Summary of Modeling Efficiency in the California Energy Commission Energy Demand Forecasts

Excerpts from Previous Staff Reports

For discussion at the:
2008 Integrated Energy Policy Report Workshop on Improved Measurement and Attribution in the Energy Demand Forecasts

August 12, 2008

DISCUSSION PAPER

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AUGUST 2008
CEC-200-2008-005

Introduction

With the adoption of the first Energy Action Plan in 2003 (Plan), energy efficiency became the "resource of first choice" for meeting the state's future energy needs. The Plan, translated into numerical goals by the California Public Utilities Commission (CPUC) in 2004, and now combined with The Global Warming Solutions Act (AB 32) of 2006, raised proper accounting of energy efficiency impacts to critical importance.

Various types of forecasting models, such as single equation econometric models or simple engineering models, can be used to assess the adequacy of the energy supply system. Most of these models when properly calibrated give satisfactory results and produce a forecast that can be used to estimate resource need. These models, however, usually single equation models with a handful of variables (electricity price, population growth, etc.), have limited value for estimating the impacts of efficiency programs. For this purpose, end-use forecasting models such as those employed for the Energy Commission's California Energy Demand (CED) forecast are necessary.

End-use models are integral to the CED methodology because they capture individual decisions with respect to end-use energy services. For example, in the residential sector, the models can simulate customer decisions on clothes washing or air conditioning usage. In the commercial sector, the models can simulate lighting retrofits. Because these models are disaggregated, they can quantify the effects of building, appliance and other efficiency standards.

This paper describes the manner in which efficiency programs are modeled in the CED forecast.[1] Such programs are incorporated explicitly in the Residential Energy Demand Forecast Model, the Commercial Building Energy Demand Forecast Model, and the Energy Demand Summary Forecast Model. The following three sections give a brief overview of each of these models, along with a discussion of how efficiency programs are incorporated. Models for the other sectors--industrial, agricultural, transportation, communications and utilities, and street lighting--do not integrate specific programs, although past efficiency impacts are accounted for since the models are calibrated to historic use. The paper concludes with a discussion of the current and future CPUC energy efficiency goals and their incorporation into the CED forecast.

Residential Energy Demand Forecast Model

The Residential Model forecasts energy demand for 24 end-uses, three housing types, and three fuel types. End-uses include space heaters, air conditioners, refrigerators, color televisions, lighting, water heating, etc. Electricity and natural gas consumption are fully modeled for all relevant end-uses, while saturations are maintained for other fuels (principally wood, liquid propane gas, and solar). Three housing types are modeled:

- Single family

- Multiple family
- Mobile home

Sixteen groupings capture differences in residential energy use for space conditioning across the state based on climate. Five vintages of housing construction represent the eras in which building codes and subsequent revisions significantly influenced the thermal characteristics of residential buildings:

- Housing built prior to 1975
- 1975-1978
- 1979-1983
- 1984-1991
- Post 1991 (which incorporates the standard revisions of 2001 and 2005)

The Residential Model forecasts energy demand in three steps. First, the model forecasts the number of households of each housing type. Household projections are the main explanatory variable for the residential sector. Second, the model projects the saturation of appliances for each of three fuel types. For example, the model determines the number of households with a gas space heating unit. Finally, the model determines the amount of energy expected to be used by each end-use appliance (unit energy consumption, or UEC). Total residential electricity consumption is the product of projected households, the fraction of households possessing a particular appliance, and the UEC, summed over all end-uses.

Efficiency

Numerous efficiency programs have been initiated to affect energy consumption in the residential sector. The bulk of efficiency impacts, including that from mandatory standards, are included in the model. The programs quantified directly by the model are listed below. A previously issued staff report[2] documents the characteristics attributed to these programs.

- 1975 HCD Building Standards
- 1978 Title 24 Residential Building Standards
- 1983 Title 24 Residential Building Standards
- 1991 Title 24 Residential Building Standards
- 2005 Title 24 Residential Building Standards
- 1976-82 Title 20 Appliance Standards
- 1984 Title 20 Appliance Standards
- 1988 Federal Appliance Standards
- 1990 Federal Appliance Standards
- 1992 Federal Appliance Standards
- OII-42 Solar Subsidies
- Pool Pump Timers
- Miscellaneous Retrofit

These programs fall into three broad categories: building standards, appliance standards, and retrofit programs. Each program consists of a series of measures that are included in the residential model. Attribution of savings is guided by the principle that savings are determined in the reverse order of introduction. This chronological sequencing approach requires that a series of model runs be performed, with programs added one at a time in the form of alternative input data. The incremental changes in output from run to run reflect the savings attributable to the individual programs.

The building standards are incorporated as part of the space conditioning UEC calculations. The method consists of utilizing a building energy simulation[3] for each new efficiency measure and normalizing the results to yield savings on a per square foot basis. These values are then adjusted to reflect the estimated penetration of the specific measure. The sources of measure penetration values for the backcast period are the biennial survey and a 1986 CPUC statewide weatherization survey. Sources for penetrations in the forecast period are staff judgment based on forecasts of trade associations, historic trends derived from previous utility surveys, and the 2002 Residential Appliance Saturation Survey.

Appliance standards often mandate minimum values for equipment performance measures; these are included in the model as adjustments to input parameters for specific end uses. For example, non-space conditioning end uses can be adjusted up to ten times during the forecast period by changing the appliance energy intensity (AEI). Space conditioning end use standards are incorporated into the attributes of certain housing vintages.

Retrofit programs include miscellaneous retrofit and OII-42 (solar water heater) programs. Evaluation of the latter entails adjusting the UEC by a solar retrofit fraction.[4] Miscellaneous retrofit applies to selected end uses. Retrofit programs are quantified by adjusting the UEC with an energy intensity factor (EIF). This parameter is defined as the ratio of the post-standards UEC to the pre-standards UEC. The retrofit UEC then is a function of the penetration of the efficiency measures and the EIF.

Commercial Building Energy Demand Forecast Model

The forecasting model for the commercial sector is similar to the Residential Model in that the model is disaggregated by categories. Whereas the Residential Model is disaggregated by household types, the Commercial Model is disaggregated by building types. The model projects energy use for 12 building types:

- Small and large office
- Restaurants
- Retail Stores
- Food and liquor stores

- Warehouses
- Refrigerated Warehouses
- Schools
- College and trade schools
- Health care facilities
- Hotels and motels
- Miscellaneous building types

Within each of the building types the models are further disaggregated by 10 end-uses:

- Space heating
- Cooling
- Ventilation
- Water heating
- Cooking
- Refrigeration
- Indoor lighting
- Outdoor lighting
- Office equipment
- Other uses

Finally, each of end-uses is modeled according to 3 fuel types, depending on the fuel used:

- Electricity
- Natural gas
- Other petroleum fuels

Like the Residential Model, the Commercial Model works in steps. The model first forecasts the amount of building floor space and vacancy rates for twelve different building types. Second, the model determines the fraction of floor space in each building "saturated" with commercial equipment for each of three fuel types. The nature of the energy-using equipment in each building type determines the commercial end-uses (for example, restaurants contain ovens and stoves; therefore, cooking is a principle end-use for that building type). Finally, the amount of energy required per square foot of floorspace is determined for each fuel type.

Total commercial energy demand is the product of three factors:

floor space x *fraction of floor space devoted to end-use*

x *energy required per sq. ft. floorspace by fuel type*.

This last term is referred to as energy use intensity (EUI). The products are summed for all end-uses and building types. The model considers the effects on energy use of changes in floor space, vacancy rates, and energy prices.

Efficiency

Efficiency program savings analysis must be closely coordinated with the Commercial Model method of operation. Of primary concern is the pervasive nature of price response in the model. The Commercial Model simulates a short-run price response affecting the utilization rate of existing equipment and a longer-run price response affecting the choice of the efficiency of new and/or replacement equipment. Efficiency program savings are measured as net savings in addition to price response.

The efficiency programs that affect the commercial building sector for the staff's 2005 forecast are listed below. Previous staff reports provide details on each program.[5]

- 1978 Title 24 Nonresidential Building Standards
- 1978 Title 20 Equipment Standards
- 1984 Title 24 Nonresidential Building Standards (Offices)
- 1984 Title 20 Nonresidential Equipment Standards
- 1985-88 Title 24 Nonresidential Building Standards (2nd Tier)
- 1992 Title 24 Nonresidential Building Standards (All buildings excluding Hospitals)
- 1998 Title 24 Nonresidential Building Standards
- 2001 Title 24 Nonresidential Building Standards
- 2004 Title 20 Nonresidential Equipment Standards
- 2005 Title 24 Nonresidential Building Standards
- Federal Schools and Hospitals Program

Each program affects specific building types and end uses. All post 1978 floor space subject to the provisions of Title 24 enters the energy equation listed above with modified marginal EUI's. New equipment in older buildings is replaced with higher efficiency (lower EUI) equipment as the Title 20 standards phase in. Because of the standards, it is necessary for the Commercial Model to keep track of both building and equipment vintages as well as equipment replacement rates.

Audit and survey data are used to determine savings due to audits and incentives for each end use and building type. Penetration of audit and incentive savings is projected as a percent of total floor space over the forecast period. Schools and hospitals program savings are provided as direct energy savings inputs from the Electricity Supply and Analysis Division of the Energy Commission. These total savings are then shared equally among the end uses in these building types.

As in the Residential Model, savings are quantified by iteratively executing the Commercial Model and successively removing the effect of each standard and/or efficiency program. The results of each run are then subtracted from the preceding one to obtain individual program savings estimates.

Energy Demand Summary Forecast Model

The Summary Model combines the energy consumption forecasts for the residential, commercial [including transportation, communication and utilities (TCU), and street lighting], industrial, and agriculture and water pumping sectors. Electricity and natural gas forecasts are developed from the individual sectoral models for final adjustments and tabular displays. The Summary Model combines these forecasts for purposes of preparing total electricity and natural gas consumption reports for each utility planning area.

Four adjustments are made to sector forecasts by the Summary Model. First, residential and commercial space conditioning estimates for the backcast and forecast period are adjusted for weather. Forecasts developed from the residential and commercial models assume that normal or long-term weather conditions will prevail in the future. Forecasts of the energy used to heat and cool space depend, in part, on whether actual weather conditions deviate from long-term norms.

Second, certain efficiency program savings (notably appliance and building energy standards) are considered in the sector models. However, the energy savings for certain programs are externally quantified and subtracted from the raw results of the sectoral models in the Summary Model (see below).

Third, the weather- and efficiency-adjusted sector forecasts are calibrated to historical consumption levels. The intent is to assure that the projected values for the forecast base period 1980-2006 approximate the actual values.

Finally, certain consumption does not fall into the categories established in the energy modeling system. This “unclassified” consumption is generally believed to be non-residential in nature and is therefore distributed proportionally to the non-residential sectors. This adjustment is usually undertaken in the Summary Model.

Efficiency

Many utility-sponsored programs, such as utility incentives, affect energy savings through improvements in efficiency but are not included as variables in the appropriate sector models. Other programs do not have operating data classified in a manner conducive to attribution to the North American Industry Classification System (NAICS) code-defined sectoral models. The programs in these categories are listed below. Savings from these utility and public agency programs are quantified in the Summary Model:

Residential:

- New Construction (Utility)
- Master Meter (Utility)

Commercial:

- New Construction (Utility)
- Miscellaneous Retrofit (Public Agency)
- Energy Extension Service (Public Agency)

Industrial:

- Industrial Energy Management Services and Incentives (Utility)

Agricultural

- Energy Management Services and Incentives (Utility)

Quantification involves three steps. First, first-year impacts are assigned a useful measure life. Second, a degradation factor is applied to each year of the useful life to account for poor maintenance or equipment failure. Third, the final results are aggregated and provided to the Summary Model.

Investor-Owned Utility Energy Efficiency Goals

2006-2008

In decision D.04-09-060, the CPUC established numerical goals for electricity and natural gas savings for the IOUs for the period 2004–2013.[6] This decision implements a core component of the Energy Action Plan, translating this mandate into explicit, numerical goals for reducing electricity and natural gas consumption as well as peak demand. Savings from energy efficiency programs funded by the public goods charge and procurement rates will contribute to these goals, including those achieved through the Low-Income Efficiency Program. Committed conservation programs are those programs included in the 2006–2008 program plans approved in the CPUC Energy Efficiency Rulemaking Proceeding (R04-06-010) or in other CPUC decisions, and therefore explicit adjustments are made only for those programs.

To account for these goals in the most recent forecast, staff used the impacts by sector or program category provided by each utility in its *2007 IEPR* demand forecast submittal. The electricity program savings goals used for each IOU are shown below. The planned programs and estimated impacts are evaluated, and only the effects of those programs that are not already captured in the models are included in the forecast. The resulting forecast of efficiency impacts was then used to adjust the raw residential and commercial demand forecasts.

First Year Impacts of 2004–2008 Energy Efficiency Goals

	PG&E		SCE		SDG&E	
	GWh	MW	GWh	MW	GWh	MW
2004	744	161	826	179	268	58
2005	744	161	826	179	268	58
2006	829	180	922	200	281	61
2007	944	205	1046	227	285	62
2008	1053	229	1167	253	284	62

Source: Utility demand forecast submittals to the California Energy Commission, 2007.

2009 and Beyond

Because the post-2008 IOU program strategies are under development, they have not yet been explicitly accounted for in the CED forecast. However, staff's assessment is that, historically, many of the effects of utility programs are indirectly accounted for in the models. For the programs implemented in 2006-2008, staff estimates that approximately 80 to 90 percent of the expected impacts are reflected in the models in other ways; the remainder is accounted for through direct adjustments. This assessment of significant overlap is specific to the 2006-2008 program mix which heavily targets end-uses also affected by codes and standards (such as refrigerators and commercial lighting). If the current program mix and level of effectiveness is unchanged, this level of overlap would be expected to continue in future years.

There are two important reasons why the explicit adjustment to the forecast is so small. First, much of this overlap is associated with effects that in staff's assessment are captured by other model assumptions. So the impacts are real, but they are attributed to standards, not programs. For example, in staff's commercial forecasting model, lighting intensity in large offices declines by 10 percent between 2009 and 2013 as standards are applied to buildings being replaced or retrofit. The current IOU program mix also emphasizes commercial lighting. In reality, lighting systems may be retrofit before the building reaches the model decay threshold, but this effect is not represented in staff's models. Also, the CPUC allows credit toward the goals of codes and standards compliance efforts by the IOUs. Finally, the process of calibration to historical data adjusts the forecast for actual impacts without attribution to any specific program or standard.

The second reason relates to projected program savings versus the actual net change in total consumption. Historically, verified program impacts have been found to be significantly less than projected program savings. Therefore, if actual utility savings have been, for example, 70 percent of planned savings, the forecast is calibrated to a trend with that lower level of impact (that is, a higher energy intensity trend), and the forecast assumes a similar trend for the future. If future programs are more effective, that will be an incremental reduction to the forecast. (This would also mean less cost-effective potential has been achieved, and therefore more remains available for the future). Furthermore, the net observed reduction in consumption may be reduced by offsetting behavior changes or incorrect assumptions about usage characteristics.

These overlaps would be expected to continue for post-2008 program expenditures, unless the post-2008 program designs change in substantial ways, for example by devising programs emphasizing measures that produce effects that are not captured currently within the forecasting models. The direction laid out in the October 18, 2007, CPUC decision[7] indicates a significant change of direction, targeting, for example, new construction and air conditioning rather than lighting. This change in program mix would translate to a greater explicit impact on the staff forecast. Also, the new structure of financial risks and rewards for IOUs presented in the CPUC's September 20, 2007, decision[8] could increase program effectiveness above historical levels. Also, future program strategies may place a greater emphasis on total long-term savings as opposed to near-term annual impacts, in which case the current annual targets are not a good indicator of the pattern of future savings.

The overlap between staff forecast assumptions and currently uncommitted program effects is likely to decrease in the post-2008 period but cannot be appropriately assessed until specific program plans are developed. Users of the forecast can assume it includes a level of future impacts consistent with the current program mix and effectiveness. As 2009-2011 program plans are developed and approved, staff will evaluate them and quantify appropriate adjustments to the forecast.

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[1] Much more detail can be found in California Energy Commission, California Energy Demand: 1995-2015, Volume IX, P300-95-0014, July 1995. (This publication has been posted on the CEC website with other materials for the August 12 workshop).
[2] See California Energy Commission, *California Energy Demand: 1985-2005*, Volumes III to IX, P300-85-008 - P300-85-014, August 1985.
[3] A building energy simulation employs a Department of Energy model that calculates heating and cooling loads based on building and equipment characteristics, taking into account climate zone.
[4] See California Energy Commission, *Local Energy Planning Handbook*, P400-81-036, November 1981.
[5] See California Energy Commission, *Energy Demand Forecast Method Report*, CEC-400-2005-036, June 2005.
[6] California Public Utilities Commission, *Interim Opinion: Energy Savings Goals for Program Year 2006 and Beyond*, D. 04-09-040, September 23, 2004, in Energy Efficiency Rulemaking 01-08-028.
[7] California Public Utilities Commission, *Interim Order on Issues Relating To Future Savings Goals And Program Planning For 2009-2011 Energy Efficiency And Beyond*, October 18, 2007.
[8] California Public Utilities Commission, *Interim Opinion On Phase 1 Issues: Shareholder Risk/Reward Incentive MechanismFor Energy Efficiency Programs D.07-09-043*, September 20, 2007.