The View from the Top: Application of Macro-Economic Models to Measure Energy-Efficiency Program Savings in California

Hossein Haeri, Ph.D., Jim Stewart, Ph.D., The Cadmus Group, Portland, Oregon

ABSTRACT

Energy savings and the cost-effectiveness of energy efficiency have traditionally been evaluated using a bottom-up (B-U) approach—a mix of techniques based on engineering, statistics, market research, or combination of these. Despite its history and broad appeal, this approach has several shortcomings: it is time and resource intensive; it may overstate savings, since it does not properly account for technical measure interactions; it fails to properly account for confounding factors, such as rebound effects, self-selection, measure retention and persistence; and it lacks a consistent definition for and treatment of baseline, both across B-U studies and over time;

These shortcomings contributed to the California Public Utilities Commission (CPUC) decision to investigate the viability of using alternative top-down (T-D) approaches that employ aggregate consumption and macro-economic data to measure reductions in energy use resulting from energy efficiency. The CPUC funded two studies that apply these analytic techniques. This paper describes the scope of the project, discusses the B-U approach, T-D approach literature, and reports the preliminary results of the T-D utility-level application.

The study used panel data regression analysis of electricity use in California utility service areas between 1990 and 2010 to estimate electricity savings from utility efficiency programs. The results of this study indicate the T-D approach provides a useful, inexpensive complement to the B-U approach, although it is unlikely to replace it entirely. The study found that between 2000 and 2010, the electricity efficiency programs of California's three investor-owned utilities (IOUs) saved an estimated 113,352 GWh or 5.7% at a cost of about $0.04 per kWh. During the 2006-2008 program cycle, annual net savings were equivalent to 43% of the gross savings claimed by the IOUs.

The Bottom-Up Approach

The B-U approach to measurement and verification of energy-efficiency programs is used in nearly all jurisdictions in the United States. As the term suggests, this approach treats individual energy-efficiency measures, end uses, or programs as the primary units of analysis. It estimates savings from individual measures or programs and then aggregates the results to produce system-wide load impacts.

The B-U approach lacks a unified methodology; it is multidisciplinary, relying on disparate analytic techniques to address specific evaluation issues, such as verification of gross savings, net-to-gross (NTG) calculations, and attribution of savings. Despite its history and broad appeal, the approach has four shortcomings, especially when applied to large portfolios of energy-efficiency programs.

1. Requires extensive primary data collection and, therefore, is both time- and resource-intensive.
2. May result in overstating savings, since it fails to account properly for possible technical interactions among measures and programs—a particularly critical issue in large portfolios.
3. In many cases, fails to account properly for confounding factors, such as rebound effects and self-selection.
4. Lacks consistent definition for and treatment of baseline, both across B-U studies and over time; and has failed to adequately account for measure retention and savings persistence.

In light of these shortcomings, during its 2010-2012 evaluation, measurement, and verification (EM&V) decision, the CPUC directed its Energy Division to assess and test the viability of alternative T-D approaches that use aggregate consumption data to measure reductions in energy consumption resulting from various energy-efficiency programs and efforts in California.[1] The CPUC was also motivated by its interest in developing robust methods to assess the progress of carbon emission reductions required by the energy-efficiency portion of California State Assembly Bill 32, and its adoption of the California Energy Efficiency Strategic Plan, which is intended to set utility programs on a course toward market transformation. Specifically, the CPUC was interested in exploring a full range of T-D evaluation methodologies that might help in achieving the following specific objectives:

1. ***Estimation of energy savings attributable to programs operated by California's IOUs.*** Under the existing Risk Reward Incentive Mechanism (RRIM), IOUs can earn financial rewards for meeting—or incur penalties for failing to meet—energy-savings goals established by the state. The CPUC is interested in whether or not T-D evaluation methods can supplement or substitute for existing methods, possibly reducing evaluation costs and time.
2. ***Assessment of the state's progress toward achieving its greenhouse gas reduction goals.*** Assembly Bill 32 requires the state to reduce its greenhouse gas emissions to 1990 levels by year 2020. An integral component of this plan is to reduce electricity and gas consumption in the retail sector. T-D methods could be used to assess progress toward this goal, measured in *market-gross* savings of electricity and gas consumption.[2]
3. ***Forecasting energy-efficiency programs, codes and standards, and naturally occurring savings for use in developing long-term forecasts of state electricity demand.*** The California Energy Commission (CEC) is responsible for forecasting the state's electricity demand to ensure electric resource adequacy. In 2003, the state declared energy efficiency as a "resource of first choice," meaning that energy-efficiency investments will continue to grow. Demand forecasters must incorporate energy-efficiency growth, but few reliable, historical savings data are available on which to base development of these forecasts.

The Top-Down Approach

Academics and policy makers have shown considerable interest over the past two decades in T-D approaches to measure the impacts of energy-efficiency and conservation programs. There is now a significant body of research, largely directed toward estimating savings from utility-sponsored, ratepayer-funded energy-efficiency programs.

T-D methods use macro-level data on energy-use indicators, aggregated to the sector and/or geographic area, to estimate energy savings. Energy-use indicators measure energy intensity through energy consumption per specific units (e.g., capita, square foot) or unit of output (e.g., industrial value added, gross domestic product) over a specified period of time (typically a year). These data contrast with the customer, end-use, or measure-level data commonly employed in B-U energy consumption studies.

Regression analysis of aggregate energy use has been the primary method in T-D analysis because it offers a straightforward means of estimating the impacts of utility programs on different energy-use metrics while controlling for exogenous factors that affect energy consumption. As such, the

[1] See California Public Utilities Commission (CPUC). *Decision on Evaluation, Measurement, and Verification of California Energy Efficiency Programs,* Decision 10-10-033. October 28, 2010.

[2] Market gross savings are energy savings from energy efficiency programs, building codes and appliance standards, and naturally occurring efficiency.

technique provides a reasonable framework for attributing changes in energy use to utility programs, codes and standards, and naturally-occurring conservation.

Typically, the regression model is estimated using panel regression techniques, such as fixed-effects or first-differencing. Equation 1 represents a typical specification for a regression model to analyze energy use in a particular sector for a large number of utilities over time.

$$\text{(Equation 1)} \quad e_{it} = W_{it}'\gamma + \Sigma_{j=0}^{J}\delta_j D_{it-j} + \lambda_i + \mu_{it}$$

where:

- e_{it} = energy use indicator, typically expressed in natural logarithmic form.
- W_{it} = vector of time-varying characteristics in utility service area "i" during period "t" affecting energy use, such as weather, income, electricity, and other energy source prices.
- γ = vector of coefficients indicating the relationship between energy use and the characteristics of W_{it}.
- D_{it-j} = measure of energy-efficiency program expenditures in the period "t" through "j." One or more lags control for the impacts of past investments on current energy use. The coefficient δ_j, where j=1 to J, shows the impacts of contemporaneous and past utility energy-efficiency investments on energy use.
- λ_i = utility-specific fixed effect, capturing the impacts of energy consumption characteristics that do not vary over time.
- μ_{it} = the error term, reflecting unobservable influences on energy use in utility "i" during year "t."

Many T-D studies also include one or more lagged values of the dependent variable, a time trend, or time-period fixed-effects. The lagged values capture the partial adjustment of electricity demand to its various determinants, such as prices, tastes, preferences, or time-varying factors. As electricity demand derives from the use of long-lived appliances and equipment, adjustments lag when equipment and appliances are replaced gradually. Time-trend variables or time periods capture omitted time-varying covariates of consumption, such as changes in attitudes and in codes and standards.

The "δ" coefficient provides the main object of interest in Equation 1. For example, if D_{it-j} represents per-capita expenditures on energy efficiency, the coefficient δ_{it-j} is interpreted as energy savings in period "t" per dollar of expenditures in period "t" through "j." If D_{it-j} represents expected (*ex ante*) per-capita energy savings, δ_{it-j} represents the fraction of expected energy savings in period "t" through "j" that are realized in period "t."

Review of Past Research

Since 1996, at least seven studies have attempted to estimate the energy savings of utility-sponsored energy-efficiency programs using T-D methods (Arimura, Li, Newell & Palmer 2011; Auffhammer, Blumstein & Fowlie 2008; Horowitz 2004; Horowitz 2007; Loughran & Kulick 2004; Parfomak & Lave 1996; Rivers & Jaccard 2011). Although the studies have the objective of estimating energy savings from utility efficiency programs, they differ in their measurement of efficiency investments, model specifications, estimation methods, and sample frames. Table 1 lists some of the key differences.

As shown in Table 1, the seven studies also reach dramatically different conclusions, with savings realization rates ranging from nearly 100% (Parfomak & Lave 1996) to 0% (Rivers & Jaccard 2011).

Table 1. Summary of T-D Utility Program Energy Savings Studies

Study	Sector	Study Sample and Timeframe	Energy Use Indicator	Indicator of Energy Efficiency Program Investments	Main Findings
Parfomak & Lave 1996	Commercial, industrial	39 U.S. utility service territories in 10 states, 1970–1993	Energy sales to commercial and industrial customers	Utility reported savings	Average realization rate for commercial programs of 99%
Horowitz 2004	Commercial	42 U.S. states,1989–2001	Commercial retail electricity sales/ commercial sector income	Savings of adjusted shipments of electronic ballasts	Average realization rate for commercial programs of 54%
Loughran & Kulick 2004	All sectors	324 U.S. utilities, 1989–1999	Retail energy sales	DSM expenditures	Savings between 0.3% and 0.4% of consumption
Horowitz 2007	Residential, commercial, industrial	24 U.S. states, 1989–2001	Commercial sector retail electricity sales to state service sector income	Strong versus weak commitment	Reductions in electricity intensity of 4.4% in the residential, 8.1% in the commercial and 11.8% in the industrial sector
Auffhammer, Blumstein & Fowlie 2008)	All sectors	324 U.S. utilities, 1989–1999	Retail energy sales	DSM expenditures	Savings between 0.5% and 2.8% of electricity consumption
Arimura, Newell & Palmer 2009	All sectors	513 U.S. utilities, 1989–2006	Retail energy sales	DSM expenditures per customer	Savings of 1.1% in electricity use at a cost to utilities of $0.064/kWh
Rivers & Jaccard 2011	All sectors	10 Canadian provinces, 1990–2005	Retail energy sales per capita	DSM expenditures per capita	Statistically zero savings, per-unit cost of conserved energy may be as high as $2/kWh

The stark differences in results highlight a long-standing controversy in the energy-efficiency policy arena about utility-program savings and cost-effectiveness that are estimated using conventional B-U evaluations. One contentious point has been how fully utility program evaluations have accounted for free ridership.

- In one study that analyzed data from 39 utilities from 1970 to 1993, the estimated energy-efficiency savings were equivalent to 99% of the utilities' reports (Parfomak & Lave 1996).
- Almost a decade later, Horowitz (2004) performed a similar analysis of utility program savings in the U.S. commercial sector, finding a significantly lower realization rate of 54%.
- Noting persistent doubts about utility-program savings, one study analyzed data between 1992 and 1999 for 324 utilities and found significantly lower savings, ranging from 20% to 25% of those claimed by utilities (Loughran & Kulick 2004).

- A recent study analyzed energy-efficiency program savings and cost-effectiveness in 10 Canadian provinces between 1990 and 2005, finding that energy-efficiency spending had a small and statistically insignificant impact on consumption (Rivers & Jaccard 2011).

Applying the Top-Down Approach

Data Development and Sources

Our estimation sample included data for 28 California utilities between 1990 and 2010.[3] These utilities accounted for 98.2% of electricity consumption in California and 99.7% of efficiency expenditures in California between 2006 and 2010.

Annual data for California utilities used in this study were obtained from a variety of sources:

- Average energy prices for each utility and sector were estimated from the Energy Information Administration utility revenue and sales data.
- Annual personal income data were available from the Bureau of Economic Analysis Regional Economic Accounts.
- Historical weather data on annual heating and cooling degree days were obtained from the National Oceanic and Atmospheric Administration's National Climatic Data Center.
- Historical data on the saturation of central air conditioning units and gas and electric heat were obtained from California's Residential Appliance Saturation Survey (RASS) and from the U.S. Census.
- Historical data on residential and nonresidential new construction were obtained from McGraw Hill.
- Details about California building codes and appliance standards and federal appliance standards were obtained from the CEC, the U.S. Department of Energy, and the Building Code Assistance Project.
- Energy efficiency expenditures for California's utilities were obtained from the California Municipal Utility Association, the CEC, and CPUC's Energy Efficiency Groupware Application (EEGA).
- DSM expenditures, which include expenditures on energy efficiency and demand response, were obtained from the EIA.

Model Specification and Estimation

We estimated regressions of utility annual electricity consumption per capita. Then, using the regression estimates, we estimated the electricity savings and cost per kWh of savings from utility electricity efficiency program spending.

The specifications of the utility consumption intensity models were similar to Equation 1. The dependent variable was electricity consumption per capita, and the independent variables included electricity efficiency expenditures per capita in each of the current and previous five years only. Other controls were personal income per capita, average electricity prices, average natural gas prices, weather

[3] The utilities were Anza Electric Cooperative, Azusa Light & Water, Bear Valley Electric Service, City of Alameda, City of Anaheim, City of Banning, City of Burbank, City of Colton, City of Healdsburg, City of Lodi, City of Palo Alto, City of Pasadena, City of Redding, City of Riverside, City of Roseville, City of Ukiah, Glendale Water and Power, Imperial Irrigation District, LADWP, Modesto Irrigation District, PG&E, SMUD, SDG&E, Shasta Dam Area Public Utility District, Sierra Pacific Power Company, Silicon Valley Power, SCE, and Turlock Irrigation District.

heating and cooling degree days (HDDs and CDDs), and new construction floor space per capita to capture the impacts of building codes. The model also included utility fixed effects to account for differences in per capita consumption between utilities and a time-trend variable to account for trends in consumption not captured by the other variables.

Regression Results

Table 2 lists estimates of the coefficients on current and lagged annual per capita energy efficiency (Models 1 and 2) or DSM (Models 3-5) expenditures for different regressions. Due to the inclusion of five lags of energy-efficiency expenditures as independent variables and the availability of other data, there were a maximum of 14 observations per utility. Unless noted, the models assumed the error followed an auto-regressive (AR(1)) process and were estimated by feasible generalized least squares (FGLS).

Table 2. Regression Estimates of Energy Efficiency Spending Impacts

	Model 1	**Model 2**	**Model 3**	**Model 4 (Dynamic Demand)**	**Model 5**
Expenditures ($) per capita in current year	-0.00038 (0.00053)	-0.00023 (0.00051)	-0.00012 (0.00087)	-0.00049 (0.00097)	0.00016 (0.00054)
Expenditures ($) per capita year t-1	-0.00069 (0.00052)	-0.00021 (0.00052)	0.00084 (0.00083)	0.00040 (0.00057)	-0.00011 (0.00055)
Expenditures ($) per capita year t-2	-0.00109** (0.00049)	-0.00113** (0.00049)	-0.00068 (0.00090)	-0.00121** (0.00059)	-0.00104* (0.00061)
Expenditures ($) per capita year t-3	-0.00122* (0.00046)	-0.000704 (0.00050)	-0.000013 (0.00089)	0.00024 (0.00076)	-0.00127** (0.00054)
Expenditures ($) per capita year t-4	-0.000275 (0.00066)	0.000116 (0.00063)	-0.000553 (0.00092)	-0.000648 (0.00041)	-0.000438 (0.00054)
Expenditures ($) per capita year t-5	-0.00292* (0.00058)	-0.00153* (0.00044)	-0.00155* (0.00092)	-0.00153** (0.00065)	-0.00195*** (0.00051)
$\chi 2$, p-value from test of joint significance of expenditures coefficients	41.5 $p<0.01$	28.0 $p<0.01$	9.4 $p=0.15$	7.8 $p<0.256$	35.0 $p<0.001$
Utilities in estimation sample	3 IOUs	3 IOUs and SMUD	28 Calif. utilities	28 Calif. Utilities	8 Calif. Municipal Utilities
Expenditures data source	EEGA, historical program reports	EEGA, historical program reports	EIA	EIA	EIA
Estimation period	1997-2010	1997-2010	2001-2010	2001-2010	2001-2010
N obs.	42	53	280	252	80

Notes: Dependent variable is annual electricity consumption per capita. Models 1-3, 5 estimated by FGLS. Model 4 estimated by GMM. Standard errors in parentheses. *** $p<0.1$; ** $p<0.05$; * $p<0.01$

Model 1. The first model was estimated with 14 years (1997-2010) of data for the IOUs (PG&E, SCE, and SDG&E). Current and lagged per-capita energy-efficiency expenditures were negatively correlated with consumption; the effects of these variables were jointly significant at the 1% level ($\chi^2(6)=41.5$, $p<0.01$). Two-, three-, and five-year lagged expenditures had individually significant effects at the 10% level. The coefficient on two-year lag expenditures implies that a $1 increase in expenditures of two years ago decreased current consumption by approximately 0.1% ($p=0.07$).

Model 2. In the second model, we added the Sacramento Municipal Utility District, which also has a long history funding energy efficiency. Energy-efficiency expenditures were jointly significant at the 1% level of statistical significance, and all coefficients except four-year lagged expenditures had negative signs. The variables were jointly significant ($\chi^2(6)=28.0$, $p<0.01$)).

Model 3. The third model was estimated with 10 years of data (2001-2010) for 28 California utilities that accounted for 98.2% of California's electricity consumption and 99.7% of electricity efficiency expenditures. Annual DSM expenditures were obtained from EIA. All coefficients on current and lagged expenditures were negative; although only five-year lagged expenditures were individually significant. The expenditures' coefficients were jointly significant at the 20% level ($\chi^2(6)=9.4$, $p=0.15$), and their magnitudes were similar to those estimated in Models 1 and 2. The most likely explanation for the reduced statistical significance of efficiency expenditures is measurement error in the EIA data; it is likely many utilities misreported or did not report their expenditures. Another contributing factor may have been differences between utilities in the share of non-residential loads. The effect of per capita efficiency spending may be less for utilities with small residential populations and relatively large industrial and agricultural loads.

Model 4. The fourth model is a dynamic demand model, which includes a lag of the dependent variable to account for the gradual adjustment of consumption to its equilibrium level. We estimated this model by General Method of Moments (GMM) after first-differencing the equation to remove unobserved time-invariant effects. Model 4 was also estimated with 10 years of data for 28 utilities.[4] The results were generally consistent with those for Model 3. Four of six DSM expenditures' coefficients were negative and two were individually significant, although they were not jointly significant ($\chi^2(6)=7.76$, $p<0.256$) at the 10% level. The coefficient on the lagged dependent variable was positive and statistically significant at the 5% level, suggesting, as hypothesized, that electricity consumption adjusted gradually to changes in prices, incomes, etc.

Model 5. To account for non-reporting of DSM expenditures in EIA and differences between utilities in the non-residential sector's share of load, the fifth model was estimated with data for the eight municipal utilities that reported positive expenditures in each year between 1992 and 2012.[5] These utilities accounted for about 33% of electricity consumption and 70% of DSM expenditures in non-IOU service territories between 2005 and 2010. Five of six DSM expenditures coefficients have the expected signs, and the coefficients are jointly significant at the 1% level (($\chi^2(6)=35.0$, $p<0.001$)). The coefficients on two-, three-, and five-year lagged expenditures are individually significant. The magnitudes of the coefficients are approximately equal to those in Models 1 and 2.

Figure 1 compares the estimated percent effects on per capita consumption of a $1 increase in per capita efficiency program spending in the current and previous five years for Models 1 (IOUs) and 5 (municipal utilities). Although Model 1 was estimated for the IOUs with expenditures data from EEGA and IOU historical program reports and Model 5 was estimated for the municipal utilities with EIA data, the estimated spending impacts are very close. It suggests investor-owned and municipal utilities obtained similar returns from investments in efficiency.

[4] The estimation occurred through GMM estimation of the first difference of **Error! Reference source not found.** (Arellano & Bond 1991; Greene 1997). We used lagged differences of the dependent variable as instruments for $\Delta\ln(kWh_{it-1})$.

[5] The utilities were SMUD, City of Alameda, City of Anaheim, City of Palo Alto, City of Redding, City of Riverside, City of Roseville, and Silicon Valley Power.

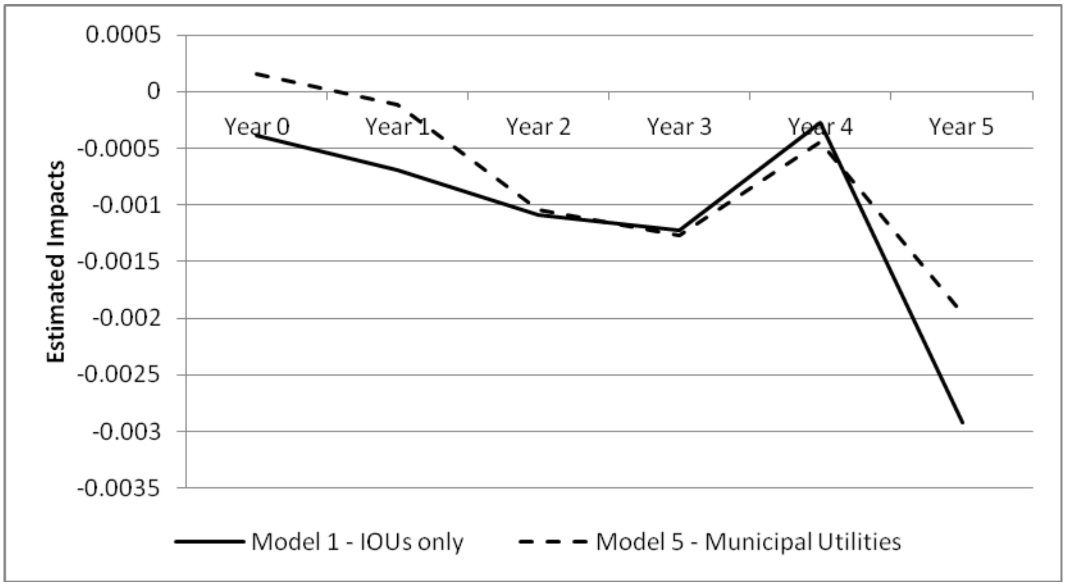

Figure 1. Regression Estimates of Efficiency Spending Impacts

Estimates of Savings and Cost per kWh Saved

We used the regression results to estimate the savings and the cost per kWh of saving for utility electricity efficiency programs. We estimated the savings and costs for the IOUs using the results of Model 1 and for the eight California municipal utilities using the results of Model 5.

Figure 2 shows the IOUs' real electricity efficiency expenditures (1997-2010) in each year and estimates of the energy savings from expenditures that year and in the previous s five years

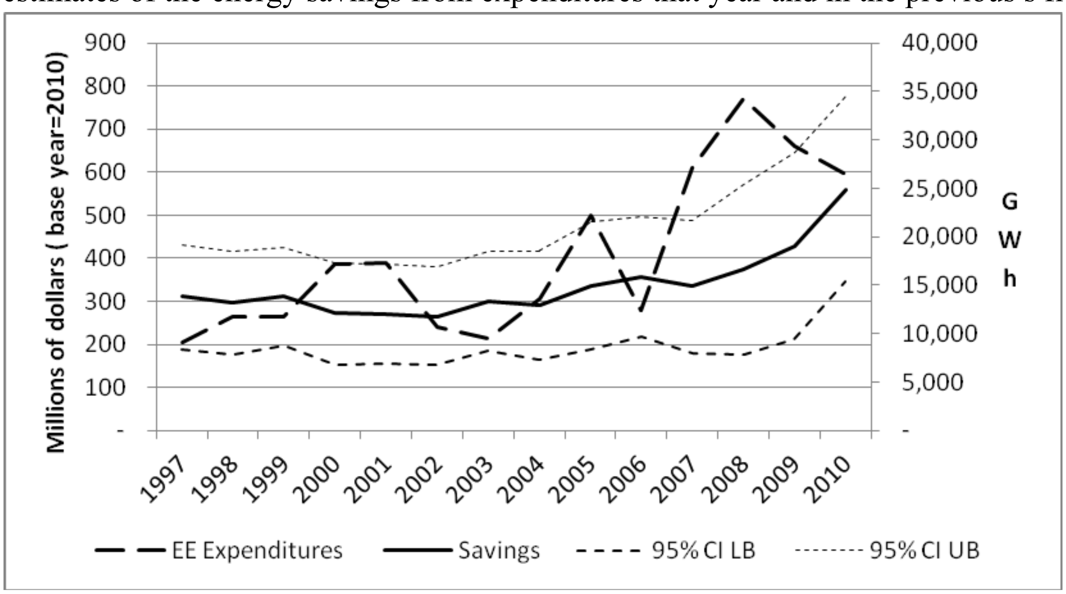

Figure 2. IOU Annual Electricity Efficiency Expenditures and GWh Savings from Spending in Current and Five Previous Years

Both IOU expenditures and savings increased significantly over the period. Annual real expenditures more than tripled between 1997 and 2010. According to the estimates, energy savings almost doubled. Annual energy-efficiency expenditures were significantly more volatile than the savings, which reflect the effects of efficiency spending over six years. To put the savings in perspective, Figure 3 reports the estimated savings from IOU expenditures in the current and previous five years in percent terms.

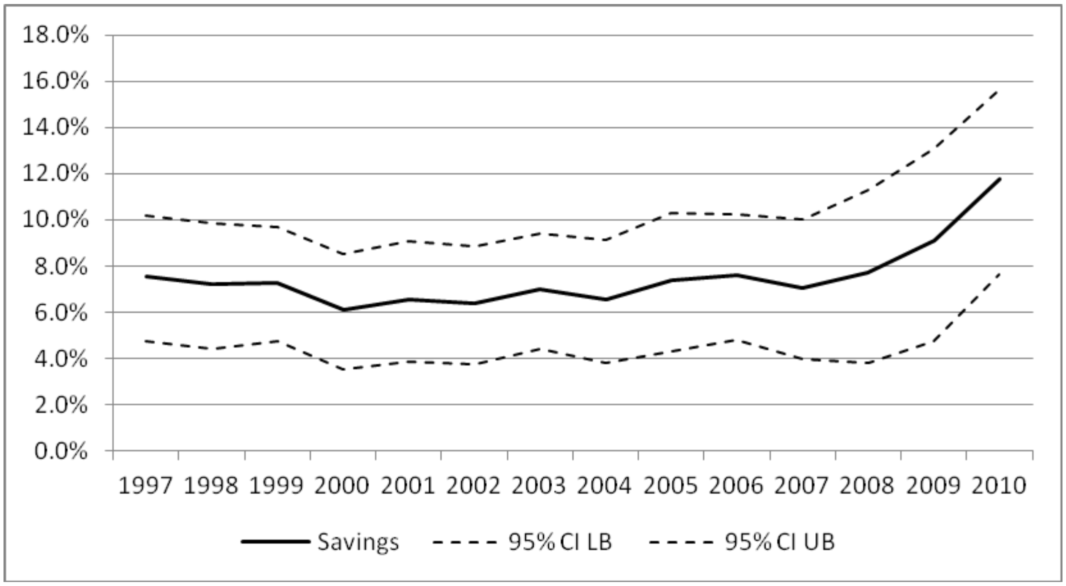

Figure 3. IOU GWh Percent Savings from Electricity Efficiency Spending in the Current and Five Previous Years

The results show that IOU efficiency spending in the current and previous five years reduced annual consumption by 6% to 8% between 1997 and 2008 and by 10% to 12% between 2009 and 2010. The increase after 2008 reflects the big run-up in spending between 2006 and 2008. The results suggest that on average spending at these levels reduced consumption by about 1% to 2% per year.

Figure 4 shows the municipal utility electricity efficiency spending in each year and GWh savings from spending in the current and previous five years. The eight municipal utilities spent between $40 and $60 million per year between 2001 and 2010. Energy savings from spending in the current and previous five years peaked in 2006 at about 2,200 GWh, which reflects high levels of efficiency spending three and four years earlier. The percent savings in Figure 5 ranged from 7% to 9% and exhibited a similar time trend.

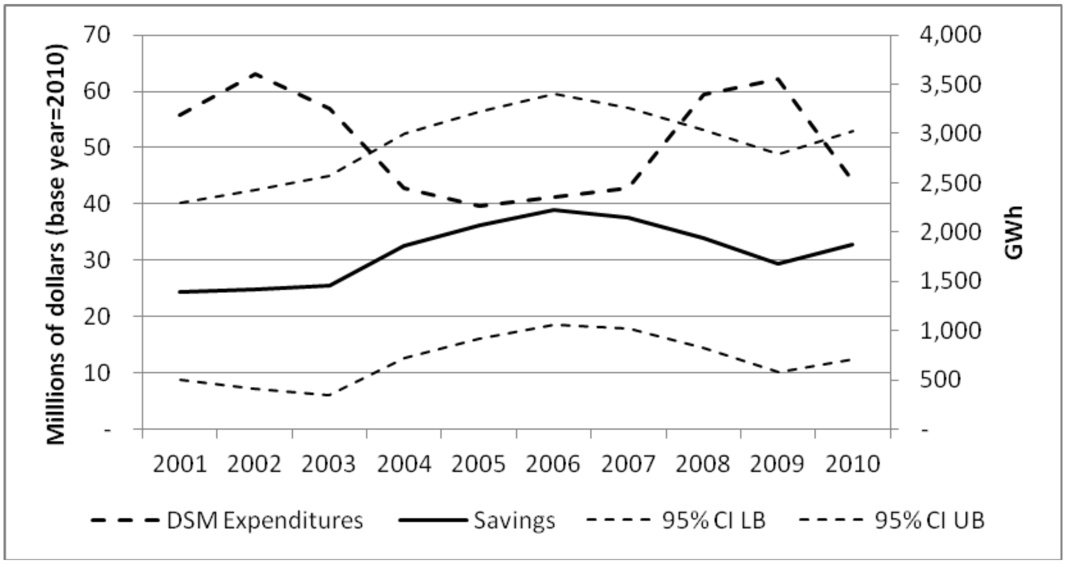

Figure 4. Municipal Utility Annual Electricity Efficiency Expenditures and GWh Savings from Spending in Current and Five Previous Years

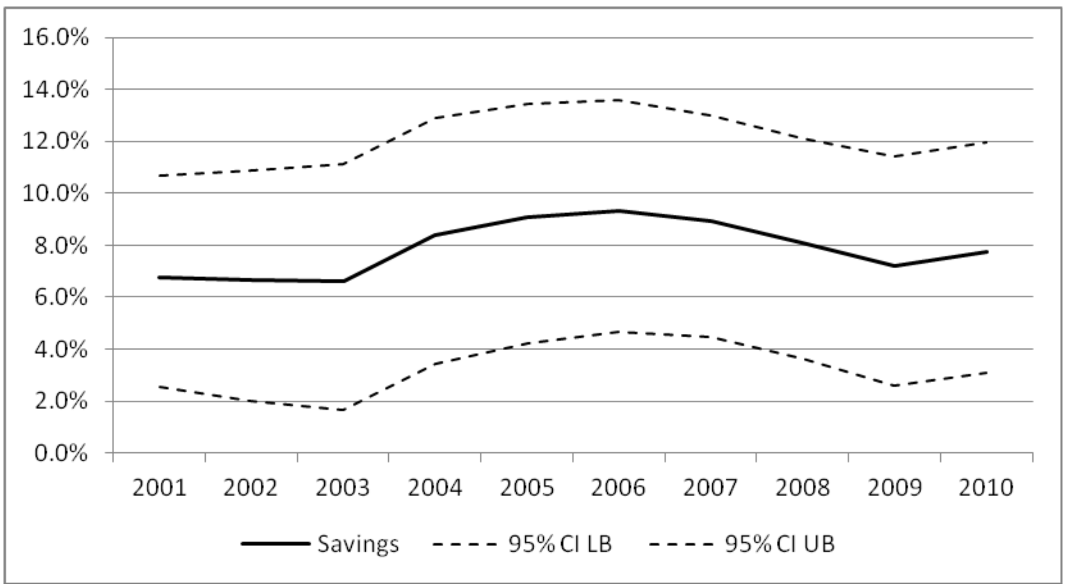

Figure 5. Municipal Utility GWh Percent Savings from Electricity Efficiency Spending in the Current and Five Previous Years

Cost of Saved Electricity. Efficiency spending can result in savings in the year of the spending as well as in future years. Looking at savings in just one year captures only part of current and past years' spending effects. Therefore, it is important that savings and costs be examined over multiple years instead.

Table 1 shows the electricity savings and costs per kWh saved from utility electricity efficiency spending for the IOUs and the eight municipal utilities in different periods. It is important to keep in mind two things. First, the estimates account for spending's effects in the current and next five years only. Savings after six years implicitly go to zero. Thus, our estimates of savings and cost per kWh saved are inherently conservative. Second, the estimates of cost per kWh are sensitive to the number of years in the period. Electricity efficiency spending will appear more cost-effective over longer periods of time as savings accumulate.

Table 1. Utility Electricity Efficiency Savings and Costs per kWh Saved

Utilities	Years	Real Expenditures (2010 $)	Electricity savings (GWh)	95% CI LB	95% CI UB	% Savings	Cost per kWh
IOUs	1992-2010	7,195,884,495	232,761	117,820	347,702	6.5%	$0.031
IOUs	2001-2010	4,559,054,277	113,352	51,378	175,325	5.7%	$0.040
IOUs	2005-2010	3,410,220,051	60,867	20,936	100,798	5.0%	$0.056
IOUs	2006-2008	1,656,693,638	11,016	-3,020	25,052	1.9%	$0.150
Municipal Utilities	2001-2010	508,088,501	12,783	4,913	20,653	5.7%	$0.040
Municipal Utilities	2005-2010	289,309,670	3,878	172	7,584	2.9%	$0.075

Notes: Savings estimates based on consumption intensity regressions. See text. Savings and cost per kWh for IOUs estimated using Model 1. Savings and cost per kWh for municipal utilities estimated using Model 5. The municipal utilities are City of Alameda, City of Anaheim, City of Palo Alto, City of Riverside, Sacramento Municipal Utility District, Silicon Valley Power, City of Roseville, and City of Redding.

Study Results and Conclusions

Between 1992 and 2010, the IOUs spent over $7 billion on electricity efficiency programs, with an estimated savings of 232,761 GWh, equivalent to about 6.5% of total consumption. The average cost of saved energy was approximately $0.03/kWh with a 95% confidence interval of [$0.021, $0.06]. During the 2000s, which saw the California electricity crisis and a resurgence of efficiency program spending, the IOUs spent approximately $4.5 billion, resulting in an estimated savings of 113,352 GWh or about 5.7% of consumption. The average cost of saved energy during this period was approximately $0.04/kWh.

Between 2005 and 2010, the IOUs spent approximately $3.4 billion, saving 60,867 GWh or 5% at a cost of $0.056 per kWh. IOU efficiency spending of $1.7 billion during the 2006-2008 utility efficiency program cycle resulted in savings of approximately 11,016 GWh or 1.9% of consumption.

This study's estimate of the cost of saved energy of approximately $0.03-$0.04/kWh is approximately equal to other U.S. utilities. For example, two recent studies of the U.S. utility efficiency program spending estimated average costs of saved energy of $0.046/kWh (Auffhammer, Blumstein & Fowlie 2008) and average program costs of $0.041/kWh (Arimura, Li, Newell & Palmer 2011).

The eight municipal utilities spent $508 million between 2001 and 2010. We estimate this spending saved 12,783 GWh or 5.7% between 2001 and 2010. The average cost of saved energy was $0.040/kWh, which was the same as the cost per kWh of savings for the IOUs.

Table 4 compares claims of first-year savings with this study's estimates for the IOU's. The IOUs' savings are prorated for efficiency measure installation during the 2006-2008 three-year program funding cycle.[6] Thus, a measure installed half-way through the year counted for half as much as a measure installed at the beginning of the year. It should be noted that this comparison is inexact. This study's estimates are of *net* savings, which accounts for freeridership, spillover from program

[6] The 2006-2008 program cycle was the first time that the IOU efficiency programs were evaluated using methods in the California Energy Efficiency Evaluation Protocols and that consistent data sets were collected for the IOUs.

participants to nonparticipants, and other utility program market effects. The IOU savings claims are *gross* estimates and do not reflect adjustments for these factors.

Table 4. IOU Claims and Estimated First-Year Savings, 2006-2008 Program Cycle

IOU savings claim (GWh)	Estimated savings (GWh)	Lower Bound 95% Confidence Interval	Upper Bound 95% Confidence Interval
10,461	4,500	(7,790)	16,790

The IOUs claimed total first-year savings between 2006 and 2008 of 10,461 GWh. This study estimates the first-year savings were 4,500 GWh, or 42% of the IOUs' claim. However, as the estimate of current year efficiency spending on consumption is imprecisely estimated, there is significant uncertainty about this study's estimate. The 95% confidence interval for total first-year savings between 2006 and 2008 was [-7,790 GWh, 16,790 GWh], which includes the IOUs' claim. The imprecision of current year spending's impact on consumption is the reason it is preferable to look at its impact over multiple years.

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