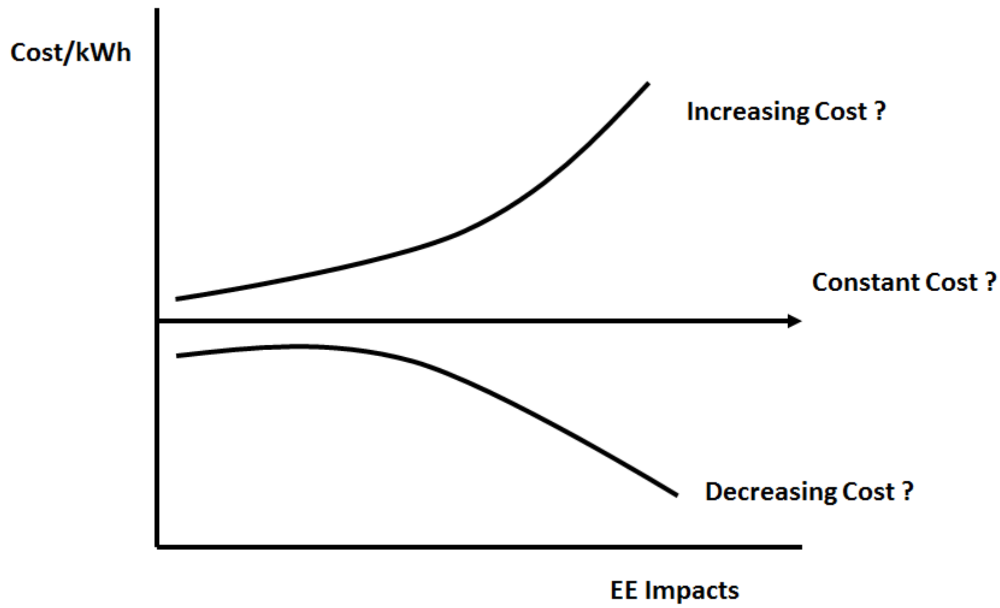
in scale (measured by percent of retail sales), but at some point unit costs for the first year savings will increase due to diminishing returns. The researchers arrive at this conclusion based on an econometric analysis that suffers from over-fitting of the data and an application that leads to a bias in the coefficients[15]. Further, this research only examined unit costs associated with incremental first year savings, not cumulative market penetration. While one of the first studies, if not the first, to pose the right questions, the research falls short of providing any enlightenment on the impact of cumulative market penetration on unit costs.

Finally, one study by Cicchetti[16] conducted extensive analysis on the unit cost of energy efficiency. Using the data compiled by the EIA, Cicchetti computed costs on a first year as well as a levelized basis. Cicchetti conducted an extensive analysis of the costs, however, again there is no insight provided on the impact of market penetration on costs.

In summary, this review of past studies on the costs of energy efficiency reveals that a significant void exists in our understanding of how the implementation costs of energy efficiency are affected by the level of market penetration. Assume for a moment that the cost-effective economic market potential for a utility service area is 20% of retail sales and that the levelized unit cost is assumed to be 5 cents/kWh. Then, the unanswered question is whether or not the 5 cents/kWh cost remains constant as the achieved percent of market potential rises from 10% (of the 20% economic potential) to 50% to 100% (see Figure 2). Can one reasonably assume that the cost to acquire the first 10% of market potential is the same as the cost to acquire the last 10% percent of the market? Or, does the unit cost become higher or lower as the portion of the market potential achieved increases?

[15] The researchers apparently tried multiple mathematical forms until they found the one with the best fit. In addition, besides using a model with specification issues, the researchers boosted the fit of the model by dropping the intercept term, an arbitrary approach that produces biases in coefficients.
[16] See Cicchetti (2009).

Figure 2



The following sections of this study will provide an initial attempt to shed light on this issue.

3. General Model Discussion

The cost of energy efficiency implementation depends significantly on the type of program or measure being implemented. The typical cost components include project administration, marketing, financial incentives paid to customers or marketing channels, and evaluation, measurement and verification. Indirect / overhead costs are not included in this list. Inclusion of indirect items could add another 30% to the total program costs[17].

The key drivers of annual cost are the number of measures or participants (program size) in a given year, which affects the volume of incentive payments and level of marketing. In other words, program size and marketing represent the key factors that influence the level of spending in a given year. Marketing costs will vary by type of program. Some programs can be implemented through direct marketing (e.g., mail, email, door-to-door) while others through marketing channels

[17] The program costs do not include incremental participant costs because the focus here is on the program administration costs which represent the costs recovered from ratepayers.

such as equipment distributors as well as retail suppliers. The issue under investigation here is whether or not the level of marketing and hence program cost is affected by the program size and how much of the market has already been reached. With regard to program size, marketing economies of scale could develop as the current period level of effort rises. However, there is a limit to the program size due to measure life of the end-use. For example, if a heat pump has a 20 year life, not all of the heat-pumps in a utility's service area become available for replacement at a given point in time. Instead, in this example, one can expect that 5% (1/20) of the heat pumps will be replaced each year. While there may be marketing cost efficiency gains in a given year, there is a natural limit based on the available equipment turnover[18]. In addition, as market penetration increases, energy efficiency implementation costs are expected to rise at higher levels of penetration of the market. The degree of impacts on program costs, from these factors, is a question to be empirically analyzed.

In addition to historical market penetration, other drivers that could potentially affect the level of program costs are the level of electric rates and the health of the economy. Regarding customer electric rates, the issue to be investigated here is the whether or not higher electric rates make it easier to market energy efficiency measures. With higher electric rates, the customer bill savings would be greater, thus reducing the payback period and making the investment in energy efficiency more cost-effective for the participating customer. With respect to the health of the economy, many economic measures could be used. The issue at question is whether or not it is tougher to market energy efficiency when the economy is under stress, e.g., during a recession or its aftermath. Since the Great Recession ended in 2009, economic growth has been lackluster and unemployment levels have remained elevated. One could contend that higher unemployment rates make it harder to market energy efficiency because energy consumers do not have the spare

[18] The volume of replacements in this example could exceed 5% if the incentives encourage customers to perform early replacement before the end of the useful life. However, these situations are not the typical expectation.

funds to invest in more efficient equipment. Conversely, one could contend that marketing energy efficiency is easier because energy consumers need to find ways to cut costs. Evidence of a relationship between program costs and electric rates and/or economic health can be explored empirically.

4. General Model Development

Assuming that energy efficiency program costs are affected by program size, historical market penetration, electric rates, and health of the economy, then a model can be specified as follows:

$$Program\ Cost = f(Market\ Size, Market\ Penetration, Electric\ Rate, Economic\ Health) \quad (1)$$

To assess the impact of these factors on program cost first requires obtaining data that can facilitate the analysis. As previously mentioned, the EIA has been collecting aggregate data for each utility jurisdiction on the impacts and costs associated with implementing energy efficiency. A discussion of the data as well as its limitations will be provided in the next section. However, the model variables need further specification for clarity prior to the actual data collection.

To compile a dataset for analysis, the definition of the variables is critical. For purposes of analysis, given the types of data available from the EIA data base, the following variable definitions will be employed:

Dependent variable:

Program cost includes the level of direct program spending (dollars) on energy efficiency programs only. Indirect costs are not included.

Independent variables:

Program size refers to the current year achievement of energy impacts as a percent of current year retail kWh sales. As program size increases, one expects the cost to increase, though it may not be an equal proportional increase due to the potential for marketing efficiencies. For example, the current year market size achieved may be 1% of retail sales in one geographic area, but in another geographic area it may be 2% of retail sales. By studying the relative impact on program spending across multiple areas with different levels of achievement, one can begin to understand how costs change as the size of the program increases.

Market penetration represents the cumulative achievement of energy efficiency sales as a percent of retail kWh sales. For this variable, as the market penetration increases and the available market potential begins to be depleted, the cost to reach deeper into the market potential may increase due to the higher cost to acquire participants who may find that the energy efficiency program offers are less interesting or compelling relative to other demands on their time and financial resources. An analysis of program spending between areas with lower market penetration versus higher market penetration may provide insights on how costs change relative to changes in market penetration.

Electric rate reflects the cost of power ($/kWh) to customers in an area. The electric rate drives the level of bill savings from implementation of the energy efficiency measures. The higher the electric rate, the easier it is for a participant to cost-justify investment in energy efficiency because the bill savings generated by the energy efficiency are greater. In this situation, higher electric rates should make it easier and less costly to market the energy efficiency programs. Including a measure of the average cost of electricity in a region should aid in understanding whether or not electric rates impact energy efficiency marketing.

Health of the economy, the final independent variable under consideration here, can be measured in a number of different ways. For example, the rates of growth in employment, per capita disposable income, or gross national product are all reasonable candidates. At the same time, the unemployment rate provides a good measure of overall economic health that is contemporaneous and reflects the state of consumer well-being as well as business confidence. The interesting issue is whether or not a higher unemployment rate indicates greater difficulty funding energy efficiency or lower difficulty. On the surface, higher unemployment rates would seem to imply that consumers have less cash to invest in energy efficiency, thus potentially raising marketing costs. Conversely, it could also mean that there is more demand for energy efficiency as a way to reduce operating costs. Analysis of this factor should also improve understanding of the drivers of program costs.

In general form, Equation 1 can be re-written as an econometric model as follows:

$$PC = \alpha + \beta 1 \cdot CPR + \beta 2 \cdot CPT + \beta 3 \cdot EP + \beta 4 \cdot UR + \varepsilon \qquad (2)$$

where:

PC	=	Program cost or spending
CPR	=	Current kWh impacts as a percent of retail sales
CPT	=	Cumulative kWh impacts as a percent of retail sales
EP	=	Average retail price of electricity adjusted for inflation (real dollars)
UR	=	National unemployment rate
ε	=	Error term

This represents the general form of the econometric model to be developed. It is expected, on an a priori basis, that the signs of the coefficients should be: $\beta 1 > 0$; $\beta 2 > 0$; $\beta 3 < 0$; and $\beta 4 > or < 0$.

The data for the model development will come from the EIA data base as well as national data on the unemployment rate and inflation.

5. Model Data

The Energy Information Administration's (EIA) Form 861 has been utilized to collect a wealth of information on energy efficiency and demand response program spending and load impacts. The EIA data for the years 1990 through 2012 may be found on the EIA website. It contains information on a number of items for each utility service area including the following:

- Direct spending on energy efficiency programs
- Direct spending on load management (demand response or demand side management (DSM)) programs
- Indirect program spending – costs not directly related to a specific program
- Incremental energy efficiency MWH and MW – current year annualized load impacts
- Annual energy efficiency MWH and MW – cumulative load impacts
- Incremental demand response MWH and MW – current year annualized load impacts
- Annual actual demand response MWH and MW – cumulative load impacts
- Incremental potential[19] demand response MWH and MW – cumulative load impacts
- Annual potential demand response MWH and MW – cumulative load impacts
- Information is also available on retail revenues and MWH sold to ultimate customers for each utility service area[20]

[19] Potential impacts reflect the expected load reductions under normal extreme weather conditions as opposed to the actual reductions achieved given the actual weather conditions.
[20] Revenues and sales for utility service areas in deregulated markets require careful handling to ensure a complete picture of revenues and sales.

- Information is also available on state level retail revenues and MWH sold to ultimate customers on EIA Form 826

Data on national inflation and unemployment may be found from numerous sources[21].

Unfortunately, the data collected through the use of EIA Form 861 has several limitations. These limitations include lack of information on the life of the measures in the portfolio of programs, consistency in reporting over time, consistency in treating effects such as free-riders, consistency in reporting program costs versus indirect costs, and impacts due to changes over time in the structure and instructions associated with Form EIA 861.

With respect to measure life, Form EIA 861 seeks data on current year annualized incremental impacts. However, the life expectancy of those impacts is unknown. Impacts from some measures could last 20 years while other associated with behavioral type programs might last just one year and require constant reinforcement to maintain the impacts. For this reason, the analysis conducted here looks at total annual spending relative to the first year impacts. Trying to compute a levelized cost requires knowledge that is just not available. While one might intuit an expected measure life for a portfolio, it is only a guess and could lead to misleading conclusions. In reviewing the EIA data, it is apparent that the reporting is not consistent. For example, kWh could be reported instead of MWH or dollars instead of thousands of dollars as specified in the instructions to the form. For this reason, this study will focus on the last three years of data for the years 2010 through 2012. Use of the most recent data should provide the best quality of data from the data base.

Regarding cost data, it is unclear what could be included in indirect costs. The categorization of costs across utility service areas will certainly be different, especially with respect

[21] See the website Freelunch.com sponsored by Moody's Analytics for general macroeconomic data including inflation and unemployment.

to treatment of overheads and utility financial incentives. For purposes of this study, only the direct program costs including incentive payments to participants will be considered in the analysis. Finally, to facilitate the research, costs and impact data is aggregated to a state level[22]. This provides a useful data set for the 50 states plus the District of Columbia.

6. Model Development

Using data for the period 2010 to 2012 opens the possibility of taking two approaches to the analysis. In attempting to glean from the data how costs are affected by program size and market penetration, use of multiple approaches can help put a range around an issue afflicted with a lot of uncertainty.

The first approach involves using all the state level data for the 2010 to 2012 time period. This involves estimating a cross-sectional / time-series model. It is cross-sectional given use of data for the 50 states plus the District of Columbia. It is time-series since it covers the period 2010 to 2012. To estimate this model over time with the cross-section requires the use of a fixed-effects panel data modeling approach that captures the underlying relationship between cost and the independent variables while letting the intercept terms capture the inherent underlying differences across the various geographies. The model estimates a separate intercept term for each of the 51 geographic areas while developing estimates for the independent variables that are the same for all the geographic areas. The methodology is designed to uncover the fundamental relationship between cost and the independent variables while differences in the characteristics of each geographic area are captured in the intercept terms.

Algebraically, Model 1, the fixed-effect panel data model, is described as follows:

$$PC_{it} = \alpha_i + \beta 1 \cdot CPR_{it} + \beta 2 \cdot CPT_{it} + \beta 3 \cdot EP_{it} + \beta 4 \cdot UR_t + \varepsilon_{it}) \quad (3)$$

[22] Future research will extend this analysis to an individual utility service area.

where:

PC_{it} = Program costs for geography i during year t

α_i = Constant term for geography i (the fixed-effect)

CPR_{it} = Current kWh impacts as percent of retail sales for geography i during year t

CPT_{it} = Cumulative kWh impacts as percent of retail sales for geography i during year t

EP_{it} = Real electricity price for geography i during year t

UR_t = National unemployment rate for year t

ß = Estimated coefficients for ß1, ß2, ß3, and ß4

ε = Error term for geography i during year t.

The second approach involves using all the data for the most recent year, 2012[23]. This is a traditional cross-sectional approach. Cross-sectional models are extremely useful because they provide a view into the long-run since the data contains multiple points along the continuum of experience. This approach does not require the use of the fixed effects panel data approach. Instead, the model can be estimated using a traditional application of ordinary least squares regression. The model to be estimated is the same as that previous presented by Equation 2.

Algebraically, Model 2, the cross-sectional model, is described as follows:

$$PC_i = \alpha + \beta 1 \cdot CPR_i + \beta 2 \cdot CPT_i + \beta 3 \cdot EP_i + \varepsilon \quad (4)$$

where:

[23] Data for Delaware and Louisiana were deleted since the EIA data indicates essentially zero cumulative impacts for the year 2012.

PC_i = Program cost or spending for geography i

CPR_i = Current kWh impacts as a percent of retail sales for geography i

CPT_i = Cumulative kWh impacts as a percent of retail sales for geography i

EP_i = Real average retail price of electricity for geography i

ε_i = Error term for geography i

The one difference from Equation 2 is that the national variable UR is removed since it would be the same in a given year for all geographic regions.

7. Model Results

Both models were estimated in logarithmic form using the data previously described. The benefit of estimating the model in logarithmic form is that the coefficients represent elasticities that enable one to compute how a percent change in the independent variable results in a coefficient adjusted percent change in the level of program costs. Table 1 below summarizes the results of the statistical analysis for both Model 1 and Model 2.

Table 1			
Model 1			
Variable	Coefficient	t-statistic	Stat Significance
Log (CPR)	0.609	7.761	Yes
Log (CPT)	0.278	3.293	Yes
Log (EP)	-11.980	-1.863	Yes
Log (UR)	2.438	0.769	No
Adjusted R-squared	0.759		Yes
Model 2			
Variable	Coefficient	t-statistic	Stat Significance
Log (CPR)	-0.003	-0.055	No
Log (CPT)	0.897	6.865	Yes
Log (EP)	-0.837	-1.527	Yes at 7% level
Adjusted R-squared	0.543		Yes

For Model 1, the results indicate that strong statistical relationships exist between the level of program cost and program size, market penetration, and real electric price. All three independent variables are statistically significant using a one-tail test given the a priori view of the expected sign for the variables. Only the unemployment rate variable was not statistically significant.

For Model 2, the results indicate that strong statistical relationships exist between the level of program cost and market penetration, and real electric price. The market penetration variable is strongly significant, while the electric price variable is weakly significant. The program size variable is not significant in this model.

These results provide a first insight into the relationship between program costs and program size and market penetration. While the data is aggregate, these results do indicate how these costs can be expected to change. At this point in time, no other study has generated these types of results and insights.

The following section provides an example of how the results can be used to forecast program costs as market penetration increases.

8. Model Application

Often under an Energy Efficiency Resource Standard, there is a requirement to achieve X% cumulative load reduction by a specific year or to reduce load 1% per year for some number of years. Sometimes these values are based upon the results of a market potential study. As an example, let's assume a market potential study concluded that the economic potential over a 20 year period was 20%, or 1% per year. Then, the question becomes: how does the program cost change as one begins to achieve impacts that approach the economic potential, keeping in mind that economic potential implies that 100% of the cost-effective measures are installed?
Given both econometric models previously presented, simulations of the cost impacts can be performed under each model to provide a range on how costs could change as market penetration increases. Another factor to consider is the achievable potential. Data in the EPRI market potential studies[24] indicate that approximately 50% of the economic potential is realistically achievable and that 75% of the economic potential would represent a high achievable potential. Tables 2 and 3 provide examples of how the coefficients from each model can be used to estimate how costs increase as the market penetration increases. Given an economic market potential of 20% of retail sales or 1% per year for 20 years, the achievable potential would be 10% or 0.5% per year, and the high potential would be 15% or .75% per year. The tables depict how average costs change when the market penetration of energy efficiency increases from 50% to 75%.

[24] This applies in the 10 to 20 year time frame. See reference numbers 24 and 25.

Table 2: Impact of Changes in Market Penetration on Program Costs

Simulation of Model 1

Key Assumptions:

Assume the economic market potential is 20% of retail sales.
If the achievable potential is 50% of the market potential, then the achievable potential represents 10% of retail sales.
Increasing achievement from 50% of the market potential to 75% of the market potential impacts the unit cost of EE.
First year cost per kWh saved starts at $.20/kWh
Incremental annual impacts are 1% of retail sales or 100,000,000 kWh per year
The current cumulative market penetration starts at 3% to reflect some existing market presence

EE as % of Retail Sales					Change in Costs
Incremental Impact	Cumulative	Costs (Real $)	Incremental kWh	$/kWh	Due to Change in Cumulative %
1.0%	3.0%	$ 20,000,000	100,000,000	$ 0.2000	
1.0%	4.0%	$ 21,853,333	100,000,000	$ 0.2185	$ 1,853,333
1.0%	5.0%	$ 23,372,140	100,000,000	$ 0.2337	$ 1,518,807
1.0%	6.0%	$ 24,671,631	100,000,000	$ 0.2467	$ 1,299,491
1.0%	7.0%	$ 25,814,750	100,000,000	$ 0.2581	$ 1,143,119
1.0%	8.0%	$ 26,839,964	100,000,000	$ 0.2684	$ 1,025,214
1.0%	9.0%	$ 27,772,653	100,000,000	$ 0.2777	$ 932,689
1.0%	10.0%	$ 28,630,519	100,000,000	$ 0.2863	$ 857,866
1.0%	11.0%	$ 29,426,448	100,000,000	$ 0.2943	$ 795,928
1.0%	12.0%	$ 30,170,134	100,000,000	$ 0.3017	$ 743,687
1.0%	13.0%	$ 30,869,076	100,000,000	$ 0.3087	$ 698,941
1.0%	14.0%	$ 31,529,199	100,000,000	$ 0.3153	$ 660,123
1.0%	15.0%	$ 32,155,279	100,000,000	$ 0.3216	$ 626,080
1.0%	16.0%	$ 32,751,223	100,000,000	$ 0.3275	$ 595,945
1.0%	17.0%	$ 33,320,276	100,000,000	$ 0.3332	$ 569,053
1.0%	18.0%	$ 33,865,161	100,000,000	$ 0.3387	$ 544,885
1.0%	19.0%	$ 34,388,189	100,000,000	$ 0.3439	$ 523,029
1.0%	20.0%	$ 34,891,343	100,000,000	$ 0.3489	$ 503,154
1.0%	21.0%	$ 35,376,332	100,000,000	$ 0.3538	$ 484,990
1.0%	22.0%	$ 35,844,648	100,000,000	$ 0.3584	$ 468,315

Cost per first year kWh for 50% of economic potential		Cost per first year kWh for next 25% of economic potential	
Total Cost	$ 198,954,991	Total Cost	$ 154,150,136
kWh for 50%	800,000,000	kWh for next 25% of retail sales	500,000,000
Cost per first year kWH	$ 0.249	Cost per first year kWH	$ 0.308
		Percent increase in unt cost	24%
Model Elasticities			
Incremental	0.609		
Cumulative	0.278		

Table 3: Impact of Changes in Market Penetration on Program Costs

Simulation of Model 2

Key Assumptions:

Assume the economic market potential is 20% of retail sales.
If the achievable potential is 50% of the market potential, then the achievable potential represents 10% of retail sales.
Increasing achievement from 50% of the market potential to 75% of the market potential impacts the unit cost of EE.
First year cost per kWh saved starts at $.20/kWh
Incremental annual impacts are 1% of retail sales or 100,000,000 kWh per year
The current cumulative market penetration starts at 3% to reflect some existing market presence

EE as % of Retail Sales					Change in Costs
Incremental Impact	Cumulative	Costs (Real $)	Incremental kWh	$/kWh	Due to Change in Cumulative %
1.0%	3.0%	$ 20,000,000	100,000,000	$ 0.2000	
1.0%	4.0%	$ 25,980,000	100,000,000	$ 0.2598	$ 5,980,000
1.0%	5.0%	$ 31,806,015	100,000,000	$ 0.3181	$ 5,826,015
1.0%	6.0%	$ 37,512,014	100,000,000	$ 0.3751	$ 5,705,999
1.0%	7.0%	$ 43,120,060	100,000,000	$ 0.4312	$ 5,608,046
1.0%	8.0%	$ 48,645,588	100,000,000	$ 0.4865	$ 5,525,528
1.0%	9.0%	$ 54,099,974	100,000,000	$ 0.5410	$ 5,454,387
1.0%	10.0%	$ 59,491,939	100,000,000	$ 0.5949	$ 5,391,964
1.0%	11.0%	$ 64,828,365	100,000,000	$ 0.6483	$ 5,336,427
1.0%	12.0%	$ 70,114,824	100,000,000	$ 0.7011	$ 5,286,459
1.0%	13.0%	$ 75,355,907	100,000,000	$ 0.7536	$ 5,241,083
1.0%	14.0%	$ 80,555,465	100,000,000	$ 0.8056	$ 5,199,558
1.0%	15.0%	$ 85,716,768	100,000,000	$ 0.8572	$ 5,161,304
1.0%	16.0%	$ 90,842,631	100,000,000	$ 0.9084	$ 5,125,863
1.0%	17.0%	$ 95,935,496	100,000,000	$ 0.9594	$ 5,092,865
1.0%	18.0%	$ 100,997,504	100,000,000	$ 1.0100	$ 5,062,008
1.0%	19.0%	$ 106,030,547	100,000,000	$ 1.0603	$ 5,033,042
1.0%	20.0%	$ 111,036,305	100,000,000	$ 1.1104	$ 5,005,758
1.0%	21.0%	$ 116,016,283	100,000,000	$ 1.1602	$ 4,979,978
1.0%	22.0%	$ 120,971,836	100,000,000	$ 1.2097	$ 4,955,553

Cost per first year kWh for 50% of economic potential		Cost per first year kWh for next 25% of economic potential	
Total Cost	$ 320,655,590	Total Cost	$ 376,571,330
kWh for 50%	800,000,000	kWh for next 25% of retail sales	500,000,000
Cost per first year kWH	$ 0.401	Cost per first year kWH	$ 0.753
		Percent increase in unt cost	88%
Model Elasticities			
Incremental	0		
Cumulative	0.897		

Under Model 1, the average cost increases from $0.249/kWh to $0.308/kWh or 24%. Under Model 2, the cost increases from $0.401/kWh to $0.753/kWh or 88%. The key point here is not the size of the unit cost numbers, but the percent increase. These values produce a range of average cost increases of 24% to 88% as market penetration increases. This is a wide range, but is based on actual program cost experience. It provides guidance on the expectation that as the market penetration of energy efficiency increases, the unit cost increases.

9. Implications for Future Research

From the review of other studies, it is apparent that little to no evidence exists on the relationship between program costs, program size, and market penetration. But now, the research conducted in this study provides an initial insight into this relationship. While the range of estimated impacts on cost is rather wide, selecting a market penetration driven percent increase in energy efficiency costs in the middle of the range seems appropriate. This percent increase would be applied in estimating costs when the program impacts are expected to exceed the achievable potential. At the same time, efforts to improve targeted marketing can help with cost management.

It should be obvious that further research in this area is warranted. As mentioned, this study is the first to investigate how costs can rise with increases in program size and market penetration. The findings point to the existence of cost efficiencies with respect to program size, but rising costs as market penetration increases. The results developed here are at a very high level. The potential for greater insights may exist by monitoring individual program costs over time. Future research along that direction seems appropriate. The results could vary significantly from one program to the next. Analysis could also be conducted at the portfolio level for individual utility energy efficiency efforts or a cross-section of individual utilities. Only through further research can the range be narrowed and/or confirmed.

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