A New Approach to Estimate Commercial Sector End-Use Load Shapes and Energy Use Intensities

H. Akbari, J. Eto, S. Konopacki, A. Afzal, K. Heinemeier, and L. Rainer
Lawrence Berkeley Laboratory

We discuss the application of an end-use load shape estimation technique to develop annual energy use intensities (EUIs) and hourly end-use load shapes (LSs) for commercial buildings in the Pacific Gas and Electric Company (PG&E) service territory. The results will update inputs for the commercial sector energy and peak demand forecasting models used by PG&E and the California Energy Commission (CEC). EUIs were estimated for 11 building types, up to 10 end uses, 3 fuel types, 2 building vintages, and up to 5 climate regions.

The integrated methodology consists of two major parts. The first part is the reconciliation of initial end-use load-shape estimates with measured whole-building load data to produce intermediate EUIs and load shapes, using LBL's End-use Disaggregation Algorithm, EDA. EDA is a deterministic hourly algorithm that relies on the observed characteristics of the *measured* hourly whole-building electricity use and disaggregates it into major end-use components. The end-use EUIs developed through the EDA procedure represent a snap-shot of electricity use by building type and end-use for two regions of the PG&E service territory, for the year that disaggregation is performed. In the second part of the methodology, we adjust the EUIs for direct application to forecasting models based on factors such as climatic impacts on space-conditioning EUIs, fuel saturation effects, building and equipment vintage, and price impacts. The core data for the project are 1) detailed on-site surveys for about 800 buildings, 2) mail surveys (~6000), 3) load research data for over 1000 accounts, and 4) hourly weather data for five climate regions.

Introduction

End-use electricity demand forecasts are the critical link between supply- and demand-side planning activities in support of integrated resource planning (Eto, Blumstein, Jaske 1988). End-use information on the structure of electricity demand is especially important for utility and state planners considering explicit interventions to modify future demands (also known as demand-side management). Yet, historically, the empirical basis to support end-use forecasts and demand-side planning has been weak compared to the information available to support supply-side planning. Not surprisingly, the resulting uncertainties associated with demand-side data have led to significant differences of opinion between utility and state planners regarding the future demand for electricity.

This paper describes a unique research project to develop a common, updated set of commercial sector end-use energy use forecasting inputs that has been fully reconciled with measured data (Akbari et al. 1993). The EUIs have been developed to support five stages of disaggregation within the Pacific Gas and Electric (PG&E) service territory: 11 commercial building types; up to 10 end uses (as appropriate for the building type); up to 3 fuel types (as appropriate for the end use); 5 sub-service territory forecasting regions; and 2 distinct vintages corresponding to the period prior to and immediately following the adoption of the first generation of California building and equipment standards.

Cost savings have been achieved by the implementation of a new method for combining information from detailed on-site surveys, mail surveys, hourly class load research and weather data to develop a complete set of commercial sector end-use energy use intensities (EUIs) and load shapes, which have been reconciled to measured loads. Coordination has been achieved through the development of a common base set of end-use EUIs and load shapes that is then adjusted in a transparent fashion for direct incorporation into the existing forecasting models of both PG&E and the California Energy Commission (CEC).

The methodology consists of two major parts: 1) reconciliation of initial end-use load-shape estimates with measured whole-building load data to produce intermediate EUIs and load shapes; and 2) procedures to transform intermediate outputs into a revised set of inputs for CEC and PG&E forecasting models. The first part of the methodology was originally documented in Akbari, et al. (1988) and has been compared to related approaches by Eto, et al. (1990). More recently, Rohmund, McMenamin, and Bogenrieder (1992) demonstrated an application based on relationships established by the methodology. Consequently, this paper reviews the first part of the methodology only briefly (see Reconciliation Methodology), focussing instead on the second part of the methodology and project results (see Developing PG&E and CEC Forecasting Model Inputs)

Reconciliation Methodology

The major analytical advance of our methodology is the reconciliation of estimated end-use load shape with measured whole-building load-shape data. There are three major steps in this process: *1) development of initial engineering estimates of end-use load shapes; 2) development of average measured whole-building load shapes;* and *3) reconciliation of 1 with 2.* Figure 1 illustrates the primary data sources and relationships between these steps.

Initial Estimates of End-Use Load Shapes

In the first step of the reconciliation, we make initial estimates of end-use load shapes for each building type. These estimates are developed using one or more prototypes to represent each building type. The primary building data for prototype development include the on-site surveys of about 800 buildings (including billing data and weights) and Commercial Energy Use Survey (referred to as the mail survey) of over 6000 accounts. For HVAC end uses (heating, cooling, ventilation), the initial estimates result from simulation of the prototype using the DOE-2.lD building energy simulation program (BESG 1990). The diversity of building and system types, often

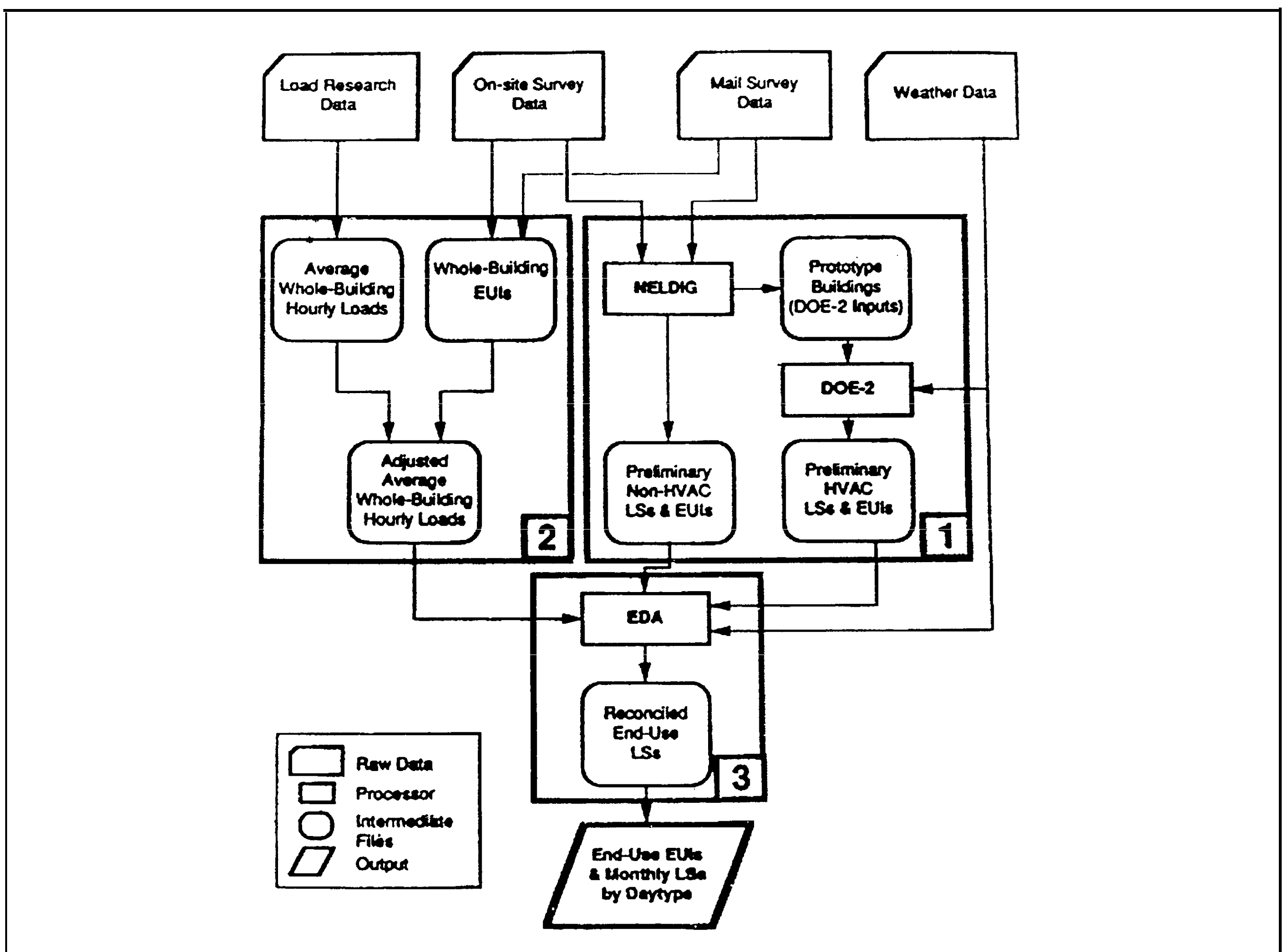

Figure 1. Integrated Commercial LS and EUI Estimation Methodology[1]

required development of multiple prototypes to represent a single building type. For non-HVAC end uses (lighting, equipment, cooking, etc.), the estimates result from engineering analysis of data on reported schedules and installed capacities. The schedules and capacities are taken from the on-site and mail surveys, which are used as input to the Non-HVAC EUI/LS and DOE-2 Input Generator (NELDIG).

Table 1 provides a summary of all the prototypes with their corresponding weights. The prototypes were developed through an analysis of on-site surveys, mail survey responses, and previous prototypes developed by LBL and others for the commercial sector. Initially two simulations of each prototype were performed. The first uses Oakland/Alameda weather to develop an initial estimate of energy use for the Coastal weather zone. The second uses Sacramento weather to develop an initial estimate of energy use for the Inland weather zone.

Average Whole-Building Electricity Use Profiles

Whole-Building Load Shapes. In the second step of the reconciliation, we developed average whole-building electricity use profiles for each building type. These profiles provide control totals against which our initial estimates are reconciled. Two sources of data are used: Load research data (LRD) are used to develop the prototypical whole-building load *shape*, while supplementary data on total commercial sector energy use intensity by building type (also known as whole-building EUIs) were used to determine *magnitude* (which is expressed as a total EUI for the building type in units of kWh/ft^2yr).

Whole-Building EUIs. Whole-building EUIs played a critical role in our methodology to reconcile simulation and engineering estimates with measured whole-building load research data. Our approach was based on several important assumptions. First, the highest quality data for determining whole-building EUIs are those contained in the on-site survey, followed by the mail survey. Second, despite this preference for reliance on the on-site survey, use of the on-site survey may not be appropriate for some building types due to the small number of buildings surveyed. Third, in any case, the mail survey, due to its much larger sample size, is a more appropriate source of information for developing weighting factors to combine whole-building EUIs from sub-building types into a single EUI for a building type and region.

Table 2 summarizes the results of our analysis for development of whole-building EUIs. There were three steps in

Table 1. Prototype Identification by Building Type

Building Type	Prototype(s)	Weights Coastal	Weights Inland
Small Office	Small Office	1.00	1.00
Large Office	Large Office	1.00	1.00
Retail	Large Retail	0.24	0.19
	Small Retail	0.76	0.81
Restaurant	Fast Food	0.21	0.23
	Sit-Down	0.79	0.77
Food Store	Food Store	1.00	1.00
Warehouse	Refrigerated	0.57	0.34
	Non-Refrigerated	0.43	0.66
School	Primary School	0.21	0.19
	Secondary School	0.79	0.81
College	Office/Lab/Classroom	0.75	0.75
	Library	0.05	0.05
	Dormitory	0.20	0.20
Health	Hospital	0.87	0.92
	Nursing Home	0.13	0.08
Lodging	Large Hotel	0.82	0.48
	Small Hotel/Motel	0.18	0.52
Miscellaneous	Miscellaneous	1.00	1.00

Table 2. Whole-Building Electric EUIs. The aggregate EUIs are calculated by weight averaging the component buildings EUIs.

	Coastal		Inland	
Building Type	**Weight**	**EUI (kWh/ft^2yr)**	**Weight**	**EUI (kWh/ft^2yr)**
Restaurant		**36.5**		**37.2**
sit-down	0.79	28.0	0.77	28.0
fastfood	0.21	68.7	0.23	68.0
Food Store	1.00	**44.2**	1.00	**46.5**
Warehouse		**18.4**		**13.5**
refrigerated	0.57	28.7	0.34	29.3
	0.43	4.8	0.66	5.4
non-refrigerated				
School		**4.5**		**4.8**
primary	0.21	6.3	0.19	6.0
secondary	0.79	4.0	0.81	4.5
College	1.00	**5.3**	1.00	**7.0**
Health		**25.5**		**27.1**
hospital	0.87	28.0	0.92	28.6
nursing	0.13	8.9	0.08	10.5
Lodging		**6.4**		**7.7**
small hotel	0.18	6.1	0.52	7.1
large hotel	0.82	6.5	0.48	8.4
Miscellaneous	1.00	**6.1**	1.00	**7.5**

the process. First, we developed service area-wide whole-building EUIs for each sub-building type. Second, we developed distinct, sub-building type whole-building EUIs for each climate zone, using simulations of the prototypes. Third, we combined sub-building type, climate-zone specific whole-building EUIs into a single whole-building EUI for each building type and climate zone.

Step 1: We relied on whole-building EUIs developed from the on-site survey data, whenever the sample size (by sub-building type) exceeded about 15. This was possible for all building types, except secondary school, college, nursing, and lodging. In using the mail survey to develop EUIs for these remaining buildings, we made an effort to address data quality concerns by first eliminating the highest and lowest 5% of values (10% total), before calculating the resulting "trimmed" mean.

Step 2: We introduced, but bounded the use of, engineering judgement into the development of separate whole-building EUIs for the coastal and inland climate regions. That is, we used simulations of the prototypes, adjusted for the saturation (separately for coastal and inland) of end uses (electric cooling, water heating, and space heating) and relative floor areas (coastal versus inland) to develop coastal and inland adjustment factors, which we then applied to the whole-building EUIs previously developed on a service area wide basis.

Step 3: We combined sub-building type and climate-specific whole-building EUIs, within each climate region, using floor area weights developed from the mail survey. In this case, the weights refer to the relative floor area of sub-building types to a single building category.

Application of this procedure leads to somewhat counter-intuitive results for one whole-building EUI (warehouse) and for one sub-building EUI (primary school). However, we believe both results are well-supported by the data. In the case of Warehouse, a higher proportion of the more energy-intensive, refrigerated warehouses in the coastal region leads to a larger whole-building EUI for the warehouse building type for the coastal region than for the inland region. Similarly, in the case of the primary school sub-building type, higher electric saturations for cooling and water heating leads to a higher coastal whole-building EUI than inland EUI. Nevertheless, when combined on a floor-area-weighted basis with the secondary school, the trend is reversed (consistent with intuition); the overall whole-building EUI for the school is larger for inland than for coastal.

The whole-building EUI was used to normalize the whole-building load shapes such that integration of the adjusted whole-building load shape for the year equals the whole-building EUI. Consequently, the whole-building EUI was an extremely important input to the reconciliation process because it largely determines the magnitude of the reconciled end-use EUIs; that is, the sum of the reconciled EUIs must exactly equal the whole-building EUI.

Reconciliation of Initial Estimates to Whole-Building Electricity Use Profiles

In the third step of the reconciliation, we applied the End-use Disaggregation Algorithm (EDA) to obtain reconciled end-use LSs. EDA methodology is documented in Akbari, et al. (1988). The corresponding end-use EUIs are simply the integration of the end-use LSs for the entire year.

Table 3 summarizes the initial and reconciled EUIs for all building types for both coastal and inland regions. For those buildings that the reconciled non-HVAC EUIs for coastal and inland regions were statistically *indifferent*, Table 3 provides average figures.

We have also developed average monthly, seasonal, and annual LSs for standard, non-standard, and peak day conditions, for all building types and for both coastal and inland climate regions. Figures 2 and 3 show examples of such simulated and reconciled LSs for retail store in inland climate region.

Developing PG&E and CEC Forecasting Model Inputs

For the second part of our methodology, we developed procedures that combined reconciled EUIs (from application of EDA) with additional analysis of the DOE-2 prototypes and additional information from the mail and on-site surveys to specify a complete set of revised energy use inputs for both the CEC and PG&E models. The basic approach was to start with the reconciled EUIs as a true representation of 1986 energy use and develop adjustment factors that disaggregate these EUIs in a manner that was consistent with CEC's and PG&E's current forecasting procedures.

These adjustments and refinements include: 1) development of 1986 EUIs for end-uses not estimated through application of EDA (electric heating, and all non-electric end uses); 2) re-specification of all 1986 EUIs to a 1975 base year through application of the short-run price elasticity of demand and historic energy prices; 3) removal of fuel saturation effects for all reconciled electric end uses, except those for which, by definition, the saturation is 100% (indoor and outdoor lighting, and miscellaneous); 4) incorporation of previous LBL work to further disaggregate the electric miscellaneous EUI into distinct categories for office equipment and miscellaneous; 5) for the space conditioning end uses, accounting explicitly for the effects of the first generation of mandatory minimum building energy efficiency standards; 6) for the space conditioning end-use specification used by the CEC model, accounting separately for the impacts of equipment energy efficiency; 7) finally, for the space conditioning end use specification used by the CEC model, accounting separately for the additional variations in energy use for the 5 sub-regions represented by the 2 regions for which explicit reconciliations were performed.

Development of EUIs for Electric Heating and Non-Electric End Uses

There were several classes of EUIs that could not be estimated using the LBL reconciliation procedure. They included electric space heating, and non-electric space heating, water heating, cooking, and miscellaneous end uses. Electric space heating has a very low saturation in the PG&E service territory; we did not, for example, detect the presence of electric space heating in our analysis of the load research data (except for the lodging building type). Accordingly, we could not extract profiles for these end uses using our reconciliation procedures. Non-electric space heating, water heating, cooking, and miscellaneous energy use were not estimated using the reconciliation process for the obvious reason that they are not electric end uses.

Our approach for developing EUIs for these end uses was to estimate them directly from the on-site and mail survey data. For the non-electric, non-space conditioning end uses (water heating, cooking, and miscellaneous), this is a straightforward application of various engineering factors to the installed capacity and utilization information reported in the survey data. For the space conditioning end uses (electric and non-electric space heating), we relied on additional simulations of the same DOE-2 prototypes used to estimate initial conditions for the EDA reconciliations for electric cooling and ventilation.

Expressing Reconciled EUIs Relative to the 1975 Base Year

Having now completed the development of a full set of EUIs for all end uses for 1986, we next re-specified these EUIs relative to the 1975 base year used by both CEC and PG&E in their forecasting models. The re-specification

Table 3. Simulated and EDA-Reconciled EUIs (kWh/ft^{2}yr)

	Non-HVAC End Uses							HVAC			
	Indoor Lighting	**Outdoor Lighting**	**Misc. Equip.**	**Office Equip.**	**Refrig**	**Cooking**	**Water Heating**	**Heating**	**Fans**	**Cooling**	**Total**
Simulation: Coastal											
Small Office	5.82	0.89	1.25	1.20	0.17	0.06	0.15	0.00	0.31	1.02	10.87
Large Office	6.77	0.23	1.57	1.21	0.08	0.09	0.04	0.00	2.33	2.77	15.09
Retail	6.63	0.36	0.88	0.00	0.42	0.03	0.04	0.00	0.49	1.13	9.98
Restaurant	6.89	1.62	5.32	0.00	6.30	3.32	0.24	0.00	1.84	2.41	27.94
Food Store	8.88	0.91	4.57	0.00	11.49	0.37	0.07	0.00	1.46	0.89	28.64
Warehouse	2.06	0.36	2.16	0.00	11.98	0.00	0.01	0.00	0.66	0.20	17.43
School	5.36	0.50	0.58	0.00	0.48	0.10	0.27	0.00	0.68	0.40	8.37
College	4.30	0.11	0.50	0.00	0.02	0.06	0.06	0.00	1.00	0.92	6.97
Health	12.57	0.43	9.22	0.00	0.29	0.19	0.01	0.00	1.65	3.11	27.47
Lodging	4.43	0.30	2.01	0.00	0.44	0.10	0.02	0.00	0.49	1.07	8.86
Miscellaneous	2.48	0.55	3.39	0.00	0.31	0.00	0.03	0.00	0.40	0.09	7.25
Reconciled: Coastal											
Small Office	4.62	1.54	1.39	1.11	0.17	0.03	0.12	0.05	0.22	0.82	9.69
Large Office	10.48	0.44	2.14	1.73	0.09	0.15	0.05	0.00	2.98	3.88	20.40
Retail	5.12	0.78	0.54	0.24	0.44	0.03	0.03	0.00	0.34	0.84	8.36
Restaurant	8.56	2.17	6.72	0.07	7.57	4.24	0.31	0.00	4.35	2.51	36.50
Food Store	14.26	1.43	6.97	0.06	14.66	0.54	0.11	0.00	3.41	2.76	44.20
Warehouse	2.26	0.39	2.80	0.22	11.52	0.00	0.01	0.00	1.09	0.11	18.40
School	2.91	0.31	0.15	0.15	0.27	0.06	0.15	0.00	0.46	0.05	4.51
College	2.90	0.15	0.20	0.22	0.06	0.04	0.04	0.00	1.06	0.63	5.30
Health	11.15	0.36	7.28	0.90	0.26	0.17	0.01	0.00	2.02	3.34	25.49
Lodging	2.76	0.21	1.18	0.05	0.30	0.06	0.01	0.32	0.60	0.90	6.39
Miscellaneous	1.46	0.42	1.90	0.16	0.45	0.00	0.00	0.00	1.07	0.53	5.99
Simulation: Inland											
Small Office	5.82	0.89	1.25	1.20	0.17	0.06	0.15	0.00	0.75	3.22	13.51
Large Office	6.77	0.23	1.57	1.21	0.08	0.09	0.04	0.00	2.71	3.78	16.48
Retail	6.60	0.37	0.86	0.00	0.45	0.03	0.04	0.00	0.71	2.80	11.86
Restaurant	7.02	1.66	5.38	0.00	6.37	3.34	0.24	0.00	2.55	6.73	33.29
Food Store	8.88	0.91	4.57	0.00	11.49	0.37	0.07	0.00	1.64	1.86	29.79
Warehouse	2.14	0.35	2.39	0.00	7.18	0.00	0.01	0.00	0.77	0.67	13.51
School	5.38	0.50	0.58	0.00	0.48	0.11	0.27	0.00	0.79	1.14	9.25
College	4.30	0.11	0.50	0.00	0.02	0.06	0.06	0.00	1.83	2.50	9.38
Health	12.98	0.44	9.61	0.00	0.29	0.19	0.01	0.00	1.68	3.83	29.02
Lodging	3.85	0.45	1.48	0.00	0.64	0.08	0.02	0.00	0.79	3.98	11.29
Miscellaneous	2.82	0.55	3.76	0.00	0.31	0.00	0.03	0.00	1.12	0.65	9.24
Reconciled: Inland											
Small Office	4.62	1.54	1.39	1.11	0.17	0.03	0.12	0.05	0.57	3.13	13.09
Large Office	10.48	0.44	2.14	1.73	0.09	0.15	0.05	0.00	4.03	5.71	26.36
Retail	7.05	0.82	0.75	0.24	0.47	0.03	0.04	0.12	0.80	2.24	12.56
Restaurant	7.63	1.97	5.87	0.07	6.80	3.69	0.26	0.00	5.73	5.17	37.19
Food Store	13.97	1.29	6.40	0.06	15.15	0.50	0.11	0.00	4.43	4.61	46.52
Warehouse	1.81	0.52	2.31	0.22	6.97	0.00	0.01	0.00	0.92	0.74	13.50
School	3.06	0.28	0.17	0.15	0.25	0.07	0.16	0.00	0.62	0.05	4.81
College	3.59	0.11	0.23	0.22	0.04	0.04	0.05	0.00	1.43	1.29	7.00
Health	10.98	0.36	7.23	0.90	0.24	0.16	0.01	0.00	2.49	4.74	27.11
Lodging	2.78	0.41	0.98	0.05	0.53	0.04	0.00	0.43	1.27	1.33	7.82
Miscellaneous	1.84	0.39	2.45	0.16	0.43	0.00	0.00	0.00	1.13	1.10	7.50

consisted of taking into account the effects of energy price changes between 1975 and 1986, which was based on both a measure of the short-run price elasticity of demand and the historic price series. We accounted separately for both non-price impacts on the space conditioning EUIs (i.e., the effects of minimum energy performance standards) and technological change on office equipment EUIs, as described below.

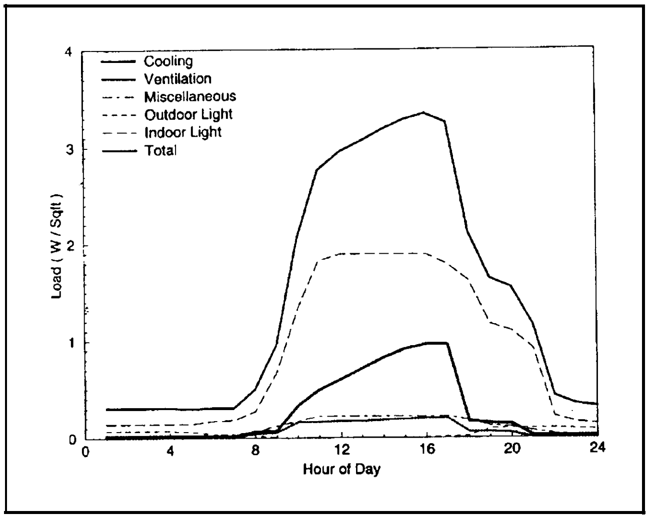

Figure 2. Retail Store Simulated Standard Day Annual End-Use LS - Inland

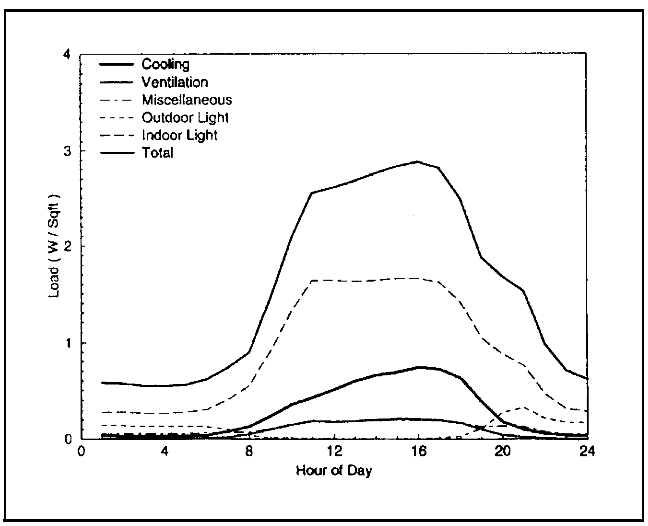

Figure 3. Retail Store Reconciled Standard Day Annual End-Use LS - Inland

CEC and PG&E currently rely on different estimates of and formulation for the short-run price elasticity of demand. In order to respect these differences, we developed separate price adjustment factors. The price elasticities and resulting price adjustment factors are summarized in Akbari et al. (1993). The price elasticity of demand relates percentage changes in price to percentage changes in demand for a given fuel and building type (in the case of CEC) or for a given fuel and end use (in the case of PG&E).

Accounting for Fuel Saturation Effects

The whole-building EUI or control total used in the reconciliation process reflected the aggregate impact of the various saturations of electricity end uses in the PG&E service territory. Since the CEC and PG&E forecasting models account for fuel saturations separately by end use, the effects of the observed aggregate saturations embedded in the reconciled EUIs must be removed. We developed saturation estimates through analysis of the mail survey data (Akbari et al. 1993).

Accounting for Office Equipment EUIs

Office equipment energy use has been an important new component of commercial sector load growth. Both CEC and PG&E now explicitly represent this end use in their forecasting models. Previously, it was treated jointly with other miscellaneous electricity use. The data used in our project also reflect this older, more aggregated view of miscellaneous equipment. Accordingly, application of the EDA reconciliation procedure yielded only a single EUI for electric miscellaneous.

The importance of the office equipment end use led to a detailed examination of office equipment energy use trends in the PG&E service territory by LBL (Piette et al. 1991). We used this work to estimate the EUI for this end use and subtracted these EUIs from the miscellaneous EUI estimated with EDA. Therefore, the electric miscellaneous EUI represents the residual of the original miscellaneous EUI and LBL's previous analysis of office equipment EUI.

Disaggregating Reconciled EUIs by Building and Equipment Vintage

The CEC and PG&E commercial sector energy demand forecasting models separately tracked energy use by several different vintages for a given building type. These vintages were intended to reflect different eras of building construction practices and equipment choice. For the time period under consideration, the most important vintages correspond to the time immediately prior to and after the enactment of the first generation of mandatory building and appliance minimum efficiency standards by the state of California. We estimated the quantities labeled "U75" and "EU179," which are the titles used by CEC in their forecasting model for these building and equipment vintages.

We relied on DOE-2 simulations to provide ratios that then modify the reconciled EUIs. In this case, the prototypes themselves were modified to reflect conditions unique to each vintage. The challenge for implementing this procedure was the absence of high quality data to support the development of unique prototypes corresponding to each vintage. That is, there are very few buildings built after 1978 represented in either the on-site survey or mail survey.

In addition to available on-site and mail survey data, we relied on California's energy performance standards (Titles 24 and 20) and on ASHRAE standards 90/75 and 90.2P. Notably, some aspects of the California standards do not apply to several of the building prototypes examined including nursing homes, both primary and secondary schools, hotels and motels, and colleges.

Non-HVAC End Uses

Non-HVAC electric end-uses (cooking, hot water, indoor lighting, outdoor lighting, miscellaneous equipment, and refrigeration) for the 1975 Vintaged EUIs (U75) are calculated by removing the saturation effect from the 1986 EUI and then adjusting this result by the price effect. Non-HVAC gas end-uses (cooking, hot water, and miscellaneous equipment) for the 1975 Vintaged EUIs were calculated by adjusting the 1986 EUI for the price effect.

Climatic Impacts on Space-Conditioning EUIs

Space-conditioning EUIs (cooling, ventilation, and heating) are influenced by climate. Within the PG&E service territory, the CEC forecasts energy use separately for five climatic regions. Generally speaking, different premises of the same building type would experience different heating, cooling, and ventilation loads (and, therefore, EUIs) depending on which of these regions they were located.

In principle, these differences could be estimated directly with separate reconciliations. That is, one can develop unique initial estimates of end-use EUIs and LSs for each region and reconcile them separately for each region. This approach could not be used because sufficient quantities of LRD were not always available to support the development of unique average whole-building electricity use profiles for each region.

Instead, a hybrid approach was taken. Separate reconciliations were made for the coastal and inland regions where sufficient data were available. For the remaining CEC forecasting regions, a separate set of DOE-2 simulations were run for each prototype using weather data from each region. The *ratios of simulated energy use* for cooling, ventilation, and heating from these simulations to those used in the reconciliations were then used to *adjust the reconciled HVAC EUIs* to produce a unique value for each region.

We adjusted the end-use EUIs obtained from EDA reconciliation for all the above factors and developed input for CEC and PG&E forecasting models for five climate zones and two base years (1975 and 1979). Table 4 provides an example of forecasting model inputs for PG&E model.

Summary

We discussed an integrated methodology to develop an updated set of commercial sector end-use energy use forecasting inputs that has been fully reconciled with measured data. We developed EUIs for five stages of disaggregation within the forecasting models: 11 commercial building types; up to 10 end uses; up to 3 fuel types; up to 5 sub-service territory forecasting regions; and up to 2 distinct vintages corresponding to the period prior to and immediately following the adoption of the first generation of California building and equipment standards. For the electricity end uses, 36 sets of daily LSs have been developed representing average weekday, average weekend, and peak weekday electricity use for each month of the year by building type for both the inland and coastal climate zones.

Our methodology had two distinct stages: First, we developed up to 10 reconciled electricity end-use EUIs and load shapes for each of the 11 building types in the inland and coastal regions of the PG&E service territory using information collected in 1986. Second, we developed procedures to translate these results into a complete set of commercial sector forecasting model inputs recognizing the separate modeling conventions used by PG&E and CEC.

Acknowledgement

This work was jointly supported by Pacific Gas & Electric (PG&E) and the California Energy Commission (CEC) through the California Institute for Energy Efficiency (CIEE), and by the U.S. Department of Energy, under contract DE-AC0376SF00098.

Endnotes

1. The method consists of three parts: 1) development of preliminary EUIs and LSs using NELDIG and DOE-2, 2) construction of average whole-building EUIs by building type, and 3) reconciliation of the preliminary EUIs and LSs with average whole-building hourly load, using EDA.

Table 4. PG&E 1975 EUIs for coastal (Oakland) and Inland (Sacramento) Climate Zone [kBtu/ft^{2}yr]. EUIs labeled ne' were not estimated

	Coastal			Inland									
Building/Fuel	**Heat**	**Cool**	**Vent**	**Heat**	**Cool**	**Vent**	**HotW**	**Cook**	**Refr**	**OtLt**	**InLt**	**OfEq**	**Misc**
Small Office													
Elec	4.14	4.61	1.08	6.80	14.57	2.58	1.08	0.20	0.80	5.31	15.92	0.72	4.79
NGas	9.20	13.27	ne	15.12	47.93	ne	0.29	0.01	ne	ne	ne	ne	0.00
Othr	6.96	13.27	ne	11.44	47.93	ne	ne	ne	ne	ne	ne	ne	ne
Large Office													
Elec	11.98	20.92	12.93	14.08	25.04	16.66	1.01	0.84	0.39	1.52	36.12	1.13	7.37
NGas	19.96	116.05	ne	23.47	147.08	ne	0.34	0.30	ne	ne	ne	ne	0.42
Othr	15.12	116.05	ne	17.78	147.08	ne	ne	ne	ne	ne	ne	ne	ne
Retail													
Elec	5.02	3.25	1.99	7.73	7.89	3.64	0.50	0.17	2.06	2.76	20.99	0.14	2.24
NGas	12.94	9.51	ne	19.92	29.91	ne	0.25	0.04	ne	ne	ne	ne	0.33
Othr	9.80	9.51	ne	15.09	29.91	ne	ne	ne	ne	ne	ne	ne	ne
Restaurant													
Elec	10.66	16.11	16.75	16.00	19.49	17.57	7.49	30.47	25.15	7.13	27.91	0.10	21.71
NGas	20.00	49.11	ne	30.01	72.71	ne	12.00	24.01	ne	ne	ne	ne	0.00
Othr	15.15	49.11	ne	22.73	72.71	ne	ne	ne	ne	ne	ne	ne	ne
Food Store													
Elec	24.46	12.70	15.93	19.97	19.87	22.62	3.11	2.65	52.54	4.69	48.66	0.07	23.05
NGas	49.26	49.02	ne	40.23	70.17	ne	6.00	1.28	ne	ne	ne	ne	19.18
Othr	37.32	49.02	ne	30.48	70.17	ne	ne	ne	ne	ne	ne	ne	ne
Warehouse													
Elec	12.98	1.34	7.70	17.06	6.65	6.70	0.08	0.00	44.46	1.59	7.03	0.07	8.82
NGas	22.77	2.94	ne	29.92	15.62	ne	0.12	0.00	ne	ne	ne	ne	2.69
Othr	17.25	2.94	ne	22.67	15.62	ne	ne	ne	ne	ne	ne	ne	ne
School													
Elec	52.57	2.80	2.53	57.53	1.22	3.51	4.68	0.45	0.94	1.00	10.30	0.10	0.55
NGas	95.82	13.04	ne	104.86	6.11	ne	7.71	1.01	ne	ne	ne	ne	0.00
Othr	72.59	11.01	ne	79.44	5.16	ne	ne	ne	ne	ne	ne	ne	ne
College													
Elec	8.36	9.31	5.59	8.39	8.21	4.27	2.50	0.18	0.17	0.45	11.20	0.14	0.76
NGas	14.93	25.32	ne	14.99	40.37	ne	3.10	0.00	ne	ne	ne	ne	4.16
Othr	11.31	25.32	ne	11.36	40.37	ne	ne	ne	ne	ne	ne	ne	ne
Health													
Elec	11.86	28.83	9.94	12.18	39.11	13.48	4.55	1.04	0.86	1.24	38.15	0.68	24.98
NGas	39.53	155.75	ne	40.59	193.73	ne	2.63	0.47	ne	ne	ne	ne	5.75
Othr	29.95	155.75	ne	30.75	193.73	ne	ne	ne	ne	ne	ne	ne	ne
Lodging													
Elec	2.47	4.73	3.55	2.22	1.96	3.11	1.52	0.24	1.62	1.07	9.55	0.03	3.72
NGas	30.76	20.49	ne	31.60	11.71	ne	2.47	0.81	ne	ne	ne	ne	5.04
Othr	23.30	20.49	ne	23.94	11.71	ne	ne	ne	ne	ne	ne	ne	ne
Miscellaneous													
Elec	6.07	14.33	13.56	6.89	7.68	5.04	0.00	0.00	1.57	1.38	5.69	0.14	7.51
NGas	15.81	22.76	ne	17.94	34.65	ne	0.00	0.20	ne	ne	ne	ne	6.85
Othr	11.98	22.76	ne	13.59	34.65	ne	ne	ne	ne	ne	ne	ne	ne

References

ADM Associates, Inc., 1987. "PG&E Commercial On-Site Survey Data Base," California Energy Commission.

Akbari, H., Eto, J., Konopacki, S., Afzal, A., Heinemeier, K., and Rainer, L. 1993. "Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities in the PG&E Service Area," Lawrence Berkeley Laboratory Report LBL-34263, December.

Akbari, H., Heinemeier, K., Le Coniac, P., and Flora, D., 1988. "An Algorithm to Disaggregate Commercial Whole-Building Electric Hourly Load into End Uses," *Proceedings of ACEEE 1988 Summer Study on Energy Efficiency in Buildings,* Volume 10, pp. 13-36, Asilomar, CA, August.

Building Energy Simulation Group (BESG). 1990. "Overview of the DOE-2 Building Energy Analysis Program, Version 2.lD," Lawrence Berkeley Laboratory Report LBL-19735, Rev. 1, Berkeley, CA.

Eto, J. H., Akbari, H., Pratt, R., and Braithwait, S. 1990. "End-Use Load Shape Data: Application, Estimation, and Collection," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings,* Volume 10, pp. 39-55, Asilomar, CA, August.

Eto, J. H., Blumstein, C., and Jaske, M. 1988. "Changing Needs in Electricity Demand Forecasting: A California Perspective," *Proceedings of the ACEEE 1988 Summer Study on Energy Efficiency in Buildings*, Volume 8, pp. 70-81, Asilomar, CA, August.

Piette, M. A., Eto, J. H., and Harris, J. P. 1991. "Office Equipment Energy Use and Trends," Lawrence Berkeley Laboratory Report LBL-31308, Berkeley, CA, September.

Rohmund, I., McMenamin, S., and Bogenrieder, P. 1992. "Commercial Load Shape Disaggregation Studies," *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, Volume 3, pp. 251-262, Asilomar, CA, August.