# WHITE PAPER

# _MACRO CONSUMPTION METRICS

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# CPUC'S EM&V GOALS

## Old directive

(see California Public Utilities Commission, *2006-2008 Energy Efficiency Program Evaluation Report.* Prepared by the Energy Division. July, 2010, San Francisco, CA.)

- verify the costs and installations of energy efficiency program activities;
- update the ex-ante parameters used to estimate program savings and benefits; and,
- publish reports that calculate earnings the utilities are eligible to claim

## New directive

(see California Public Utilities Commission, *Decision on Evaluation, Measurement, and Verification of California Utility Energy Efficiency Programs*. Decision 10-10-33 (Rulemaking 09-11-014). October, 2010, San Francisco, CA).

- quantify the permanent, long-term effects of energy efficiency public programs both for energy supply and environmental reasons

# DEMAND RESEARCH'S VALUE PROPOSITION FOR THE CPUC

An updatable, permanent, state-of-the-art, geographic database that permits the CPUC to monitor the long-term impacts of energy efficiency policies on state and local energy consumption and environmental protection

A substantial reduction in the size, and cost, of the CPUC's conventional, IPMVP-type, EM&V activities

# OVERVIEW OF DEMAND RESEARCH'S RECOMMENDED APPROACH

- Reduced form econometric models of energy demand – they can be time series or panel. Each one is for a single fuel, and a single customer type, market segment, or economic sector; the general approach is applicable to all well-defined customer groups in well-defined geographic areas

- The data for these models come from state, local, and federal agencies and are free to the public – they are geographically-based and can be divided as finely as the the census tract or zip code levels

- Compiling, merging, and joining all of the specified datasets is a large and complex job –however, once the fixed costs are incurred for doing this for the residential sector, the marginal costs of expanding the database for the commercial, industrial, and agricultural sectors are relatively modest

- The approach directly addresses the CPUC Decision – it provides estimates of the long-term impact of public policies on energy consumption trends and environmental conditions. IPMVP-type studies will still be needed to audit program implementation contractor work, adjust gross savings estimates, and improve programs: however, because IPMVP evaluations will not be relied on as the sole means of estimating "energy savings," much smaller and faster EM&V studies can be commissioned

| | Policy Impact Methodology Check-List | *Bottom- Up Methods* | | *Top-Down Methods* | |
|---|---|---|---|---|---|
| **Factor** | ***"Does the method…when estimating long-term energy savings."*** | **Monitoring** | **Billing** | **Indicators** | **Models** |
| 1. | control for the effects of changes in energy prices | no | no | no | yes |
| 2. | control for the effects of changes in income, profits, or net wealth | no | maybe | no | yes |
| 3. | control for changes in macroeconomic conditions or business cycles | no | no | maybe | yes |
| 4. | control for changes in economic structure or activity-levels | no | no | yes | yes |
| 5. | control for consumer learning, adaptation, and changes in preferences | no | no | no | yes |
| 6. | control for policy gaming (free ridership) | yes | yes | no | yes |
| 7. | control for policy diffusion (spillover) | maybe | maybe | no | yes |
| 8. | control for autonomous technology trends | no | no | no | yes |
| 9. | control for changes in the number of installed efficiency measures | yes | no | no | no |
| 10. | control for changes in post-installation hours of use estimates | yes | no | no | no |
| 11. | produce revised savings estimates for individual programs | yes | maybe | no | maybe |
| 12. | produce revised estimates of 1st year gross and net savings | yes | yes | no | no |
| 13. | produce estimates of long-term net savings | no | no | no | yes |
| 14. | produce sufficient information for determining financial incentives | yes | yes | no | maybe |
| 15. | produce a complete estimate of the standard error of net impacts | no | yes | no | yes |
| 16. | produce empirical evidence of long-term changes in energy use, thereby verifying policy-related changes in GHG emissions | no | no | no | yes |

# ENERGY INDICATORS

## WEBSITE EXAMPLES:

- INTERNATIONAL ENERGY AGENCY
- NATURAL RESOURCES CANADA (OFFICE OF ENERGY)
- U.S. DEPARTMENT OF ENERGY (EERE)
- ODYSSEE (FUNDED BY EUROPEAN COMMISSION)

| Term | Definition |
|---|---|
| Energy indicator | Any statistic that provides information related to energy consumption. Typically this statistics is composed of a time series, energy-related variable. However, any variable that is highly-correlated with energy use, such as the number of personal computers in a building, may also be considered an energy indicator. |
| Energy intensity | A ratio in which an energy-related variable such as energy use or energy costs is in the numerator, and the denominator of the ratio is a variable that is closely related to the numerator. |
| Energy intensity index | a statistic created by combining two or more energy intensity ratios; these indexes may be simple (an arithmetic average) or complex, depending on how they are constructed and how they weighted. |
| Activity index | a statistic created by rearranging the terms of certain types of energy intensity indexes in such a way that the effects of the relative sizes of the denominators of each ratio is quantified. |
| Efficiency index | a statistic created by rearranging the terms of a certain type of energy intensity index in such a way that the effects of the relative sizes of the denominators is removed from the energy intensity index. |

# BENEFITS OF ENERGY INDICATORS

## DIRECTLY LINKS TOTAL ENERGY USE (OR SPECIFIC FUELS) TO ACTIVITIES OR PHYSICAL OBJECTS

- physical: steel production, passenger miles
- economic: industry value added, personal income
- societal: population, households
- equipment/appliances/end use: refrigerator, space heat, cooking

# THE MOST SCIENTIFICALLY RIGOROUS ENERGY INDICATORS ARE PRODUCED BY INDEX DECOMPOSITION, E.G., THE FISHER IDEAL INDEX

$$F_t^{act} = \sqrt{L_t^{act} P_t^{act}}$$

$$F_t^{eff} = \sqrt{L_t^{eff} P_t^{eff}}$$

$$F_t^{Total} = F_t^{act} F_t^{eff}$$

$$\text{Attribution to Activity} = \left( \frac{\ln(F_t^{act})}{\ln(F_t^{Total})} \right)$$

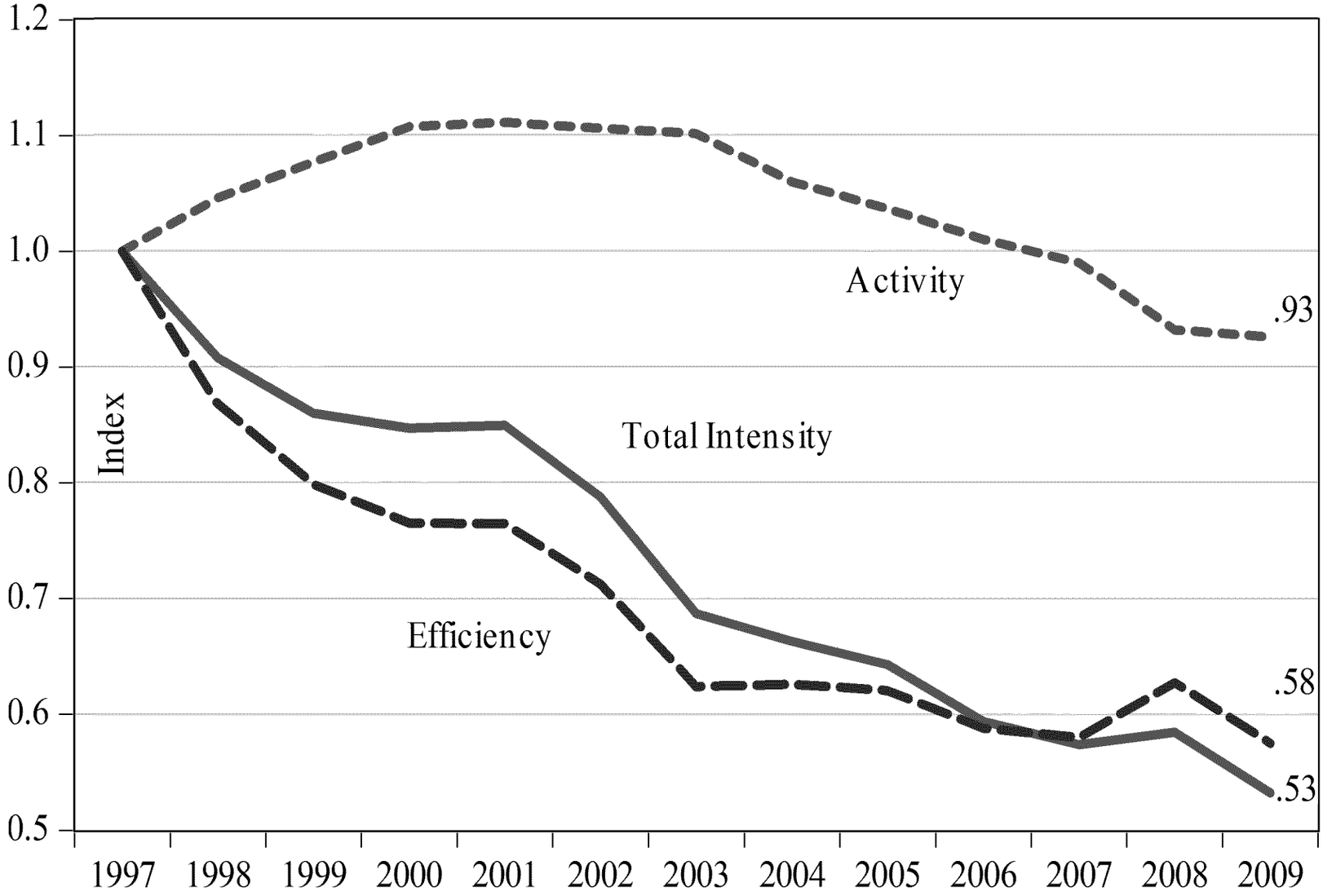
$$\text{Attribution to Efficiency} = \left( \frac{\ln(F_t^{eff})}{\ln(F_t^{Total})} \right)$$

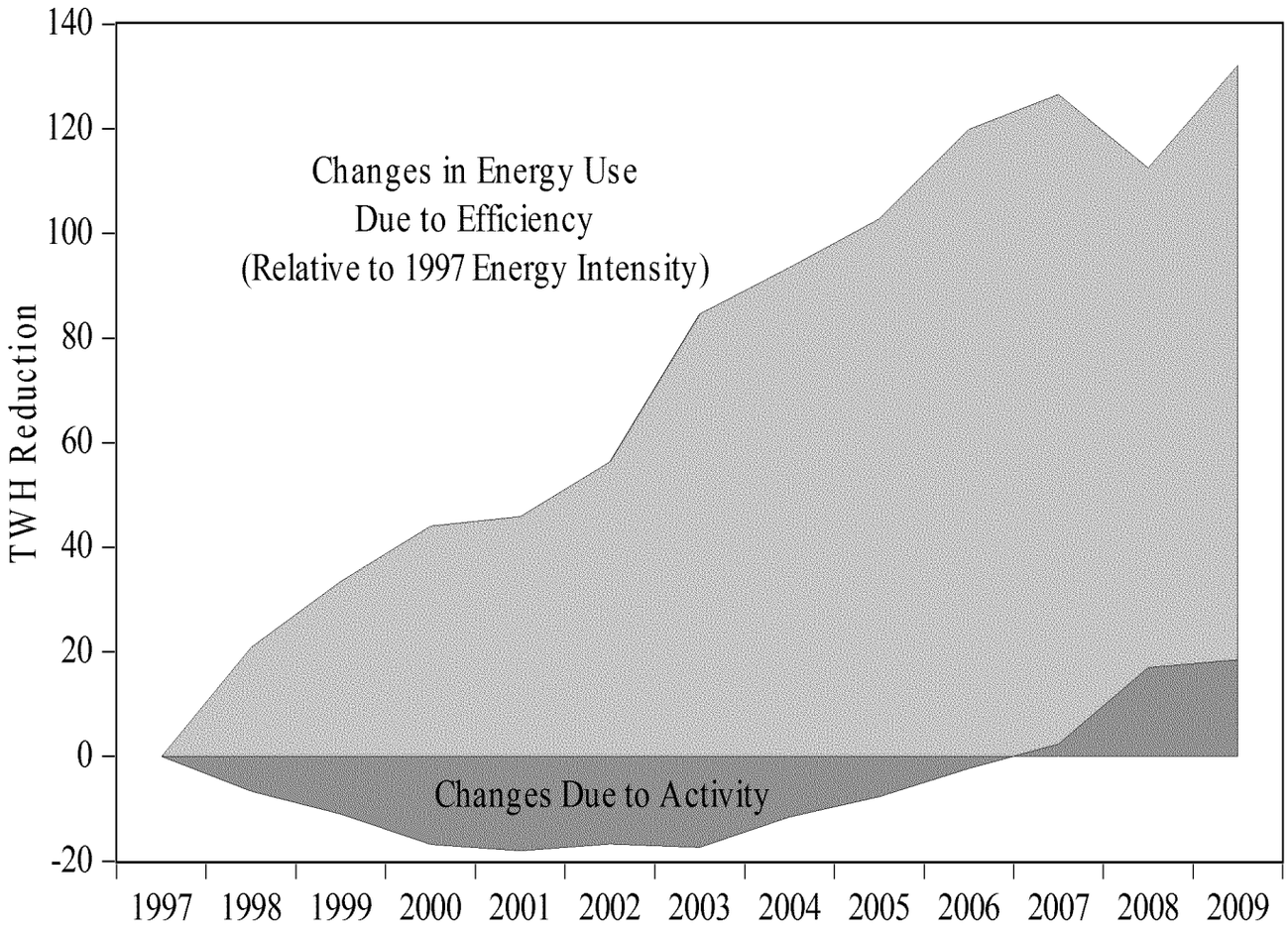
$$\text{Counterfactual}_t = (\text{Total Intensity}_o \times \text{Total Activity}_t)$$

$$\text{Efficiency Impact}_t = (\text{Counterfactual}_t - \text{Actual}_t) \times \left( \frac{\ln(F_t^{eff})}{\ln(F_t^{Total})} \right)$$

| INDUSTRY | NAICS | YR | GWH | GDP | INTENSITY | GDP SHARE |
|---|---|---|---|---|---|---|
| Food | 311 | 2008 | **98,092** | **179** | 549.5 | 0.31 |
| Chemicals | 324 | 2008 | **50,675** | **116** | 437.8 | 0.20 |
| Computers | 335 | 2008 | **33,539** | **284** | 118.0 | 0.49 |
| Food | 311 | 2009 | **91,634** | **175** | 522.3 | 0.29 |
| Chemicals | 324 | 2009 | **48,083** | **128** | 375.0 | 0.21 |
| Computers | 334 | 2009 | **31,681** | **294** | 107.8 | 0.49 |

INDEX DECOMPOSITION PRODUCES THREE INDEXES: TOTAL , ACTIVITY, AND EFFICIENCY






| Year | % Efficiency Savings |
|---|---|
| 1998 | **13%** |
| 1999 | **20%** |
| 2000 | **23%** |
| 2001 | **23%** |
| 2002 | **28%** |
| 2003 | **36%** |
| 2004 | **37%** |
| 2005 | **37%** |
| 2006 | **41%** |
| 2007 | **42%** |
| 2008 | **38%** |
| 2009 | **44%** |

# DISADVANTAGE OF ENERGY INDICATORS

## •CANNOT ATTRIBUTE CHANGES IN EFFICIENCY TO PUBLIC POLICIES (OR ANY SPECIFIC CAUSE)

for this reason, energy indicators cannot meet the CPUC's new EM&V directive, i.e., *to quantify the permanent, long-term effects of energy efficiency public programs both for energy supply and environmental reasons* (CPUC Decision 10-10-33)

# ECONOMETRIC (AGGREGATE) ENERGY DEMAND MODELS

FOR EXAMPLE,

- M. J. HOROWITZ (*THE ENERGY JOURNAL*, 2004)
- M. J. HOROWITZ (*THE ENERGY JOURNAL*, 2007)
- M. J. HOROWITZ (*ENERGY EFFICIENCY*, 2011)
- M. J. HOROWITZ (IN PROGRESS)

# POLICY COUNTERFACTUALS: FELICITOUS MERGERS OF RESEARCH DESIGNS & REGRESSION MODELS

| STUDY | ANALYSIS APPROACH | SAVINGS |
|---|---|---|
| Horowitz (2004) | Target Variable | • DSM Savings<br>• Market Trans. |
| Horowitz (2007) | Simulation | Difference-in-Differences |
| Horowitz (2011)<br>Horowitz (~2012) | Policy Residual | Load Forecast |

# MCM RESEARCH DESIGNS BASED ON GEOGRAPHY (AND TIME)

a) census tracts (n~7,000)

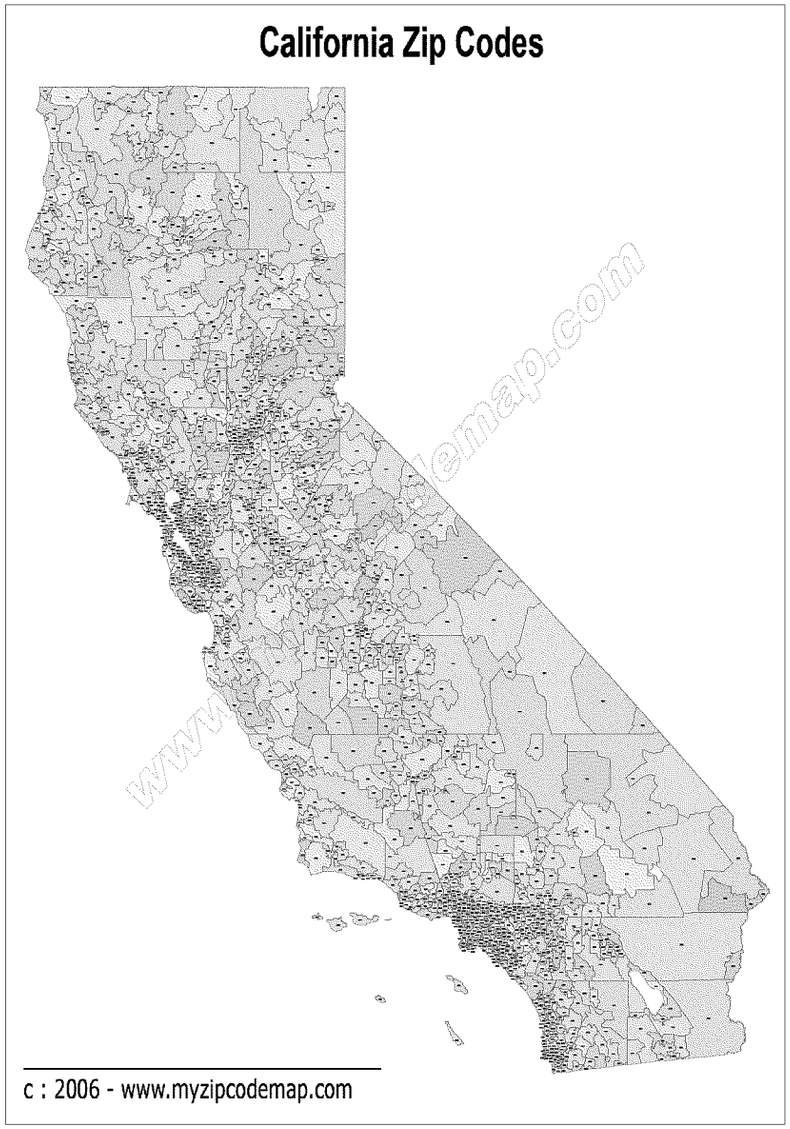
b) zip codes (n~6,000)

c) counties (n=58)

d) utility service territories (n~50)

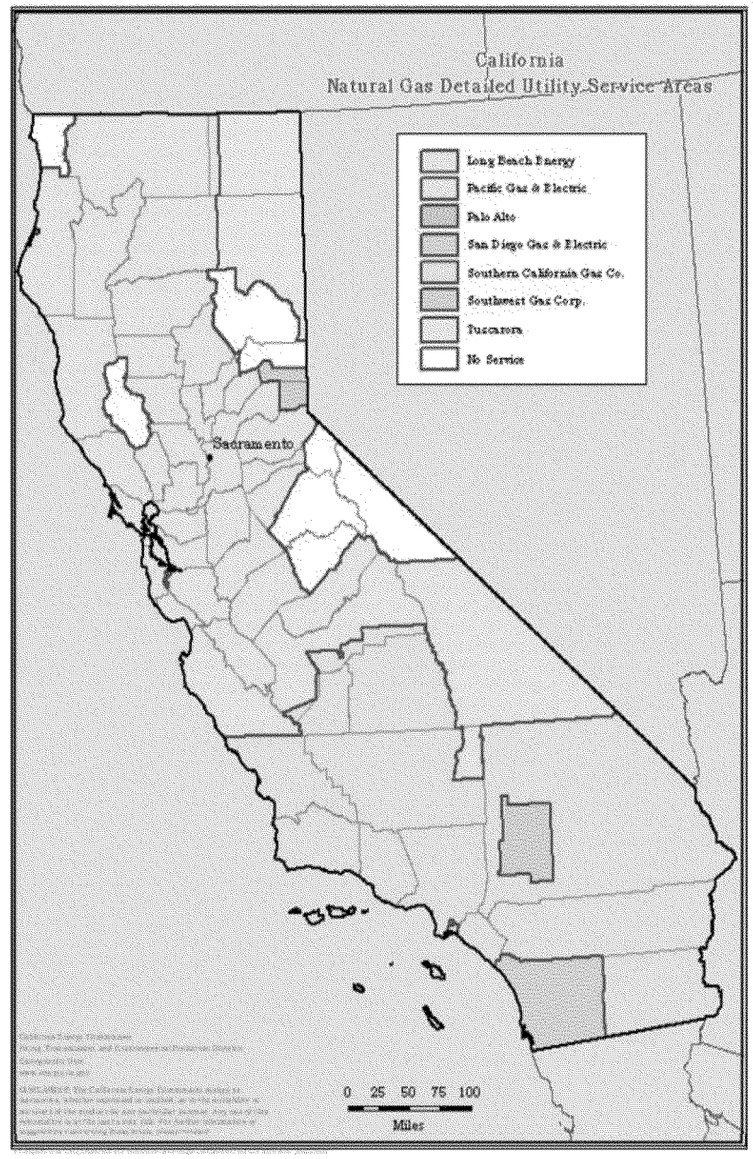
e) climate zones (n=>16)

f) planning zones (n=8)


California Zip Codes
c : 2006 - www.myzipcodemap.com


DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
LAKE
COLUSA
SUTTER
YUBA
PLACER
YOLO
EL DORADO
Sacramento
SONOMA
NAPA
ALPINE
SACRA-MENTO
AMA-DOR
SOLANO
CALAVERAS
SAN FRANCISCO
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
Los Angeles
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL


California
Electric Utility Service Areas
Area served by both
Surprise Valley & PacificCorp
PacifiCorp
Surprise Valley
Trinity
Shasta Lake
Redding
Lassen
Shelter Cove
Area served by both
Lassen & Plumas-Sierra
Biggs
Plumas - Sierra
PG&E
Truckee-Donner
Gridley
Ukiah
Sierra Pacific
Pittsburg
Roseville
Mountain Utilities
Healdsburg
SMUD
Hercules
Lodi
Stockton
Alameda
Municipal
Power
Area is served by both
MID & PG&E
Valley Electric
MID
TID
Oakland
C.C.S.F.
Merced
Palo Alto
LADWP -
Owens Valley
Silicon Valley
Power
PG&E
SCE
Victorville
Aha Macav
Azusa
Pasadena
Rancho Cucamonga
Needles
Colton
Glendale
Lompoc
Burbank
Bear Valley Electric
Banning
LADWP
Morongo
Anza Electric
Vernon
Industry
Cerritos
IID
SDG&E
Anaheim
Corona
Riverside
Moreno Valley


California
Natural Gas Detailed Utility Service Areas
Long Beach Energy
Pacific Gas & Electric
Palo Alto
San Diego Gas & Electric
Southern California Gas Co.
Southwest Gas Corp.
Tuscarora
No Service
Sacramento
0 25 50 75 100
Miles

# EX. 1: TARGET VARIABLE APPROACH: RESIDENTIAL SECTOR

Using census tract or zip code level data (demographic, economic, social), aggregate billing data are analyzed over a period of years. One possible model may be:

$$E_{it} = \sum_{i=1}^{n} a_i L_i + \sum_{t=1}^{t} a_t T_t + \sum a'X' + a_1 \text{Target}_1 + e_{it}$$

There may be one or more target variables in the model, e.g.,

- aggregate ex ante or ex-post savings estimates
- index of program participation or equipment sales
- dummy variables for different start dates or levels of program participation

The coefficients of the target variables are used to derive net, long-term policy impacts

# EX. 2: SIMULATION APPROACH: COMMERCIAL BUILDINGS

$$I = \text{Intensity} = \text{E/A} = \text{Energy/Activity}$$

$$R = \text{split function for locations } U \text{ and } W$$

$$I_{t,R} = f(X'_{t,R})$$

$$I^{W}_{Simulated,t} = b^{U}_{0} + \sum_{j=1}^{n} b^{U}_{j} X^{W}_{t}$$

$$\text{Counterfactual} = E^{W}_{Simulated,t} = I^{W}_{Simulated,t} \times A^{W}_{t}$$

$$\text{Policy Savings} = E^{W}_{Simulated,t^*} - E^{W}_{Actual,t^*}$$

An energy demand model is estimated for locations *U* (e.g., utility service territories) with one type of policy (or little or no commitment to energy efficiency). The model is used to simulate energy demand for an alternative set of locations, *W,* with a different type of policy.

# EX. 3: POLICY RESIDUAL APPROACH: MANUFACT. SECTOR

U.S. Annual Survey of Manufacturers (ASM) data, by state, at the 3-digit NAICS level combines with IOU aggregate billing data for 18 manufacturing industries for the ten years,1997 through 2006. An energy demand model may appear as:

$$E_{it} = \sum_{i=1}^{18} b_i N_i + \sum_{t=10}^{10} b_t T_t + b_1 PRICE_{it} + b_2 OTHPRICE_{it}$$
$$+ b_3 VALUE_{it} + b_4 CAP_{it} + b_5 HOURS_{it} + b_6 EMPLOY_{it}$$
$$+ b_7 PAYROLL_{it} + b_8 MATERIAL_{it} + \varepsilon_{it}$$

The residuals for the out-of-sample years, 2007 through 2009, measure aggregate public policy impacts.

# DEMAND RESEARCH'S MCM PILOT PROJECT PROPOSAL

1. Build geographically-granular database
2. Process utility billing data
3. Select evaluation topic(s)
4. Compile program/policy histories
5. Conduct, explore, test, assess

# 1. BUILD GEOGRAPHICALLY-GRANULAR DATABASE

*Demand Research* proposes to test the MCM concept by first focusing on electricity energy efficiency in the residential sector

As time and budget permit, the second phase of the pilot project will focus on the commercial sector, and the third phase on the the industrial/agricultural sectors

It is anticipated that after constructing the residential database, the construction of the other databases will go much more smoothly and quickly

The database platform will integrate data from many different sources and permit variables to be created and merged without time-consuming programming or processing

The database will be multi-purpose in that the cross-sectional (geographic) and time-series data will permit an unlimited number of electricity (and natural gas) MCM studies to be undertaken (subject to the provision of billing data)

| Federal Data Source | Dataset |
|---|---|
| Energy Information Administration (U.S. DOE) | State energy data, all fuels, by sector<br>Utility electricity sales, by sector |
| Bureau of Economic Analysis (U.S. Dept. of Commerce) | REIS state/country accounts<br>Industry GDP by state<br>GDP, quantity indexes, price deflators |
| Census Bureau (U.S. Dept. of Commerce) | Annual Survey of Manufacturers<br>Annual Community Survey<br>Decennial population and housing census<br>Quinquennial economic survey |
| Nat. Climatic Data Center (U.S. Dept. of Commerce) | Local HDD and CDD |
| Bureau of Labor Statistics (U.S. Dept. of Labor) | Consumer/producer price indexes<br>Local area unemployment |
| Economic Research Service (U.S. Dept. of Agriculture) | Farm characteristics |
| Federal Reserve Board | National financial and industry time trends |

**California Data Sources**

CEC's Energy Consumption Database (ECDMS)
CEC databases used for load forecasting and special studies
CPUC documents and records (e.g., EEGA)
Residential Appliance Saturation Survey
DEER database
Past and present EM&V studies
Other agencies and organizations

# 2. PROCESS UTILITY BILLING DATA

Demand Research will request residential historical billing data, by census tract

The data will be cleaned, processed, and aggregated by billing data experts

Anticipated difficulties include:

- distinguishing between single and multifamily bills
- centering bills on calendar months
- inconsistencies between year and utilities

# 3. SELECT EVALUATION TOPIC(S)

Two of the most strategically-important policy issues confronted by the CPUC involve the impacts of residential lighting measures and building codes on energy consumption

Together with the CPUC, Demand Research will select primary and secondary residential policy evaluation topics for study that are:

- of most value to policymakers
- can reasonably be expected to be completed in the available pilot project time period

# 4. COMPILE PROGRAM/POLICY HISTORIES

Program/policy histories serve several indispensible purposes:

(a)they are essential for specifying the optimal research design, regression model, and counterfactual

(b)they guide the selection or construction of target variables and their integration into the evaluation

(c)they permit benchmarking of MCM findings with bottom-up findings (gross, adjusted-gross, net, etc.) and CEC load forecasts

(d)they guide program, or measure, attribution analyses

# 5. CONDUCT, EXPLORE, TEST, ASSESS

- emphasis on policymaker needs
- focus on policy counterfactuals, not individual sub-hypotheses
- reliance, not slavish dependence, on tests of significance
- conformance with current scientific standards

# DEMAND RESEARCH'S MCM PILOT PROJECT TASKS AND TIMELINE

| Task | Activities | 2011 Sept. | Oct | Nov | Dec | 2012 Jan. | Feb | Mar | Apr | May | June | July | Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Residential** | | | | | | | | | | | | |
| 1.1 | Data Collection | | | | | | | | | | | | |
| 1.2 | Data Processing | | | | | | | | | | | | |
| 1.3 | Model Development | | | | | | | | | | | | |
| 1.4 | Data, Model Review | | | | | | | | | | | | |
| 1.5 | Final Model/Report | | | | | | | | | | | | |
| 2 | **Commercial** | | | | | | | | | | | | |
| 2.1 | Data Collection | | | | | | | | | | | | |
| 2.2 | Data Processing | | | | | | | | | | | | |
| 2.3 | Model Development | | | | | | | | | | | | |
| 2.4 | Data, Model Review | | | | | | | | | | | | |
| 2.5 | Final Model/Report | | | | | | | | | | | | |
| 3 | **Industrial/Ag** | | | | | | | | | | | | |
| 3.1 | Data Collection | | | | | | | | | | | | |
| 3.2 | Data Processing | | | | | | | | | | | | |
| 3.3 | Model Development | | | | | | | | | | | | |
| 3.4 | Data, Model Review | | | | | | | | | | | | |
| 3.5 | Final Model/Report | | | | | | | | | | | | |

Please note: A majority of the activities needed to develop the residential database and perform the analyses are generic and overlap those required for the commercial and industrial/agricultural sectors, hence the lightly shaded areas for these sectors. Due to the fixed costs involved, the marginal labor hours/costs associated with completing the databases and analyses for these two other sectors are substantially lower than for the residential sector.