Macro Consumption Metrics Pilot Study
Technical Memorandum – Preliminary Findings

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August 21, 2012

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EXECUTIVE SUMMARY

This technical memorandum describes the preliminary findings of the *Demand Research* Macro (or Total) Consumption Metric Pilot Study. These findings focus on the reductions in energy use attributable to the energy efficiency policy (the combined collection of energy efficiency programs, building codes, appliance standards, and other public initiatives) existing in California in 2006, 2007, and 2008. The data used for this study encompass over 6,000 California census tracts that make up the service territories of PG&E, SDG&E, SCE, and SGC. The source of the energy consumption data are the IOU's monthly customer billing data that are annualized, address-normalized, and merged by 2010 census tracts. The data span 2006 through 2010.

Using econometric models designed with the same basic structure, policy impacts are estimated for the PG&E and SDG&E residential sector both for electricity and natural gas consumption (residential sector data for SCE and SCG are forthcoming). For the commercial and industrial sectors, electricity policy impacts are estimated for PG&E, SDG&E, and SCE collectively at the county level. Natural gas policy impacts for these sectors are estimated for PG&E and SDG&E, only; SCG commercial and industrial sector data will not be available for this study. Also, the impacts of residential building codes on housing units built between 2000 and 2004 are estimated both for electricity and natural gas consumption.

The upper panel of Table ES1 contains the electricity efficiency policy impact findings for the four year period from 2006-2009; the lower panel contains the findings for the five year period from 2006-2010. Table ES2 is in the identical format and displays the findings for natural gas efficiency policy.

Table ES1: State-Level Policy Impact Findings, Electricity

kWh: 2006-2009 Period	Avg. Ann. Energy Consum.	Last Yr. Cum. Ex Ante Savings	Pct. Est. Impact	Avg. Ann. Est. Impact
Ind. (PG&E, SDG&E, SCE)	41,554,138,628	2,048,456,628	13.6%	5,668,443,641
Com. (PG&E, SGG&E, SCE)	76,735,020,087	3,403,092,575	1.2%	916,539,984
Res. (PG&E)	30,132,043,300	480,430,254	4.7%	1,408,088,335
Res. (SDG&E)	7,483,267,512	105,504,485	3.9%	289,567,961
Res. Codes (PG&E)[1]	2,571,722,287		1.9%	48,775,285
Res. Code (SDG&E)[1]	742,521,437		3.2%	23,700,542
Total	155,904,469,527	6,037,483,943		8,355,115,748
Cumulative % Impact		3.9%		5.4%
Pct. Standard Error (+/-)				28.6%
kWh: 2006-2010 Period				
Ind. (PG&E, SDG&E, SCE)	41,879,937,508	2,512,486,691	17.8%	7,471,169,145
Com. (PG&E, SGG&E, SCE)	76,829,480,556	4,412,722,613	2.1%	1,611,926,492
Res. (PG&E)	30,207,548,725	526,324,700	6.4%	1,923,104,970
Res. (SDG&E)	7,432,945,519	129,427,756	4.2%	313,568,580
Res. Codes (PG&E)[1]	2,552,293,975		2.0%	51,114,791
Res. Code (SDG&E)[1]	729,653,042		2.9%	21,086,973
Avg. Total. Ann. Consum.	156,349,912,308	7,580,961,761		11,391,970,952
Cumulative % Impact		4.8%		7.3%
Pct. Standard Error (+/-)				18.9%

[1] Average annual sales total does not include residential code energy sales.

Based on the collected findings of all the eight electricity consumption econometric models estimated for this study, in 2009 the total impact of electricity efficiency policy in all sectors, and including residential building code impacts for housing units built between 2000 and 2004, is a decline in energy use 8,355 GWh. This is a 5.4 percent decline relative to the average, total energy consumption per year in the 2006-2009 period. The relative standard error of the impact estimate is 28.6 percent; at the 90 percent confidence level the relative standard error is plus or minus 47 percent. By comparison, in 2009 the cumulative ex ante estimate of electricity reductions for the 2006-2009 period due to downstream, IOU-implemented energy efficiency programs is 3.9 percent relative to 2009 total electricity consumption. It is not the purpose of this study to speculate as to why there are differences in the ex ante and model-based energy consumption reduction estimates. Suffice it to say that the cumulative ex ante estimates of energy reductions due to downstream, IOU-implemented energy efficiency programs are used in this study as *indicators* of the impacts of the broader set of public initiatives that comprise *de facto* state-wide energy efficiency *policy*.

Cumulative policy impacts for the 2006-2010 period are 7.3 percent. The relative standard error of this estimate is plus or minus 18.9 percent, or 31 percent at the 90 percent confidence level. The cumulative IOU energy efficiency program ex ante energy reduction estimate is 4.8 percent of average total energy consumption over the five year period.

Table ES2 indicates that the eight natural gas consumption econometric models yield findings of 1.9 percent percent policy impacts over the four year estimation period.

Table ES2: State-Level Policy Impact Findings, Natural Gas

Therms: 2006-2009 Period	**Avg. Ann. Energy Consum.**	**Last Yr. Cum. Ex Ante Savings**	**Pct. Est. Impact**	**Avg. Ann. Est. Impact**
Ind. (PG&E,SDG&E)	5,124,383,847	87,353,504	1.1%	56,171,929
Com. (PG&E, SDG&E)	1,198,857,181	17,121,520	18.6%	222,477,711
Res. (PG&E)	2,012,166,142	10,406,303	1.2%	23,976,294
Res. (SDG&E)	297,293,772	2,039,215	-51.3%	-152,541,395
Res. Codes (PG&E)[1]	152,939,950		9.2%	13,873,030
Res. Code (SDG&E)[1]	25,880,855		5.1%	1,328,257
Total	8,632,700,942	116,920,542		165,285,826
Cumulative % Impact		1.4%		1.9%
Pct. Standard Error (+/-)				175%
Therms: 2006-2010 Period				
Ind. (PG&E,SDG&E)	5,143,530,663	111,485,401	1.4%	72,730,412
Com. (PG&E, SDG&E)	1,200,231,263	23,026,253	19.5%	234,511,830
Res. (PG&E)	2,018,224,763	13,930,364	3.3%	65,597,381
Res. (SDG&E)	308,983,896	2,778,731	-64.3%	-198,590,214
Res. Codes (PG&E)[1]	152,601,314		9.6%	14,650,642
Res. Code (SDG&E)[1]	25,675,625		4.1%	1,045,537
Total	8,670,970,586	151,220,748		189,945,588
Cumulative % Impact		1.7%		2.2%
Pct. Standard Error (+/-)				244%

[1] Average annual sales total does not include residential code energy sales.

The relative standard error of this estimate is very large, at 175 percent. The IOU energy efficiency program ex ante estimate of natural gas reductions for the four year period is 1.4 percent relative to average total electricity consumption. In the five year period, the impact estimate for natural gas consumption energy efficiency policy rises to 2.2 percent, again with a very large relative standard error.

This study achieves the two main goals of this pilot study articulated by Commission Decision (D.)10.10.33 (October 28, 2010). Both are related to the creation of an evaluation framework that is scientifically defensible and applicable for the foreseeable future. First, it demonstrates that an well-founded econometric framework, coupled with an appropriate, large-sample database, can be developed to evaluate the aggregate impact of the 2006-2008 energy efficiency programs on energy consumption. Second, it demonstrates that aggregate econometric models employing large samples are capable of accurately measuring the impact of the Commission's energy efficiency efforts on overall electricity and natural gas consumption in California in the context of post-2012 EM&V activities. The potential for accurate measurement is demonstrated by the standard errors that accompany the estimated electricity policy impacts for the 2006-2010 period. No other type of evaluation study can produce a relative error bound of 31 percent (at the 90 percent confidence level) around a state-level policy impact estimate that embraces all three non-transportation sectors of the economy and incorporates the uncertainties due to free ridership, spillover, rebound, measure interaction and retention, behavioral changes, and general economic conditions.

This study also achieves the two additional goals articulated by Decision (D.) 10.10.33. This detailed, small-geographic area, sector and industry-level approach to policy evaluation shows that such studies are likely to be valuable for improving estimates of aggregate reductions in Greenhouse Gases (GHG) emissions from efficiency programs as required in AB32. Also, it is likely that they can prove valuable for more directly aligning and integrating energy efficiency program findings into the California Energy Commission's (CEC) demand forecasts, and ultimately, the CPUC's resource procurement process.

General recommendations for integrating this evaluation approach into the permanent portfolio of post-2012 EM&V activities fall into two categories, database development and econometric analysis. They include:

- Expand the database with additional variables and upgrade the database for easier access.
- Develop standardized routines for data cleaning and checking.
- Develop and evaluation-oriented geographic information system.
- Explore the properties of different types of econometric impact estimators.
- Experiment with customized models for different fuels, sectors, utility service territories, market segments and customer grouping.
- Develop econometric models that target specific programs and public initiatives.

1. Introduction

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1) To assess the ability of total energy consumption approaches to accurately measure the aggregate impact of the 2006-2008 energy efficiency programs on energy consumption.
2) To assess the ability of total energy consumption approaches to accurately measure the impact of the Commission's energy efficiency efforts on the overall electric energy and natural gas consumption in California in the context of post-2012 EM&V activities.
3) To examine the ability of total energy consumption approaches to improve estimates of aggregate reductions in Greenhouse Gases (GHG) emissions from efficiency programs as required in AB32.

4) To examine the ability of total energy consumption approaches to more directly align and integrate the study results into the California Energy Commission's (CEC) demand forecasts and ultimately the CPUC's resource procurement process.
5) To provide recommendations as to the specific data needs, analytical frameworks, and systems required to integrate total energy consumption approaches into the permanent portfolio of post-2012 EM&V activities.

In many respects, the present modeling effort is similar to past econometric studies of aggregate energy consumption, most of which have been cited in the three independent white papers produced for the Commission in 2011 by Horowitz, Sanstad and Loudermilk, and The Cadmus Group. Like most prior studies, the econometric models used to analyze aggregate energy use are populated with cross section, location-specific observations whose variables are measured at two or more equal time intervals. Yet, the present study introduces many new research design features with the potential for greater development. These begin with an innovative approach to inexpensive data collection. The key features of the database created for this study are:

- Census tract-level aggregated electricity and natural gas consumption data for the five years from 2006 to 2010. In addition to census tract level electricity and natural gas consumption data, downstream (end user) IOU-implemented energy efficiency program data are available for key variables such as ex ante energy reductions, total measure costs, and IOU incentive costs per measure.
- Commercial and industrial sector energy consumption data disaggregated into NAICS-based industry categories at the county level.
- Annual small-area climate data, population and housing data for each census tract, and county, state, and national economic data.

The richness of this database permits certain types of statistical analyses to be performed for the very first time. These demonstrate that this evaluation methodology can enhance future energy efficiency policy development and evaluation efforts, energy forecasting and resource planning efforts, and environmental monitoring efforts. The following are definitions of key concepts and terminology used in this pilot study:

a) *Energy consumption*: Electricity and natural gas consumption are represented in the estimated models by utility billing data and does not include self-generation. The expression “energy use” is used synonymously with energy consumption.

b) *Ex-ante reductions in energy consumption:* The gross energy reductions reported in IOU energy efficiency program databases that are assumed to be realized from energy efficiency measures installed via IOU-run energy efficiency programs.

c) Energy efficiency policy: Policy is an umbrella term that refers to the full collection of sector-specific energy efficiency programs and public initiative that operate simultaneously in a given location. These initiative may or may not be coordinated with each other. Energy efficiency building codes and standards are one element of energy efficiency policy.

d) *Cross section, time series,* and *panel studies:* Cross section studies are made up of subjects, such as households, companies, or groups of subjects, for whom data are collected for one or two time periods. Time series or longitudinal studies are made up of data collected for multiple, equally-spaced time periods for a single subject or single group of subjects. Panel or pooled studies combine the two. They are made up of multiple subjects or multiple groups of subjects for whom data are collected for multiple time periods. The advantage of a panel study is that by combining information on how energy consumption changes from year to year (the time series component), with information on how energy consumption differs from subject to subject (the cross section component) it offers more comprehensive insights into long-term changes in energy consumption than any other type of study.

e) *Policy Impacts*: In the context of this study, policy impacts are econometric-based estimates of the reductions in consumption attributed to energy efficiency policy. Although statistics derived from IOU program tracking systems of downstream programs are used in the econometric models, they are interpreted broadly as indicators of policy impacts, not as indicators of the impacts of downstream programs alone. Since the econometric models of energy consumption control for market factors such as incomes, prices, and weather, and since the models are estimated over four or five years periods, the policy impacts are interpreted as long-term energy consumption changes that are exclude free ridership and include spillover, rebound, measure interactions, or other externalities. As such, they may be consider *net* savings in the truest sense of the word.

A concept that is not broached in this study is that of *total market gross energy savings*. This concept, used by the CPUC for program planning and goal setting, is defined as the sum of projected naturally-occurring efficiency plus the sum of ex ante reductions from all programs targeted to a specific population. There is no analog to this concept in the econometric models estimated in this study. By their nature, econometric models use historical data to provide estimates of how one or more variables influenced energy consumption.

Section 2 of this study describes the econometric modeling framework and the construction of relevant variables, Section 3 describes the policy impact findings for each sector and fuel, and Section 4 concludes with general recommendations for continuing to collect data, develop analytical frameworks, and develop the kind of system required to integrate total energy consumption approaches into the permanent portfolio of post-2012 EM&V activities.

2. Policy Modeling Framework

As this pilot study explores the use of aggregate energy consumption data to evaluate sector-level, fuel-specific, energy efficiency policy impacts on an annual, ongoing basis, the strategy of this study is to demonstrate the capability, and value, of developing a basic econometric modeling and research design framework. This approach differs from many econometric studies that are geared towards analyzing narrow technical issues using specialized tools that cannot be universally applied. The mission here is to develop a policy impact measurement approach that is relatively constant from year to year and subject to subject, thereby allowing policymakers and resource planners to be continuously informed of program accomplishments.

Toward this end, several major principles are followed throughout this study. For one, the analyses of electricity use and natural gas use are, for the most part, treated identically. This principle has its pros and cons. On the one hand it demonstrates the practicality and the validity of the approach, but on the other it sacrifices precision. For example, the same scheme that is used for the electricity consumption analysis for combining 24 industries into 13 industry categories is also used for the natural gas consumption analysis. Although different industry categories might lead to more accurate findings for both fuels, it might also lead to findings that are tied to the peculiarities of the data and and will change over time. Therefore, to best assess the future potential of this evaluation approach, standardization is imposed whenever possible.

A second, related principle is that the impact estimator and basic model specifications be similar across the three economic sectors. The word *similar* is used purposefully, because it is impossible, not to mention unwise, to apply the same models to all sectors. Different variables are available for different sectors, and different variables drive the energy use and policy impacts in different sectors. Moreover, unexpected data issues arise, such as sector-level differences in the availability and accuracy of IOU-run energy efficiency program data. Thus, while the basic framework for modeling and analysis can be similar, the details necessarily vary.

The third and last major principle followed in this study follows from the two above. In plain language, it is to not lose site of the forest for the trees. At present, 16 models are estimated for this study for the purposes of learning more about what this new evaluation method, and these data, are capable of offering. Judging the merits of an individual model based on a single statistic or diagnostic is besides the point, as is exploring why the coefficient of a variable such as “years of schooling” might have the expected sign and be statistically significant in three residential sector models with identical specifications, but not a fourth. Fine-tuning a single model is always possible. What is more important, and far more difficult, is to create an evaluation framework that is scientifically defensible and will be broadly applicable for the foreseeable future.

The following sub-sections describe the kind of model that is propagated throughout this study, the theory behind it, how the major variables in the models are constructed, and how policy impacts are estimated.

a. Panel Fixed Effects Models

All of the models estimated for this study are panel, fixed effects models. Panel models are those in which for each individual cross section unit there are data for two or more time periods. The time periods in this study are measured in years, and the maximum number or years of data that are available are five, from 2006 to 2010. The cross sections differ based on the sector that is being modeled. In the residential sector the cross section units are census tracts, and in the commercial and industrial sectors the cross section units are industries by county and by IOU.

Fixed time effects are implemented in panel models as dummy variables that differentiate each year from every other year, and fixed cross section effects are implemented as dummy variables that differentiate each cross section from every other cross section. These variables produce coefficients that are model intercept shifters; that is, they change the values of the coefficients that reflects all of the unobserved but systematic factors that affect the dependent variable. In particular, fixed time effects coefficients reflect idiosyncratic factors that are specific to a particular year but affect all cross sections. Conversely, fixed cross section effects, are specific to each cross section but not specific to any one year. Because fixed effects gather up the influences of all the variables that are unobserved (and are thus left out of the model) they are general corrections for omitted variable bias. However, for this very reason their coefficients cannot be interpreted as reflecting the impact of any single missing variable. The technical relationship between fixed effects and omitted variables is discussed further on in this section along with the topic of missing energy price variables.

Besides the fixed effects variables, each panel model contains a number of continuous variables that are typically considered determinants of energy use, such as weather and income. The dependent variable in all of these model is *energy use per site*. It is important to note that utility customers can be counted in one of two ways; either by the officially listed *premises* being served, or by customer *accounts*. As publically-available independent variables are geared towards explaining the energy use per building or per location, the former is chosen to represent customers. It more accurately reflects the number of unique buildings being served by a utility than does the number of accounts being billed.

The choice of independent variables in each model is first determined by which variables are available. In the commercial and industrial sectors, not only are there few economic variables in publically-available databases, but the types of variables differ. For example, in the same U.S. Bureau of Economic Analysis local area personal income database, county-level number of employees is available annually for disaggregated commercial sector NAICS but not for disaggregated manufacturing sector NAICS. However, county-level industry employee earnings is available at a disaggregate level for both sectors.

A second criteria for choosing independent variables in each model is more complex and contextual. It has to do with the appropriateness of the variable, its explanatory power, and its overlap with similar variables. For example, including a variable representing the number of room in a housing unit in a model of single family home electricity consumption is appropriate and may have reasonably good explanatory power. However, it may also be correlated with household income. On top of that, household income may be correlated with years of schooling. The choice of including one, two, or all three variables in the model is judgmental and ultimately depends on the performance of each variable alone and together, and most importantly, on the goal of the analysis. If the income effect is the primary phenomenon of interest, perhaps the other two variables should be excluded from the model. On the other hand, if the focus is on the energy consumption attributable to extra rooms and extra years of schooling, perhaps it is the income variable that should be excluded.

For each sector, the goal in modeling and analysis is to maintain the same functional form and the same variables. In keeping with model standardization rather than customization, the semi-log functional form is used for all models. This is a conventional form. In practice it means that the dependent variable, *energy use per site,* is transformed into natural logarithms while one or more of the independent variables is left in its original, linear form. The semi-log form works especially well for estimating energy efficiency policy impacts. Later on in this section the method for calculating policy impacts with an linear independent variable will be described.

b. Indicators of Policy Impacts

The datasets provided for this project by the IOUs contain census tract-level information on customer energy use. In addition, they contain census tract-level information on energy efficiency products purchased through each IOU's downstream energy efficiency programs. For all three economic sectors, this information includes ex ante energy reduction estimates and the total costs of the energy efficient products. For the commercial and industrial sectors, the data also include the incentives paid by the IOUs to consumers purchasing the energy efficient products. All three of these variables come in to play in one model or another in estimating policy impacts. Ex ante energy consumption reductions and incentive costs are used as policy impact indicators, and total measure costs are used as instruments for these two variables, a subject to be discussed further on.

IOU energy efficiency program estimates of ex ante energy reductions and incentive costs are used as policy impact indicators because their levels tend to be highly correlated with the full scope of energy efficiency policy, and hence policy-related energy reductions. In this study, these values are cumulated year-over-year to produce monotonically increasing values that represent the current year, and all prior year, policy impacts. Letting *s* be the ex ante annual energy reductions from every individual measure purchased through a downstream program, total energy reduction per cross section and time period, *S*, is:

$$S_{it} = \text{Total Annual Ex Ante Energy Reduction}_{it} = \sum s_{it} \quad (1)$$

where *i* represents a cross section and *t* represents a time period. Letting *IMC* represent incentive costs and *TMC* represent total measure costs, cumulative ex ante energy consumption reductions (*SAVCUM)*, cumulative incentive costs (*INCCUM)*, and cumulative total measure costs, (*MEACUM)*, are calculated as:

$$SAVCUM_{it} = S_{i,t} + S_{i,t-1} + ... + S_{i,t-n} \quad (2)$$
$$INCCUM_{it} = IMC_{i,t} + IMC_{i,t-1} + ... + IMC_{i,t-n} \quad (3)$$
$$MEACUM_{it} = TMC_{i,t} + TMC_{i,t-1} + ... + TMC_{i,t-n} \quad (4)$$

The two monetary values, as well as all the monetary values analyzed in this study, are transformed into constant 2010 dollars using the most recent GDP implicit price deflator.

When the range in energy use from cross section to cross section or time period to time period is not miniscule, using the absolute values just defined are likely to be ineffective as explanatory variables. To produce a scaled, relative value, in equation (5) cumulated ex ante reductions in a given cross section and year are divided by total energy use per cross section per year, e_{it}, to produce *SAVCUMRATIO*, or Z_1. This is the amount of ex ante cumulative energy reduction in any year relative to the actual energy consumption in that year, referred to as e_{it}. For scaling purposes, in equation (6) cumulative incentive costs are divided by the total energy expenditures or bills, $bill_{it}$, in a given year, to produce *INCCUMRATIO*, or Z_2, and in equation (7) cumulative total measure costs are divided by $bill_{it}$ to produce *MEACUMRATIO*, or W_1.

$$SAVCUMRATIO_{it} = Z_{1,it} = \sum (S_{i,t} + S_{i,t-1} + ... + S_{i,t-n}) / e_{it} \tag{5}$$

$$INCCUMRATIO_{it} = Z_{2,it} = \sum (IMC_{i,t} + IMC_{i,t-1} + ... + IMC_{i,t-n}) / bill_{it} \tag{6}$$

$$MEACUMRATIO_{it} = W_{1,it} = \sum (TMC_{i,t} + TMC_{i,t-1} + ... + TMC_{i,t-n}) / bill_{it} \tag{7}$$

For commercial and industrial sector natural gas consumption, the denominator *bill* in equations (6) and (7) is replaced with total therm consumption, $e_{thern,\, it}$. This is due to the fact that total natural gas expenditures are not available for these sectors for this study.

Even with these cumulative indicators it is often possible that policy impacts remain undetectable. This can be due to the fact that the indicator values, despite being cumulative, are small. For example, a cross section whose expected reductions in each year is 0.5 percent of total energy use might only have a cumulative reduction ratio, Z_1, of 2 percent after four year (this could vary somewhat depending on whether other factors cause energy use in year four to increase or decrease). In such cases, the best hope for detection is to trim the analysis sample so that it only includes those cross sections where detection is possible. There is no rule of thumb to what the cutoff of relative indicator values must be. However, if there is a reasonable point at which policy impacts can be detected, then at the very least possible it is possible to reject the hypothesis that the program had no effect.

There are several ways to create sample cutoff points. One way is to use increasingly stringent ratios to screen observations, another is to rank observations by ratio and then apply cutoffs by rank, and a third is to select different fractions of the samples based on going from low-to-high or high-to-low ratios. Since all three of these methods are based on the order of the ratio values, they all lead to similar results.

c. Instrumental Variables

Despite large differences in the amount, and types, of variables available for modeling the consumption of two fuels in three economic sectors, it is possible to provide a description of the general model specification that will be used for most of the analyses in this study. With p_{it} symbolizing the number of sites or premises in each cross section in each year, annual energy consumption per site per cross section and year, E_{it}, is calculated as

$$E_{it} = \text{Annual Energy Consumption Per Site}_{it} = e_{it} / p_{it} \tag{8}$$

For the multivariate analyses in this study the relationship between E_{it} and a policy impact indicator variable, either Z_1 or Z_2, is characterized by the following two simultaneous equations:

$$E_{it} = a'_0 + a_1 X'_{it} + a_2 Z_{it} + u_{it} \tag{9}$$
$$Z_{it} = b'_0 + b_1 E_{it} + b_2 W'_{it} + v_{it} \tag{10}$$

Equation (9) is what must be estimated in order to measure policy impacts. In it, a'_0 represents one or more constants, a_1 and a_2 represent non-zero coefficients associated with independent variables, and u is the model error term. Also, the vector X' contains independent variables that are causally related to energy use, such as climate, and the variable Z is an indicator of policy impacts. It is the coefficient of this variable, a_2, that expresses the relationship between energy efficiency policy and energy use.

Equation (10) shows that while Z influences E, the reverse is also true. This poses a problem in estimating a_2 in equation (9) because independence of the right-hand variables from the left-hand variable is a necessary condition for regression models to produce consistent, unbiased coefficients. Estimating equation (9) without correcting for the relationship between Z and E will lead to Z being correlated with u, resulting in an inconsistent and biased estimate of the value of a_2.

Since the primary goal of this study is to investigate the degree to which energy efficiency policy has had an impact on energy use, the endogeneity of Z must be remedied. Fortunately, equation (10) not only points out the problem, but points to the solution. The independent variables in equation (10), denoted by W', can be used to remove the correlation between Z and u. These variables are correlated with Z, but independent of E and are referred to in the context of simultaneous equation estimation as *instruments*

The technique for solving the simultaneity problem involves first estimating equation (10) and then using the coefficients of this model to produce forecasts of Z, shown as Z^*, in equation (11).

$$Z^*_{it} = b'_0 + b_1 X'_{it} + b_2 W'_{it} \tag{11}$$

These forecasts replace the original values of *Z* in equation (9), and the new model, shown as equation (12), is then estimated.

$$E_{it} = c'_0 + c_1 X'_{it} + c_2 Z^*_{it} + u^*_{it} \tag{12}$$

This simultaneous equations technique is known as two-stage least squares, TSLS, or as instrumental variables estimation. If all the necessary conditions are met, then unlike a_2, the coefficient c_2 is a consistent estimate of the impact of policy activities on energy use, and a less biased one.

Although theoretically sound, from a practical perspective there remains the possibility that the TSLS coefficient estimates in equation (12) can be inferior to those produced by ordinary least squares (OLS) estimation in equation (9). This can occur when the *Z* is, in fact, not endogenous, or when the instruments in the first stage regression, equation (10), are poorly correlated with *Z*. Diagnostic tests are available to assess these issues.

The energy efficiency policy impact indicator used for the residential and manufacturing models is Z_1, the cumulative ex ante energy reduction ratio. For the commercial sector models the cumulative incentive costs ratio, Z_2,is used. For both indicators, the same two instruments are employed. The first is previously defined in equation (7) and symbolized by W_1, i.e., the cumulative total measure cost ratio. This variable is not related to energy use, but is likely to be closely correlated with the ex ante energy reductions and incentive costs ratios. The second instrument is energy supply costs, *SC*. This is the unit cost of energy (either electricity or natural gas) per cross section and year. It is calculated as:

$$SC_{it} = W_{2,it} = \frac{bill_{it}}{e_{it}} = \frac{\sum\left(es_{j,it} \times r_{j,it}\right)}{e_{it}} \tag{13}$$

where $es_{j,it}$ is the energy use for each site *j* within a cross sectional unit *i* in year *t*, and $r_{j,it}$ is the IOU rate schedule faced by each site. The sum of this product is the total expenditures on a fuel in a particular cross section and year. Dividing this value by the total energy use in a cross section, e_{it}, results in the unit supply cost, SC_{it},, or $W_{2,it}$. W_2 is also expected to be related to the cumulative ex ante energy reductions ratio (Z_1), and the cumulative incentive costs ratio (Z_2). By construction this is an average supply cost that is only indirectly related to E_{it}. This is because IOU rates are multi-tiered and administered by the CPUC based on costs of service, time of use, and so on. Thus, expenditures can differ substantially between two or more cross sections even when the same amount of total energy is purchased. The rates or prices facing consumers may be identical, but the application of the rates will differ based on patterns of energy use and/or the number of consumers in a cross section. The average cost per unit of energy, *SC*, thus reflects the costs of supply for a pattern of energy use rather than the price for a fixed quantity of energy use.

d. Omitted Energy Prices

Two independent variables that are almost always included in aggregate energy demand models are the unit price of the fuel being studied and the unit price of its closest substitutable fuel. This practice follows orthodox economic principles and works reasonably well when the units of analysis are states or countries, or utilities in different states, but is also problematic in many situations. For example, according to a recent study (Steinbuks, 2012), a large number of econometric studies find that regardless of relative price changes, in the manufacturing sector the substitution of other fuels for electricity, or electricity for other fuels, is limited. There is an obvious reason for the lack of fuel substitution in the manufacturing sector, not to mention the commercial and residential sectors. Most of the appliances, equipment, and end uses that require electricity cannot be adapted to any other fuels. Furthermore, since on a Btu basis electricity is often three times more expensive than other fuels, consumers using equipment that are non-electric do not tend to switch to electricity-run equipment. It should thus come as no surprise when econometric studies find that the elasticity of demand for electricity with respect to natural gas prices is effectively zero. Depending on electricity and natural gas supply costs, significant negative cross price elasticities can also be found.

The strict, seemingly inarguable principle for using own- prices to explain own quantity demanded also has its limitations in many circumstances. Where electricity, and to a large degree natural gas, are purchased from regulated utilities, as is mainly the case in all three economic sectors, prices tend to reflect supply and service costs, not the intersection of supply costs and willingness-to-pay. In addition, prices are administered (thus the use of the expression "rates" rather than "prices" by public utility commissions) and are therefore slow to change. Rates also tend to be multi-tiered by usage levels, time of day dependent, and seasonally dependent. All of which is to say that it is far from clear what price, or set of prices, should even enter into an electricity or natural gas consumption model. This question is particularly problematic with studies such as the present one that span five or fewer years and focus on a single utility, or multiple utilities having a common regulator. In short, in the present context it seems that there is not necessarily much harm that occurs in the energy consumption models from missing both of the energy price variables.

The technical relationship between omitted variables and model bias deserves explication if for no other reason than to anticipate what may occur in the event that missing energy price coefficients are non-zero (statistically significant and presumably of the correct sign). In equation (14), the disturbance term, *u*, is assumed to have the usual OLS properties, most especially that it is uncorrelated with the independent variables X_1 and X_2 (that is, as described above, that X_1 and X_2 are not endogenous). Supposing that in equation (14) the unavailable variable is X_2 and that the relationship between X_2 and X_1 can be described by equation (15):

$$E = f_0 + f_1 X_1 + f_2 X_2 + u \quad (14)$$

$$X_2 = g_0 + g_1 X_1 + v \quad (15)$$

Then, by substitution and collection of terms:

$$E = f_0 + f_1 X_1 + f_2 (g_0 + g_1 X_1 + v) + u \quad (16)$$

or

$$E = (f_0 + f_2 g_0) + (f_1 + f_2 g_1) X_1 + (f_2 v + u) \quad (17)$$

or

$$E = h_0 + h_1 X_1 + \varepsilon \quad (18)$$

What equations (14) and (15) show is that when X_2 is related to E (meaning that f_2 in equation (14) is non-zero) and when X_2 is correlated with X_1 (meaning that g_1 in equation (15) is non-zero), its exclusion from the estimated model for E will lead to a misrepresentation of the unique impact of X_1 on Y, i.e., bias in the coefficient h_1 in simplified model shown as equation (18). Moreover, since g_1 is, by definition, the correlation of X_2 and X_1 multiplied by the ratio of their standard deviations, and since standard deviations are always positive, the sign of the product of f_2 and g_1 in equation (17) is determined by the sign f_2 and the correlation between X_2 and X_1. Thus, if the true coefficient f_2 in equation (14) is positive and the correlation between X_2 and X_1 is positive, or they are both negative, their product will be positive and h_1 will be higher than X_1's true coefficient, f_1. Conversely, a negative element multiplied by a positive element will lead to a negative bias such that h_1 will be lower than f_1.

To be concise, this means that the bias in a model that is caused by omitting a variable is a function two things; whether or not it has a non-zero effect on the outcome variable, and what its relationship is to the included variable(s). Thus, if the price of an energy substitute is expected to have no effect on the outcome variable, or own-price exhibits so little variation that it, too, is expected to be uncorrelated with the outcome variable, then their omission causes no harm. However, if a variable such as own price is expected to be correlated with the quantity demanded, then its relationship to the other independent variables in the model must be analyzed.

Of all the variables that are included in the energy consumption models in this study, the ones most likely to be correlated with own-price are fixed time effects, fixed cross section effects, and Z_1 and Z_2, the indicators of policy impacts. While knowing the direction of the correlation between prices and fixed effects depends on knowing how real prices have changed over time and for specific cross sections, it is safe to assume that the direction of correlation between prices and the Z variables is positive because, all things being equal, higher real energy prices should stimulate greater energy efficiency. Therefore, since the sign of the own price variable is expected to be negative, the bias in the coefficient of the policy impact indicator variable is expected to be negative. Barring confounding factors such as cross correlations with the fixed effects, this means that the coefficient of the policy impact indicator variable will overstate policy impacts.

Practically speaking, omitted variable bias in the policy impact indicator variable is a moot point. The fact that annual changes in real energy prices are often small, that the time spans of the study periods are relatively short, and that consumers in a given rate class in a given utility face the same prices, means that omitted variable bias, if present at all, is most likely to appear in the fixed cross section and fixed time effects coefficients. And since fixed effects are included in each model not only to ameliorate the potential problem with omitted energy price variables, but to ameliorate the problems caused by other potentially important unobserved variables too, the precise influence of omitted prices on the fixed effects coefficients cannot be known. It depends not only on the correlation between the prices and the fixed effects, but on the correlation between the fixed effects and the other unobserved variables.

e. Policy Impact Estimation

For this study, the energy reductions attributable to energy efficiency policy are calculated via the coefficient of the policy impact indicator, that is, the coefficient c_2 in equation (12) that is attached either to Z^*_1 or Z^*_2, depending on the specific model. Total cumulative energy reductions (*TCR*) over any model estimation period can then be found by:

$$TCR_{Z_1} = c_{2,Z_1} \times \frac{\sum SAVCUM_t}{\sum e_t} \times \bar{e}_t \tag{19}$$

$$TCR_{Z_2} = c_{2,Z_2} \times \frac{\sum INCCUM_t}{\sum bill_t} \times \bar{e}_t \tag{20}$$

where *SAVCUM* , *INNCUM*, *e*, and *bill* are as previously defined and $\bar{e}$ represents average annual energy consumption per year. As the individual models that produce c_2 only contain samples of the relevant populations (due to missing values, sample trimming, etc.), to calculate the total policy impacts, *TCR*, data for the entire model populations are used to produce $\Sigma SAVCUM$, $\Sigma INCCUM$, Σe, $\Sigma bill$, and $\bar{e}$. In plain language, the calculation of policy impacts (*TCR*) using *SAVCUMRATIO* as the *Z* variable can be seen as the coefficient of *Z* (the marginal impact of the policy indicator over the estimation period) multiplied by (a) the ratio of aggregate ex ante reductions in energy use over the estimation period to aggregate energy consumption over the estimation period, multiplied by (b) average annual energy consumption over the estimation period.

It is important to emphasize that these policy impact estimates are calculated for the average annual energy consumption for all the years in the model estimation period, not for any individual year. This is because the coefficient c_2 represents the marginal impact of *Z* on energy consumption over all the years in the estimation period, not any one particular year; in other words, it is an *average* marginal impact for the period as a whole. It follows, for example in equation (19), that the first multiplicand for c_2 is total *SAVCUM* over the entire estimation period divided by total energy consumption over the entire estimation period (not single year total *SAVCUM* divided by the single year total energy consumption). And likewise, the second multiplicand for c_2 is average total energy consumption over the all the years in the estimation period, not any single year's total energy consumption. Calculated this way, *TCR* is interpretable as the full impact of energy efficiency policy on energy consumption over the estimation period. Further, the baseline for measuring the *percentage change in energy consumption due to energy efficiency policy* is simply the average annual energy consumption per year over the estimation period, $\bar{e}$.

Two final issues related to policy impact estimation are the choice of the policy impact estimation period for evaluating the impacts of 2006-2008 programs, and the method used to produce confidence intervals for the combined findings. The first issue arises because of three considerations:

- not all energy efficiency policy actions in a given year are implemented on January 1 of that year -- rather, they are distributed throughout the 12 months;
- energy efficiency policies continue beyond the specified program evaluation period; and,
- to produce long-term estimates of policy impacts it is desirable to have at least 2 years of post-program data.

Choosing the three years of 2006-2008 as the model estimation period has several disadvantages. For one, it reduces the number of observations populating the models by at least one-fourth, if not two-fifths. For another, assuming that half the ex ante energy reductions reported in every year are actually realized in the same year they are reported (ex ante energy reductions are annualized values), the *TCR* for the 2006-2008 period will include the partial reductions for calendar year 2005 policies and only two-and-a-half of the three policy years of interest. And last, the three year estimation period, weakens the interpretation of the findings as long-term policy impacts.

For these reasons, a better estimation period is 2006 though 2009. Using 2009 data in the analysis adds 33 percent more data, permits *TCR* to represent all of the policy impacts in the 2006-2008 policy period (while also including partial impacts from 2005 and 2009), and allows for a more reliable estimate of long term program impacts.

A third alternative is to use the five years from 2006 through 2010 as the estimation period. This has even greater advantages than using the four year period except for the fact that *TRC* then encompasses part of 2005, all of 2009 and part of 2010 policy impacts. Nevertheless, from a long-term policy perspective this is undoubtedly the best model estimation period. For all the analyses that follow, results are reported for the four and five year model estimation periods.

The final element of the policy modeling framework is the method used for combining the separate model findings into statewide totals and calculating confidence intervals. The actual combining of the estimated policy impacts is done by summing, by fuel, for each estimation period. The standard error associated with each sum is calculated by taking the square root of the sum of the squared standard errors of each estimated policy impact. The 90 percent confidence interval for the combined impacts are calculated by multiplying the aggregated standard error by the z-value of 1.645.

3. Impact Evaluation Findings

a. Residential Sector

For all the sector and fuel-specific analyses in this study key energy consumption and program tracking data elements were inspected prior to modeling for missing values, seemingly erroneous data or outliers, and high and low end values that might skew the sample statistics or suggest multi-modal distributions. Because census tracts rather than counties are the units of observation in the residential sector, F-tests were conducted to determine whether the data from the different utilities could be pooled.

Table 1 shows the total sample sizes (number of census tracts) for the two utilities for which residential electricity consumption data are available and the two utilities for which natural gas consumption are available. Based on the findings from the complete dataset, electricity consumption per site per census tract was restricted to be between 1,000 and 15,000 kWh and natural gas consumption per site per census tract had to be greater than zero and less than 5,000 therms per year. These restrictions produced minor losses of observations, e.g., in 2006 a total of 34 census tract in PG&E's service territory were dropped from the electricity consumption analysis and 7 from the natural gas consumption analysis.

Additional screening was imposed based on the values of energy supply costs and the cumulative ex ante annual reduction ratios. For the former, estimated natural gas supply costs were restricted to be between 10 cents and one dollars (in constant 2010 dollars) and for the latter, the 2009 cumulative ex ante reduction ratio for each fuel could not exceed 50 percent.

Table 1: Residential Sector Sample Sizes, by Utility and Fuel, 2006

2006	**Mean**	**Median**	**Max**	**Min.**	**Std. Dev.**	**n**
kWh/Site/Tract						
PG&E	6,948	6,638	14,994	1,215	2,293	2,830
SDG&E	6,247	5,893	14,734	1,617	2,212	677
Therms/Site/Tract						
PG&E	520	468	4,960	105	269	2,930
SDG&E	405	373	2,434	212	152	609

Initial diagnostic tests, such as pairwise F-tests of the equality of the electricity consumption model coefficients, indicated that the null hypothesis of no differences between utilities could be rejected. As a result, all of the analyses in the residential sector are performed separately for each utility and each fuel. The PG&E and SDG&E electricity consumption models for the two different estimation periods, 2006 to 2009 and 2006 to 2010, are displayed in Tables 2 and 3, respectively. Coefficients that are statistically significant at the 95 percent confidence level or higher are in bold. Endogeneity tests indicate that the null hypothesis of exogeneity can be rejected at the 95 percent confidence level or greater; weak instrument tests indicate that the null hypothesis can also rejected for the hypothesis that the coefficients of the two instruments are jointly zero. Variable mnemonics beginning with "ln" refer to their values being transformed into natural logarithms. In these models, as in all the models in this study, the base year for the fixed time effects is 2006.

Hundreds of population and housing-related variables are available via the Census. Nevertheless, the twelve Census variables specified in all the residential models are identical, selected intuitively based on their general appropriateness for explaining residential sector electricity and and natural gas consumption. This one-size-fits-all approach leads to models whose coefficients are not always statistically significant, and which do not necessarily produce the very best model for a particular utility or fuel. However, standardized models are best for addressing the CPUC's pilot study goals. Future studies can delve further into optimal model specifications.

For the 2006-2010 estimation period, the PG&E model indicates that the average annual policy impact was 6.4 percent reduction in average annual GWh consumption. This is shown by the *%TCR* statistic, which is formed by dividing estimated total cumulative reduction (*TCR*) by average annual total electricity consumption. In Table 3, the SDG&E model indicates for the 2006-2010 estimation period that the cumulative policy impact was 4.2 reduction in average annual GWh consumption.

Table 2: Residential Sector Electricity Consumption Model, PG&E

PG&E	**Description**	**2006-2009**		**2006-2010**	
lnKWH	kWh per Site/Census Tract	Coeff.	SE	Coeff.	SE
C	Intercept	**7.49318**	0.03829	**7.52415**	0.03895
D07	2007	**0.04328**	0.00923	**0.04907**	0.00989
D08	2008	0.01523	0.01527	0.02718	0.01645
D09	2009	**0.05092**	0.01696	**0.06383**	0.01828
D10	2101			**0.09686**	0.02018
XAGGHHINCOME	Aggregate Income	**0.00000**	0.00000	**0.00000**	0.00000
AVGSIZEHH	Average Household Size	**-0.02958**	0.00505	**-0.02773**	0.00485
COLLEGE	People went to College	**-0.00010**	0.00001	**-0.00009**	0.00001
GROUPPOP	Population in Group Housing	0.00001	0.00001	0.00001	0.00001
MEDIANAGE	Median Age	**0.00162**	0.00049	**0.00194**	0.00049
MEDIANROOMS	Median rooms of HU	**0.13712**	0.00367	**0.13144**	0.00343
HU1DETACHED	Detached Housing Unites	0.00001	0.00001	**0.00001**	0.00001
HU3OR4	3 and 4-plexs	**-0.00032**	0.00002	**-0.00030**	0.00002
HUMOBILEHOME	Mobile Homes	**0.00038**	0.00002	**0.00038**	0.00002
HUBOATRVVAN	Boat, RV, Van Housing Units	0.00000	0.00029	-0.00003	0.00026
BUILT2004DUM	Dum 30% New 2000 to 2004	**-0.01897**	0.00978	**-0.02003**	0.01039
VACANTHU	Number of Vacant HU	**-0.00015**	0.00002	**-0.00017**	0.00002
HDD	Heating Degree Days	**0.00015**	0.00001	**0.00014**	0.00001
CDD	Cooling Degree Days	**0.00025**	0.00000	**0.00024**	0.00000
Z*1	Cum. ex ante kWh Savings Ratio	**-4.55708**	1.09533	**-5.45169**	1.18636
Adj. R-sqd		0.62		0.57	
n		10,700		13,336	
TCR	Total Cum. Reduction (GWh)	1,408		1,923	
% TCR	TCR/Avg. Ann. Consum.	4.7%		6.4%	

Table 3: Residential Sector Electricity Consumption Model, SDG&E

SDG&E	**Description**	**2006-2009**		**2006-2010**	
lnKWH	kWh per Site/Census Tract	Coeff.	SE	Coeff.	SE
C	Intercept	**7.32904**	0.04004	**7.33981**	0.03425
D07	2007	0.01019	0.01179	0.00881	0.01062
D08	2008	0.00256	0.01211	0.00114	0.01075
D09	2009	**0.04659**	0.01819	**0.03967**	0.01489
D10	2101			**0.05508**	0.01859
AGGHHINCOME	Aggregate Income	**0.00000**	0.00000	**0.00000**	0.00000
AVGSIZEHH	Average Household Size	**-0.04592**	0.00824	**-0.04200**	0.00698
COLLEGE	People went to College	**-0.00010**	0.00001	**-0.00010**	0.00001
GROUPPOP	Population in Group Housing	**0.00001**	0.00000	**0.00001**	0.00000
MEDIANAGE	Median Age	0.00070	0.00078	0.00094	0.00066
MEDIANROOMS	Median rooms of HU	**0.23176**	0.00633	**0.22784**	0.00544
HU1DETACHED	Detached Housing Unites	**-0.00006**	0.00001	**-0.00006**	0.00001
HU3OR4	3 and 4-plexs	**-0.00023**	0.00003	**-0.00022**	0.00003
HUMOBILEHOME	Mobile Homes	**0.00038**	0.00003	**0.00038**	0.00002
HUBOATRVVAN	Boat, RV, Van Housing Units	**0.00198**	0.00056	**0.00207**	0.00051
BUILT2004DUM	Dum 30% New 2000 to 2004	**-0.03192**	0.01821	-0.02890	0.01628
VACANTHU	Number of Vacant HU	-0.00004	0.00003	**-0.00005**	0.00002
HDD	Heating Degree Days	**0.00012**	0.00001	**0.00011**	0.00001
CDD	Cooling Degree Days	**0.00013**	0.00001	**0.00013**	0.00001
Z*1	Cum. ex ante kWh Savings Ratio	**-4.60959**	1.24041	**-4.09427**	0.94016
Adj. R-sqd		0.78		0.78	
n		2,697		3,376	
TCR	Total Cum. Reduction (GWh)	290		314	
% TCR	TCR/Avg. Ann. Consum.	3.9%		4.2%	

The PG&E and SDG&E natural gas consumption models for the two different estimation periods, 2006 to 2009 and 2006 to 2010, are displayed in Tables 4 and 5. For these models, the program impact indicator, $Z_{1,}$ is cumulative ex ante natural gas savings, the instrument W_1 is cumulative natural gas measure costs, and the instrument W_2 is natural gas supply costs, constructed in a similar manner to how residential electricity supply costs were constructed. Endogeneity tests indicate that the null hypothesis of exogeneity can be rejected at the 95 percent confidence level or greater; weak instrument tests indicate that the null hypothesis can also rejected for the hypothesis that the coefficients of the two instruments are jointly zero.

For the 2006-2010 estimation period, the PG&E model indicates that the average annual policy impact was a 3.3 cumulative increase in average annual therm consumption. The SDG&E model indicates for the 2006-2010 estimation period that the cumulative policy impact was a 64.1 percent increase in average annual therm consumption.

Table 4: Residential Sector Natural Gas Consumption Model, PG&E

PG&E	**Description**	**2006-2009**		**2006-2010**	
lnTHERM	Therms per Site/Census Tract	Coeff.	SE	Coeff.	SE
C	Intercept	**5.82048**	0.05236	**5.85056**	0.04418
D07	2007	-0.01127	0.00764	-0.00582	0.01203
D08	2008	**-0.03518**	0.01112	**-0.01227**	0.00731
D09	2009	-0.00485	0.01373	-0.03418	0.00894
D10	2101			-0.00445	0.01011
XAGGHHINCOME	Aggregate Income	**0.00000**	0.00000	**0.00000**	0.00000
AVGSIZEHH	Average Household Size	**-0.01803**	0.00729	**-0.02345**	0.00617
COLLEGE	People went to College	**-0.00009**	0.00001	**-0.00009**	0.00001
GROUPPOP	Population in Group Housing	-0.00001	0.00001	0.00000	0.00001
MEDIANAGE	Median Age	**0.00763**	0.00086	**0.00727**	0.00072
MEDIANROOMS	Median rooms of HU	0.00857	0.00755	0.01125	0.00656
HU1DETACHED	Detached Housing Unites	**-0.00014**	0.00001	**-0.00014**	0.00001
HU3OR4	3 and 4-plexs	**-0.00040**	0.00004	**-0.00042**	0.00004
HUMOBILEHOME	Mobile Homes	**0.00029**	0.00004	**0.00030**	0.00004
HUBOATRVVAN	Boat, RV, Van Housing Units	0.00044	0.00040	0.00031	0.00034
BUILT2004DUM	Dum 30% New 2000 to 2004	**-0.09152**	0.01244	**-0.09601**	0.01099
VACANTHU	Number of Vacant HU	**0.00013**	0.00004	**0.00015**	0.00003
HDD	Heating Degree Days	**0.00004**	0.00001	**0.00003**	0.00001
CDD	Cooling Degree Days	**-0.00002**	0.00001	**-0.00003**	0.00001
Z*1	Cum. ex ante Therm Savings Ratio	-3.34138	39.52364	-7.34058	25.06951
Adj. R-sqd		0.36		0.38	
n		6,748		8,773	
TCR	Total Cum. Reduction (MDth)	2,398		6,560	
% TCR	TCR/Avg. Ann. Consum.	1.2%		3.3%	

Table 5: Residential Sector Natural Consumption Model, SDG&E

SDG&E	Description	2006-2009		2006-2010	
lnTHERM	Therms per Site/Census Tract	Coeff.	SE	Coeff.	SE
C	Intercept	**5.81180**	0.07470	**5.77604**	0.06603
D07	2007	**0.03752**	0.01415	**-0.03065**	0.02264
D08	2008	-0.02361	0.01473	0.03940	0.01399
D09	2009	**-0.08450**	0.01961	**-0.02229**	0.01436
D10	2101			-0.07801	0.01821
AGGHHINCOME	Aggregate Income	**0.00000**	0.00000	**0.00000**	0.00000
AVGSIZEHH	Average Household Size	**-0.06368**	0.01293	**-0.06382**	0.01111
COLLEGE	People went to College	**-0.00021**	0.00002	**-0.00020**	0.00002
GROUPPOP	Population in Group Housing	**0.00003**	0.00001	**0.00003**	0.00001
MEDIANAGE	Median Age	0.00044	0.00106	0.00057	0.00091
MEDIANROOMS	Median rooms of HU	**0.04327**	0.00940	**0.04733**	0.00842
HU1DETACHED	Detached Housing Unites	**-0.00018**	0.00002	**-0.00017**	0.00002
HU3OR4	3 and 4-plexs	**-0.00084**	0.00008	**-0.00081**	0.00007
HUMOBILEHOME	Mobile Homes	**0.00025**	0.00003	**0.00026**	0.00003
HUBOATRVVAN	Boat, RV, Van Housing Units	-0.00026	0.00063	-0.00047	0.00065
BUILT2004DUM	Dum 30% New 2000 to 2004	-0.05132	0.04349	-0.04072	0.03939
VACANTHU	Number of Vacant HU	**0.00031**	0.00007	**0.00035**	0.00007
HDD	Heating Degree Days	**0.00004**	0.00001	**0.00004**	0.00001
CDD	Cooling Degree Days	**0.00008**	0.00002	**0.00009**	0.00001
Z*1	Cum. ex ante Therm Savings Ratio	**176.15380**	47.60054	**155.14510**	42.47758
Adj. R-sqd		0.37		0.37	
n		2,213		2,806	
TCR	Total Cum. Reduction (MDth)	-15,912		-19,859	
% TCR	TCR/Avg. Ann. Consum.	-51.3%		-64.1%	

b. Commercial Sector

Table 6 lists the 2-digit NAICS (North American Industry Classification System) codes for the commercial sector and their recoded classifications after combining industries. Table 7 contains summary statistics related to kWh per site per county for those counties in which the kWh per site in an industry is more 20,000 kWh and less than 1,00,000 kWh per year. In 2006, these cutoffs result in a loss on the low end of 83 county observations (8 of which had kWh per site values of zero and 42 of which had values that were greater than zero but less than 10,000 kWh). On the high end, 4 county observations were lost.

Table 6: Commercial Sector NAICS and Study Codes

2-digit NAICS	Industry Description	Study Recode
51	Information	C1
52	Finance and insurance	(Office)
53	Real estate and rental and leasing	
54	Professional and technical services	
55	Management of companies and enterprises	
92	Government and government enterprises	
44,45	Retail Trade	C2
61	Educational services	C3
62	Health care and social assistance	C4
71	Arts, entertainment, and recreation	C5
72	Accommodation and food services	C6
42	Wholesale trade	C7
48,49	Transportation and warehousing	(Misc.)
56	Administrative and waste services	
81	Other services, except public administration	

Table 7: Commercial Sector Annual kWh per Site, 2006

Code	Mean	Median	Max	Min.	Std. Dev.	n
C1	66,369	51,921	278,945	20,046	54,488	56
C2	123,386	125,572	212,129	23,050	42,630	60
C3	219,141	199,341	743,494	23,957	120,560	56
C4	101,401	98,541	188,140	32,990	39,464	52
C5	105,548	79,870	727,026	24,195	107,843	54
C6	110,827	113,251	244,193	23,089	44,463	60
C7	58,018	49,650	185,885	20,811	34,979	45
All	113,902	97,076	743,494	20,046	86,245	383

In the design of this study all the energy consumption and program tracking data for the commercial and industrial sectors are built up from census tracts to counties within each utility service territory. As such, some counties are entered into the analysis multiple times, because some of the counties in California are served by more than one IOU. Table 8 contains the same information for the sample used for the econometric analysis. It consists of roughly one-third of the observations of the larger sample, the ones with the higher cumulative ex ante electricity reduction ratios, Z_1, in 2009. These observations were selected because the preliminary analyses were unable to detect energy reductions from the original sample. Note that the relative sample sizes of the industries change, but the electricity consumption statistics for each industry are roughly similar.

Table 8: Restricted Sample Commercial Sector Annual kWh per Site, 2006

Code	Mean	Median	Max	Min.	Std. Dev.	n
C1	56,645	66,102	72,361	31,473	22,023	3
C2	124,558	126,843	188,622	48,988	33,889	41
C3	250,399	226,985	445,547	125,787	93,264	14
C4	90,306	81,357	152,262	64,918	31,867	6
C5	69,773	51,636	147,513	35,195	41,974	7
C6	106,036	108,545	176,894	38,029	31,378	34
C7	57,901	47,461	185,885	23,803	34,755	30
All	112,258	105,549	445,547	23,803	68,637	135

Preliminary analysis of the commercial sector models revealed that even after restricting the sample based on the Z_1 rankings, the variable itself exhibited a high positive correlation with energy use, one that could not be remedied with TSLS. Thus, the alternative indicator of program impacts, the cumulative incentive costs ratio, or Z_2, was included in the specification. As this is a financial ratio, no restrictions are placed on the magnitude of this value. The findings for the models containing Z_2, are shown in Table 9. As before, variable mnemonics beginning with “ln” refer to their values being transformed into natural logarithms.

In this model, the base for the fixed cross section effect for utilities is SDG&E and the base for fixed industry effects is the collection of miscellaneous industries , C7. It is important to note that by employing fixed cross section effects by industry and utility, it is not possible to include county fixed effects in the model. This is not a cause for concern because counties within a single state in and of themselves are not likely to play a major role in the influencing the energy use of any industries. However, county-level weighting, by industry mix, is used to control for county-level heteroscedasticity. For each model, county-specific residuals vectors are used to form county-specific variances, and then weighted least squares (WLS) is applied to form feasible GLS estimates.

In addition to the policy impact indicator, the continuous variables in the model represent industry earning per employee, the share total county employees that are in each industry, and heating and cooling degree days. The findings indicate that for either estimation period, the coefficient of the policy impact indicator, Z_2, is not statistically significant. Endogeneity testing indicates that the null hypothesis of exogeneity can be rejected for the 2006-2010 period but not for the 2006-2009 period. Weak instrument testing indicates that the hypothesis that the two instrument coefficients, W_1 and W_2, are jointly zero can be rejected. The 2006-2010 estimation period findings indicate that cumulative policy impacts for this sample, which includes all three IOUs, are 2.1 percent of average annual electricity consumption.

Table 9: Commercial Sector Electricity Consumption Model

PG&E, SDG&E, SCE	**Description**	**2006-2009**		**2006-2010**	
lnKWH	kWh per Site/Industry/County	Coeff.	SE	Coeff.	SE
C	Intercept	**14.536**	0.400	**14.704**	0.359
C1	Office	0.065	0.071	0.078	0.071
C2	Retail Trade	**1.040**	0.028	**1.040**	0.023
C3	Educational Services	**1.935**	0.104	**1.935**	0.090
C4	Health Care	**0.708**	0.038	**0.716**	0.033
C5	Arts and Entertain.	**0.833**	0.063	**0.804**	0.054
C6	Accommodation, Food	**1.013**	0.040	**0.993**	0.035
PGE	Fixed CS (Utility) Effect	**0.576**	0.078	**0.536**	0.070
SCE	Fixed CS (Utility) Effect	**0.285**	0.076	**0.237**	0.069
D07	Fixed TS (Year) Effect	-0.009	0.018	-0.005	0.016
D08	Fixed TS (Year) Effect	0.034	0.025	0.036	0.022
D09	Fixed TS (Year) Effect	-0.007	0.033	-0.004	0.026
D10	Fixed TS (Year) Effect			0.008	0.032
lnXEARN	Total Earning/Industry/Cty.	**0.360**	0.047	**0.335**	0.042
lnEMPSHARE	Share of Employs/Indust./Cty.	**0.072**	0.033	**0.075**	0.029
lnHDD	Heating Degree Days	**-0.675**	0.037	**-0.680**	0.033
lnCDD	Cooling Degree Days	**-0.022**	0.004	**-0.019**	0.003
Z^*_2	Cum. Incent. Cost Ratio	-0.418	0.519	-0.552	0.370
Adj. R-sqd		0.92		0.93	
n		540		675	
TCR	Total Cum. Reduction (GWh)	917		1,612	
% TCR	TCR/Avg. Ann. Consum.	1.2%		2.1%	

Table 10 contains summary statistics related to therms per site per county. Inspection of the full dataset led to a lower limit cutoff of 1,000 therms per site per industry per county, and an upper limit cutoff of 10,000. Of the non-zero valued therms per site counties, in 2006 there were 80 sites that were below the lower cutoff and 16 were above the upper cutoff.

Table 10: Commercial Sector Therms per Site, 2006

Code	Mean	Median	Max	Min.	Std. Dev.	n
C1	3,304	3,214	7,054	1,001	2,000	20
C2	1,914	1,385	5,639	1,004	1,293	13
C3	5,715	5,331	9,697	1,054	2,470	24
C4	4,352	3,875	9,575	1,517	2,181	28
C5	3,151	2,473	7,586	1,011	1,790	21
C6	4,384	4,548	8,611	1,587	1,811	33
C7	2,301	1,687	6,457	1,132	1,517	24
All	3,779	3,344	9,697	1,001	2,234	163

Table 11 contains the estimated model and policy findings for commercial sector sector natural gas consumption, where all the independent variables and all the estimation procedures are the same as for the electricity consumption models.

Table 11: Commercial Sector Natural Gas Consumption Model

PG&E, SDG&E	**Description**	**2006-2009**		**2006-2010**	
lnTherms	Therms per Site/Industry/County	Coeff.	SE	Coeff.	SE
C	Intercept	**9.849**	0.903	**9.685**	0.791
C1	Office	**-0.586**	0.118	**-0.595**	0.103
C2	Retail Trade	**-0.528**	0.076	**-0.509**	0.068
C3	Educational Services	**1.572**	0.139	**1.645**	0.121
C4	Health Care	**0.304**	0.106	**0.328**	0.095
C5	Arts and Entertain.	**0.731**	0.132	**0.783**	0.117
C6	Accommodation, Food	**0.995**	0.092	**1.045**	0.079
PGE	Fixed CS (Utility) Effect	**-0.585**	0.097	**-0.607**	0.086
SCE	Fixed CS (Utility) Effect				
D07	Fixed TS (Year) Effect	**0.159**	0.044	**0.142**	0.043
D08	Fixed TS (Year) Effect	**0.327**	0.053	**0.296**	0.048
D09	Fixed TS (Year) Effect	**0.370**	0.060	**0.335**	0.053
D10	Fixed TS (Year) Effect			**0.395**	0.063
lnXEARN	Total Earning/Industry/Cty.	**0.475**	0.060	**0.497**	0.052
lnEMPSHARE	Share of Employs/Indust./Cty.	**0.216**	0.056	**0.225**	0.051
lnHDD	Heating Degree Days	**-0.335**	0.100	**-0.328**	0.087
lnCDD	Cooling Degree Days	-0.018	0.012	-0.012	0.010

Z^*_2	Cum. Incent. Cost Ratio	**-40.979**	7.313	**-34.477**	5.550
Adj. R-sqd		0.68		0.70	
n		689		864	
TCR	Total Cum. Reduction (MDth)	222.478		234.512	
% TCR	TCR/Avg. Ann. Consum.	18.6%		19.5%	

Note that estimates of natural gas supply costs are not available for this study, hence electricity supply cost are used as an instrument in lieu of natural gas supply costs. The 2006-2010 estimation period findings indicate that cumulative policy impacts are 19.5 percent of average annual natural gas consumption. Unlike for the coefficient of the electricity consumption model, for this model the policy impact indicator, Z_2, is highly statistically significant. Endogeneity testing indicates that the null hypothesis of exogeneity can be rejected at the 95 percent level for both periods. Weak instrument testing indicates that the hypothesis that the two instrument coefficients, W_1 and W_2, are jointly zero can be rejected.

c. Industrial Sector

Broadly speaking, the industrial sector of the U.S. economy is made up of natural resources, construction, and manufacturing industries. Table 12 lists the 2 or 3-digit NAICS codes associated with these industries, a brief description of the industries the codes represent, and the consolidation and recoded classification of industries developed for this study. The industry data consolidation scheme is based on practical considerations. Industry I4 combines 2 industries that are frequently combined in government statistics, and industry code I12 combines 12 industries that individually do not account for a large proportion of California's industrial electricity use and/or have few observations.

Table 12: Industrial Sector NAICS and Study Codes

NAICS	Industry Description	Study Codes
11	Agriculture, Forestry, Fishing and Hunting	I1
21	Mining, Quarrying, and Oil and Gas Extraction	I2
22	Utilities	I3
312 311	Beverage and Tobacco Product Manufact. Food Manufact.	I4
334	Computer and Electronic Product Manufact.	I5
327	Nonmetallic Mineral Product Manufact.	I6
324	Petroleum and Coal Products Manufact.	I7
326	Plastics and Rubber Products Manufact.	I8
333	Machinery Manufact.	I9
325	Chemical Manufact.	1I0
321	Wood Product Manufact.	I11
332 322 336 331 323 339 335 337 315 316 314 313	Fabricated Metal Product Manufact. Paper Manufact. Transportation Equipment Manufact. Primary Metal Manufact. Printing and Related Support Activities Miscellaneous Manufact. Elec. Equip., Appli. and Component Manufact. Furniture and Related Product Manufact. Apparel Manufact. Leather and Allied Product Manufact. Textile Product Mills Textile Mills	I12
23	Construction	I13

Table13 contains summary statistics related to kWh per site per county. As with the commercial sector, these data are built up from census tracts to counties within each utility service territory. To bring the means and variances in energy use down to reasonable sizes, those counties in which the kWh per site in an industry is less than 10,000 kWh annually, or more than 750,000 kWh annually, are dropped. In 2006, they result in a loss on the low end of 71 county observations (20 of which had kWh per site values of zero), and a loss on the high end of 133 county observations. Raising the high end restriction to 1,000,000 kWh per site hardly affects the attrition rate and only adds 23 additional observations, but produces substantially larger relative variances and distribution skewness. As can be seen in Table 12, even after the cutoffs are applied, the standard deviations in energy use, by industry, are roughly as large as their means.

Table 13: Industrial Sector Annual kWh per Site, 2006

Code	Mean	Median	Max	Min.	Std. Dev.	n
I1	54,607	40,880	185,627	10,086	39,802	58
I2	139,353	58,001	731,521	11,678	196,388	14
I3	112,451	78,719	563,629	10,786	98,581	65
I4	246,418	177,107	714,273	12,125	190,769	30
I5	229,499	165,283	687,077	22,876	194,893	25
I6	140,026	95,079	612,900	14,145	136,248	39
I7	395,612	466,680	747,886	16,966	231,833	17
I8	243,310	213,595	690,533	14,440	198,632	25
I9	211,411	182,200	715,847	13,512	172,055	41
I10	242,270	111,257	747,723	11,900	263,273	30
I11	226,680	144,990	738,069	14,727	211,506	36
I12	197,604	128,880	715,849	14,076	191,068	53
I13	25,540	20,710	84,482	10,367	16,044	47
All	165,826	93,293	747,886	10,086	182,866	480

Table 14: Industrial Sector Therms per Site, 2006

Code	Mean	Median	Max	Min.	Std. Dev.	n
I1	10,499	6,408	28,315	5,503	8,520	7
I2	24,714	14,333	49,404	10,405	21,472	3
I3	127,023	61,970	490,120	10,346	143,296	19
I4	104,744	70,627	457,049	5,969	114,152	25
I5	29,736	18,733	83,426	8,256	24,407	13
I6	66,316	39,939	226,925	5,337	73,130	15
I7	234,504	230,177	465,093	8,839	145,240	14
I8	43,530	41,928	125,410	8,077	32,636	15
I9	26,682	12,248	114,609	6,195	36,333	8
I10	123,765	61,005	431,239	12,500	134,162	15
I11	58,312	24,518	308,565	7,241	85,507	15
I12	43,432	24,669	162,220	6,495	47,029	16
I13	7,510	7,510	7,510	7,510	na	1
All	56,640	28,109	226,925	5,337	60,241	150

Table 14 contains summary statistics related to therms per site per county. All of the features of the industries and the electricity use statistics are identical for natural gas use. In so far as cutoff values are concerned, inspection of the full dataset led to a lower limit cutoff of 5,000 therms per site per industry per county, and an upper limit cutoff of 500,000 therms per site. In 2006, they result in a loss on the low end of 334 county observations (127 of which had therms per site values of zero), and a total loss on the high end of 23 observations.

Table 15 contains the estimated models for industrial sector electricity consumption. The single economic variable in the model is the BEA's estimate of total annual earnings for employees in an industry and county.

Table 15: Industrial Sector Electricity Consumption Model

PG&E, SDG&E, SCE	**Description**	**2006-2009**		**2006-2010**	
lnKWH	kWh per Site/Industry/County	Coeff.	Std. Err.	Coeff.	Std. Err.
C	Intercept	**13.703**	0.805	**13.500**	0.713
I1	Ag. and Forestry	**-2.612**	0.057	**-2.475**	0.085
I2	Oil-Gas Extraction	**-0.431**	0.222	-0.734	0.291
I3	Utilities	**-1.867**	0.057	**-1.747**	0.086
I4	Food, Bev., Tobacco	**-0.821**	0.082	**-0.723**	0.096
I5	Computers and Electronics	**-1.284**	0.057	**-1.141**	0.086
I6	Nonmetallic Minerals	**-1.538**	0.048	**-1.398**	0.079
I8	Plastics and Rubber	**-0.487**	0.078	**-0.381**	0.108
I9	Machinery	**-1.266**	0.054	**-1.129**	0.083
I10	Chemicals	**-1.310**	0.073	**-1.121**	0.096
I11	Wood	**-1.220**	0.070	**-1.103**	0.095
I12	All Other	**-1.752**	0.066	**-1.640**	0.092
I13	Construction	**-4.203**	0.071	**-4.095**	0.093
PGE	Fixed CS (Utility) Effect	**0.884**	0.106	**0.824**	0.079
SCE	Fixed CS (Utility) Effect	**0.900**	0.082	**0.831**	0.068
D07	Fixed TS (Year) Effect	0.047	0.026	**0.061**	0.027
D08	Fixed TS (Year) Effect	**0.124**	0.043	**0.140**	0.036
D09	Fixed TS (Year) Effect	**0.155**	0.071	**0.184**	0.054
D10	Fixed TS (Year) Effect			**0.251**	0.072
lnXEARN	Total Earning/Industry/County	**0.242**	0.014	**0.246**	0.013
lnHDD	Heating Degree Days	**-0.451**	0.094	**-0.440**	0.084
lnCDD	Cooling Degree Days	**-0.042**	0.018	**-0.042**	0.014
Z^*_1	Cum. kWh Savings Ratio	**-6.452**	2.355	**-6.561**	1.576
Adj. R-sqd		0.62		0.60	
n		1,509		1,886	
TCR	Total Cum. Reduction (GWh)	5,668		7,471	
% TCR	TCR/Avg. Ann. Consum.	13.6%		17.8%	

To control for unobserved geographic effects of one kind or another that may affect energy use, heating and cooling degree day are kept as independent variables in the industrial sector models. These are not expected to affect energy use in the usual manner, such as for space conditioning in residential and commercial buildings, so interpretation of their coefficients is problematic. To ensure data quality, a small number of observations were screened out of the model if the value of Z_1, the ratio of cumulative ex ante electricity reductions to annual energy consumption was greater than 75 percent, or if W_2, electricity supply cost, was greater than one dollar. The base for the fixed cross section effect for utilities is SDG&E and the base for the fixed industry effects is I7, petroleum and coal product manufacturing. County-level weighting, by industry mix, is used to control for county-level heteroscedasticity. Endogeneity testing indicates that the null hypothesis of exogeneity can be rejected at greater than the 95 percent confidence level for all four models. Weak instrument testing indicates that the hypothesis that the two instrument coefficients, W_1 and W_2, are jointly zero can be rejected. For the 2006-2010 period cumulative policy impacts were 17.8 percent of annual average electricity use.

Table 16 contains the estimated model and policy findings for industrial sector natural gas consumption, for which data have been made available for this study only for PG&E and SDG&E. As with the prior model, to ensure data quality, observations were screened out Z_1 was greater than 75 percent or W_2, was greater than one dollar. And as with the commercial natural gas consumption model, electricity supply costs were used in lieu of natural gas supply costs.

For the 2006-2010 estimation period the findings indicate that policy impacts were 1.4 percent of annual industrial sector natural gas consumption. Endogeneity testing indicates that the null hypothesis of exogeneity can be rejected at close to the 95 percent level for the 2006-2010 period, but not for the 2006-2009 period. Weak instrument testing indicates that the hypothesis that the two instrument coefficients, W_1 and W_2, are jointly zero can be rejected.

Table 16: Industrial Sector Natural Gas Consumption Model

PG&E, SDG&E	**Description**	**2006-2009**		**2006-2010**	
lnTherms	Therms per Site/Industry/County	Coeff.	Std. Err.	Coeff.	Std. Err.
C	Intercept	-1.105	2.493	1.131	2.238
I1	Ag. and Forestry	**-3.456**	0.084	**-3.449**	0.073
I2	Oil-Gas Extraction	**-3.164**	0.257	**-3.117**	0.224
I3	Utilities	**-2.264**	0.108	**-2.334**	0.088
I4	Food, Bev., Tobacco	**-1.976**	0.105	**-1.989**	0.085
I5	Computers and Electronics	**-3.305**	0.145	**-3.312**	0.120
I6	Nonmetallic Minerals	**-1.927**	0.090	**-1.950**	0.074
I8	Plastics and Rubber	**-2.213**	0.112	**-2.227**	0.106
I9	Machinery	**-3.389**	0.111	**-3.426**	0.091
I10	Chemicals	**-1.794**	0.128	**-1.817**	0.102
I11	Wood	**-2.681**	0.108	**-2.598**	0.091
I12	All Other	**-2.905**	0.126	**-2.962**	0.113
I13	Construction	**-4.469**	0.169	**-4.059**	0.489
PGE	Fixed CS (Utility) Effect	**-1.185**	0.280	**-0.953**	0.258
SCE	Fixed CS (Utility) Effect				
D07	Fixed TS (Year) Effect	0.080	0.045	0.071	0.050
D08	Fixed TS (Year) Effect	0.029	0.037	0.043	0.038
D09	Fixed TS (Year) Effect	0.078	0.047	**0.093**	0.043
D10	Fixed TS (Year) Effect			0.093	0.054
lnXEARN	Total Earning/Industry/County	**0.191**	0.032	**0.195**	0.028
lnHDD	Heating Degree Days	**1.467**	0.275	**1.171**	0.255
lnCDD	Cooling Degree Days	**0.207**	0.075	**0.183**	0.065
Z^*_1	Cum. Therm Savings Ratio	**-1.405**	0.276	**-1.586**	0.233
Adj. R-sqd		0.47		0.42	
n		498		622	
TCR	Total Cum. Reduction (MDth)	56.172		72.730	
% TCR	TCR/Avg. Ann. Consum.	1.1%		1.4%	

d. State-Level Findings

The individual policy impact findings from the eight electricity consumption models and the eight natural gas consumption models can be added together to produce state-level estimates of policy impacts.

Over and above the total impacts of energy efficiency policy – which includes the impacts of all old and existing building codes and appliance standards – additional impacts can be calculated for just those housing units built between 2000 and 2004. This can be done by multiplying the coefficient of the variable "BUILT20DUM" in the residential sector models by the annual average energy consumption of the housing units built in the IOU census tracts between 2000 and 2004. To approximate this level of consumption, the number of housing units in each census tract built in this time period was multiplied by the average annual energy use per site in each census tract. The results of this calculation, as well as of the combining of all the model findings, are contained in Tables 16 and 17. As the energy consumption for the housing units built between 2000 and 2004 are already contained in the residential total annual consumption figures, these are not added to the statewide grand totals. Further, ex ante estimates of expected reductions are not available.

The upper panels of Table 17 and 18 contain the policy impact findings for the four year period from 2006-2009; the lower panels contains the findings for the five year period from 2006-2010.

Table 17: State-Level Policy Impact Findings, Electricity

kWh: 2006-2009 Period	Avg. Ann. Energy Consum.	Last Yr. Cum. Ex Ante Savings	Pct. Est. Impact	Avg. Ann. Est. Impact
Ind. (PG&E, SDG&E, SCE)	41,554,138,628	2,048,456,628	13.6%	5,668,443,641
Com. (PG&E, SGG&E, SCE)	76,735,020,087	3,403,092,575	1.2%	916,539,984
Res. (PG&E)	30,132,043,300	480,430,254	4.7%	1,408,088,335
Res. (SDG&E)	7,483,267,512	105,504,485	3.9%	289,567,961
Res. Codes (PG&E)[1]	2,571,722,287		1.9%	48,775,285
Res. Code (SDG&E)[1]	742,521,437		3.2%	23,700,542
Total	155,904,469,527	6,037,483,943		8,355,115,748
Cumulative % Impact		3.9%		5.4%
Pct. Standard Error (+/-)				28.6%
kWh: 2006-2010 Period				
Ind. (PG&E, SDG&E, SCE)	41,879,937,508	2,512,486,691	17.8%	7,471,169,145
Com. (PG&E, SGG&E, SCE)	76,829,480,556	4,412,722,613	2.1%	1,611,926,492
Res. (PG&E)	30,207,548,725	526,324,700	6.4%	1,923,104,970
Res. (SDG&E)	7,432,945,519	129,427,756	4.2%	313,568,580
Res. Codes (PG&E)[1]	2,552,293,975		2.0%	51,114,791
Res. Code (SDG&E)[1]	729,653,042		2.9%	21,086,973
Avg. Total. Ann. Consum.	156,349,912,308	7,580,961,761		11,391,970,952
Cumulative % Impact		4.8%		7.3%
Pct. Standard Error (+/-)				18.9%

[1] Average annual sales total does not include residential code energy sales.

Based on the collected findings of all the eight electricity consumption econometric models estimated for this study, in 2009 the total impact of electricity efficiency policy in all sectors, and including residential building code impacts for housing units built between 2000 and 2004, is a decline in energy use 8,355 GWh. This is a 5.4 percent decline relative to the average, total energy consumption per year in the 2006-2009 period. The relative standard error of the impact estimate is 28.6 percent; at the 90 percent confidence level the relative standard error is plus or minus 47 percent. By comparison, in 2009 the cumulative ex ante estimate of electricity reductions for the 2006-2009 period due to downstream, IOU-implemented energy efficiency programs is 3.9 percent relative to 2009 total electricity consumption. It is not the purpose of this study to speculate as to why there are differences in the ex ante and model-based energy consumption reduction estimates. As previously discussed, the cumulative ex ante estimates of energy reductions due to downstream, IOU-implemented energy efficiency programs are used in this study as *indicators* of the impacts of the broader set of public initiatives that comprise *de facto* state-wide energy efficiency *policy*.

Cumulative policy impacts for the 2006-2010 period are 7.3 percent. The relative standard error of this estimate is plus or minus 18.9 percent, or 31 percent at the 90 percent confidence level. The cumulative IOU energy efficiency program ex ante energy reduction estimate is 4.8 percent of average total energy consumption over the five year period.

Table 18 indicates that the eight natural gas consumption econometric models yield findings of 1.9 percent percent policy impacts over the four year estimation period. The relative standard error of this estimate is very large, at 175 percent. The IOU energy efficiency program ex ante estimate of natural gas reductions for the four year period is 1.4 percent relative to average total electricity consumption. In the five year period, the impact estimate for natural gas consumption energy efficiency policy rises to 2.2 percent, again with a very large relative standard error.

Table 18: State-Level Policy Impact Findings, Natural Gas

Therms: 2006-2009 Period	Avg. Ann. Energy Consum.	Last Yr. Cum. Ex Ante Savings	Pct. Est. Impact	Avg. Ann. Est. Impact
Ind. (PG&E,SDG&E)	5,124,383,847	87,353,504	1.1%	56,171,929
Com. (PG&E, SDG&E)	1,198,857,181	17,121,520	18.6%	222,477,711
Res. (PG&E)	2,012,166,142	10,406,303	1.2%	23,976,294
Res. (SDG&E)	297,293,772	2,039,215	-51.3%	-152,541,395
Res. Codes (PG&E)[1]	152,939,950		9.2%	13,873,030
Res. Code (SDG&E)[1]	25,880,855		5.1%	1,328,257
Total	8,632,700,942	116,920,542		165,285,826
Cumulative % Impact		1.4%		1.9%
Pct. Standard Error (+/-)				175%
Therms: 2006-2010 Period				
Ind. (PG&E,SDG&E)	5,143,530,663	111,485,401	1.4%	72,730,412
Com. (PG&E, SDG&E)	1,200,231,263	23,026,253	19.5%	234,511,830
Res. (PG&E)	2,018,224,763	13,930,364	3.3%	65,597,381
Res. (SDG&E)	308,983,896	2,778,731	-64.3%	-198,590,214
Res. Codes (PG&E)[1]	152,601,314		9.6%	14,650,642
Res. Code (SDG&E)[1]	25,675,625		4.1%	1,045,537
Total	8,670,970,586	151,220,748		189,945,588
Cumulative % Impact		1.7%		2.2%
Pct. Standard Error (+/-)				244%

[1] Average annual sales total does not include residential code energy sales.

4. Recommendations

This study achieves the two main goals of this pilot study articulated by Commission Decision (D.)10.10.33 (October 28, 2010). Both are related to the creation of an evaluation framework that is scientifically defensible and applicable for the foreseeable future. First, it demonstrates that an well-founded econometric framework, coupled with an appropriate, large-sample database, can be developed to evaluate the aggregate impact of the 2006-2008 energy efficiency programs on energy consumption. Second, it demonstrates that aggregate econometric models employing large samples are capable of accurately measuring the impact of the Commission's energy efficiency efforts on overall electricity and natural gas consumption in California in the context of post-2012 EM&V activities. The potential for accurate measurement is demonstrated by the standard errors that accompany the estimated electricity policy impacts for the 2006-2010 period. No other type of evaluation study can produce a relative error bound of 31 percent (at the 90 percent confidence level) around a state-level policy impact estimate that embraces all three non-transportation sectors of the economy and incorporates the uncertainties due to free ridership, spillover, rebound, measure interaction and retention, behavioral changes, and general economic conditions.

This study also achieves the two additional goals articulated by Decision (D.) 10.10.33. This detailed, small-geographic area, sector and industry-level approach to policy evaluation shows that such studies are likely to be valuable for improving estimates of aggregate reductions in Greenhouse Gases (GHG) emissions from efficiency programs as required in AB32. Also, it is likely that they can prove valuable for more directly aligning and integrating energy efficiency program findings into the California Energy Commission's (CEC) demand forecasts, and ultimately, the CPUC's resource procurement process.

General recommendations for integrating this evaluation approach into the permanent portfolio of post-2012 EM&V activities fall into two categories, database development and econometric analysis. They include:

- Expand the database with additional variables, particularly in the commercial and industrial sectors.
- Upgrade the database for easier access and creating a website with the capability to download customized data requests.
- Develop standardized, automated routines for cleaning customer billing and program tracking data;
- Use geographic information system software for collecting and processing local area data.
- Explore the properties of different types of econometric impact estimators.
- Experiment with customized models for different fuels and sectors.
- Analyze various market segments and customer grouping.
- Investigate the possibilities for developing econometric models that target specific programs and policies.