CALIFORNIA
ENERGY
COMMISSION

ENERGY DEMAND FORECAST METHODS REPORT

Companion Report to the California Energy Demand 2006-2016 Staff Energy Demand Forecast Report

STAFF REPORT

June 2005
CEC-400-2005-036

Arnold Schwarzenegger, *Governor*

CALIFORNIA ENERGY COMMISSION

Mohsen Abrishami
Sylvia Bender
Kae C. Lewis
Nahid Movassagh
Peter Puglia
Glen Sharp
Kate Sullivan
Mitch Tian
Belen Valencia
David Videvar
Principal Authors

Kae C. Lewis
Project Manager

Kae C. Lewis
Acting Manager
Demand Analysis Office

Valerie T. Hall
Deputy Director
Energy Efficiency and Demand Analysis Division

Scott W. Matthews
Acting Executive Director

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Page Number

TABLE OF CONTENTS
(Continued)

Page Number

TABLE OF CONTENTS
(Continued)

Page
Number

TABLE OF CONTENTS
(Continued)

Page Number

LIST OF TABLES

Table Number		Page Number

LIST OF TABLES
(Continued)

Table Number | Page Number

LIST OF TABLES
(Continued)

LIST OF FIGURES

CHAPTER 1

ENERGY DEMAND FORECASTING AT THE CALIFORNIA ENERGY COMMISSION: AN OVERVIEW

Introduction

This report is a companion report to *California Energy Demand: 2006*-2016 (CED 2006). The report provides an overview of the energy demand forecasting methods and models used by the Demand Analysis Office of the California Energy Commission (Energy Commission) in CED 2006. Although forecasting methodology is discussed in CED 2006, this report goes into more detail on the structure of the sectoral energy consumption and peak demand models, the data sources used to support the models, and the estimation of savings from demand side management (DSM) programs.

Evolution of Demand Forecasting at the Energy Commission

To develop energy policies that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety, the Energy Commission is directed by Public Resources Code (PRC) Section 25301 to conduct regular assessments of all aspects of energy demand and supply. These assessments serve as the foundation for analysis and policy recommendations to the Governor, Legislature, and other agencies in the *Integrated Energy Policy Report (Energy Report)*.

Prior to Deregulation: 1975-1996

Since 1975 the Energy Commission's responsibilities have included forecasting electricity and natural gas (and other fuels) demand for the primary purpose of insuring adequate, but not excessive, electricity supplies. This activity has supported the fulfillment of two statutory goals: the certification of power plants, and the promotion of energy efficiency. During 1975-1996, the Energy Commission's biennial *Electricity Report* documented the Energy Commission's adopted electricity demand forecast for each of the state's eight electric utility planning areas (see Table 1-2) and specified the need for power plants for the ensuing two year period.[1] The energy forecasting and planning process served to integrate energy efficiency policy with power plant licensing approval. All efficiency savings "reasonably expected to occur" must, by statute, be included in the adopted demand forecasts as part of an "integrated assessment of need."[2]

The adoption of the *Electricity Report* was preceded by hearings examining the differences between the Energy Commission staff and utility-sponsored electricity demand forecasts. The hearings focused on forecast methodologies, model input assumptions, and efficiency policy presumptions. Once the Energy Commission adopted planning area demand forecasts, the remainder of the proceeding sought to determine the need for resource additions to meet this level of demand.

Under the terms of the Energy Commission's enabling legislation, the staff's role was initially limited to evaluating utility forecast submittals, provided in a format referred to as the “common forecasting methodology” (CFM). In 1984, however, the Energy Commission staff assumed an independent forecasting role, which provided it an opportunity to present its assumptions on electricity demand growth. Thus, the Energy Commission staff electricity demand forecasts were presented to the Energy Commission along with those submitted by major California utilities. In this and subsequent *Electricity Report* cycles, proceedings were conducted around an initial review of forecast submittals, submissions by all parties regarding major issues, hearings on issues selected by the Committee, and revised forecasts conforming to Committee-directed changes as a result of the hearings. The Energy Commission adopted both the Energy Commission staff and utility revised forecasts, which ultimately served as the basis for capacity expansion for the ensuing two years.

Onset of Electric Industry Deregulation: 1997-2001

In October 1995, in preparation for the 1996 *Electricity Report*, the last demand forecast was conducted under the above-described regime. In 1996, the California Legislature passed Assembly Bill 1890 (Chapter 854, Statutes of 1996, Brulte), which initiated the deregulation of the state’s electric power industry. This decoupled the state’s regulatory responsibility for licensing power plants from forecasts of future energy demand, rendering the latter unnecessary, or so many believed. During this time the Energy Commission suspended the collection of utility data and the evaluation and comparison of utility forecasts. In order to provide policymakers, stakeholders and the public with information regarding current and forecasted electricity market conditions, however, the Energy Commission produced “Energy Outlook” reports in 1998, 2000, and 2002 that provided a ten-year assessment of the state’s electricity system. These assessments included the staff’s statewide end use electricity (annual energy and peak) and annual natural gas demand forecasts with an emphasis on key economic, demographic and weather drivers, and highlighted the deregulation issues impacting the forecasts.

Post Energy Crisis Mandate: 2002-present

The notion that state energy demand and supply forecasts were no longer necessary ended with the California energy crisis of 2000-01. At that time, Californians responded immediately to the negative impacts of deregulated and unplanned electricity markets. In 2002, the California Legislature passed Senate Bill 1389 (Chapter 568, Statutes of 2002, Bowen and Sher) which required the Energy Commission to adopt a biennial “integrated energy policy report” (*Energy Report*) which contains an assessment of trends in electricity and natural gas supply and demand. These include forecasts of statewide and regional electricity and natural gas consumption; annual and seasonal peak demand; factors contributing to projected demand growth; and the impacts of electricity and natural gas efficiency, load management and other demand response activities. The legislation directed the utilities to resume their cooperation with the Energy Commission in supplying the data required for the assessments and forecasts. The first demand forecast in an *Energy Report* complying with SB 1389 was published in November 2003. Although biennial energy demand forecasts serve a different role in a deregulated environment, SB 1389 "reinstated" them as a significant energy system planning tool.

Also passed in 2002 was Assembly Bill 57 (Chapter 835, Statutes of 2002, Wright), which directed the California Public Utilities Commission (CPUC) to establish a process by which load serving entities (LSEs) under its jurisdiction would procure resources to meet the demand for electricity and insure the reliability of those supplies. The CPUC instituted a rulemaking to develop guidelines for a long term (10-year) procurement planning process. In addition, guidelines were also established to insure resource adequacy during periods of peak demand using reserve margin percentage requirements for electricity.

In 2003, California's energy agencies developed a common policy vision, articulated in the *Energy Action Plan*. This vision centers on designated preferred resources, most notably demand-side programs and renewable generation that would be relied upon to meet California's future energy needs. To implement the *Plan*, the Energy Commission and the CPUC have collaborated to streamline and coordinate the planning and procurement processes initiated by SB 1389 and AB 57. In 2004 the two agencies strengthened their collaboration in the process of evaluating and adopting long term resource plans for the state's three major investor-owned utilities (IOU) and developing resource adequacy requirements for CPUC-jurisdictional LSEs. In September 2004 the CPUC directed that, beginning with the *2005 Energy Report*, future CPUC long-term resource procurement proceedings will rely on Energy Commission forecasts and resource assessments.

This critical step established that future CPUC procurement rulemakings would take place only after the Energy Commission has published its *Energy Report*. The decision also required the IOUs incorporate the results of the most recent *Energy Report* into their long-term procurement plan filings, beginning with the July 2004 submittal. This decision ensures that state energy policy guides resource procurement, guaranteeing that California relies first on its preferred energy resources.

State agencies are increasingly coordinating their analyses and assessments, with the goal being an integrated planning cycle, one that ensures the development of the energy infrastructure in such a fashion that the state's economic, environmental and reliability goals are met. The Energy Commission is currently undertaking assessments for the *2005 Energy Report*. The adopted forecast, or range of forecasts, will provide a foundation for the analysis and recommendations of the *2005 Energy Report*, including resource assessment and analysis of progress towards energy efficiency, demand response and renewable energy goals. The CPUC will use the forecasts in its 2006 procurement plan proceeding, as will the California Independent System Operator

(CA ISO) in its controlled grid study and other transmission planning studies. Energy Commission supply and demand assessments are also used in the *California Gas Report*, produced for the CPUC by Pacific Gas & Electric (PG&E) and Sempra Energy.

Due, in large part, to the constraints imposed by available data, the CED 2006 forecast continues to provide projections on a planning area basis. While this has been necessary in years past as power plant siting approval required a demonstration of need, planning in a deregulated environment may be better served by a forecast which considers geographic areas bounded by constraints on the transmission of electricity. The joint consideration of decisions regarding new generation, transmission expansion, and DSM programs in an integrated fashion requires forecasts of loads within CA ISO-defined zones and local reliability areas. This, in turn, will require changes in the data which are collected, and in the way that data are compiled and analyzed.

In November 2004 the Energy Commission filed its first formal requests for information under this new planning regime. To provide the Energy Commission and the public with the opportunity to consider a range of perspectives on demand futures, the Energy Commission requested electricity demand forecasts, demand-side management impacts, and related information from all LSEs with loads greater than 200 megawatts (MW). Thus, the majority of California's investor-owned and municipal utilities, as well as other large electricity service providers, now contribute to a statewide integrated energy plan to ensure reliable electricity and natural gas supplies.

Role of Demand Side Management

A critical part of the demand forecast is the estimation of the energy saved from DSM activities. The Energy Commission is required to include in its forecasts all such demand reductions which are "reasonably expected to occur" (RETO) during the forecast period. These demand reductions result from customer responses to fuel prices and from efficiency and demand response (including dynamic[3] and time-of-use pricing) programs sponsored by utilities, government agencies and others.

Since 1975 DSM savings have come from various sources. A substantial portion of these energy savings have resulted from the appliance and building standards (California Code of Regulations Titles 20 and 24) implemented by the Energy Commission. Another major portion of historical savings have been the utility programs mandated by the CPUC to provide efficiency services in the form of energy audits, financial incentives and load-shifting activities. AB 1890 created a ratepayer-funded Public Goods Charge (PGC) to promote energy efficiency in California's deregulated electricity market. The PGC umbrella of publicly-funded DSM activities now includes municipal utility DSM programs, and, administered by the CPUC, those of the IOUs and third party entities, such as local governments and non-governmental organizations. In 1999, the PGC was expanded to include natural gas DSM programs.

Due in part to the role played by conservation and load management in limiting outages during the energy crisis of 2000-01, DSM programs are now "front and center" as components of state energy policy. In 2002 the CPUC initiated a rulemaking to revamp

PGC administration and policies, In addition, in 2002 the CPUC and Energy Commission initiated a joint rulemaking to explore the use of dynamic pricing. The *Energy Action Plan* heightened the importance of these efforts in establishing its "loading order," which calls for maximizing energy efficiency, conservation and load management before more traditional supply options are developed. Implementing the policies in the *Energy Action Plan* through the CPUC's new resource procurement process places a strong focus on the electric and natural gas savings estimated in the demand forecast as a result of DSM activities.

Energy Demand Forecast Methodology

The Energy Commission's demand forecasting methodology features a variety of different models that follow into three large groupings: annual electric and natural gas consumption models and an electric hourly load model by sectors (or types of consumers). In most sectors, the Energy Commission's methodology attempts to simulate individual energy use decisions as they pertain to end use energy services. Examples of energy services are the comfort derived from a heated home, the clean dishes from a dishwasher, the illumination from a light fixture, and the evaporation of water from pulp in a paper making machine. Energy in the form of natural gas, electricity (or other fuels) operates machinery to produce the service derived. Therefore, energy demand is a derived demand, not a direct one.

End use energy consumption estimates can be developed from the application of analytical engineering techniques and econometric techniques for extracting information from customer use data. Early generation end use models were developed using largely engineering methods. As better data became available, disaggregate econometric techniques were incorporated. The advantage of end use modeling over other forecasting techniques is the ability to explain more fully how energy is actually used and factors affecting change in energy use. For example, the Energy Commission staff uses models involving different levels of end use detail to characterize the manner in which efficiency programs affect both energy requirements and peak demand. Table 1-1 lists the end use and consumer characteristics of each of the sectoral models used.

Table 1-1

Characteristics of Forecast Sectoral Models

Sector	Consumer Type/NAICS* Code	End uses Covered
Residential	Residential electricity and natural gas consumers; 3 housing types	24 major appliance and space conditioning categories
Commercial	Electricity and natural gas for 12 building types; sector includes 21 NAICS codes: 115, 2331, 326212, 42, 44-45, 48841, 493, 512, 514, 52-55, 561, 61, 62 (excluding 62191), 71, 72, 81 (excluding 81293), and 92 (excluding 92811	10 equipment and space conditioning categories
Transportation, Communications and Utilities (TCU)	All electricity and natural gas usage in NAICS codes 221, 48 (excluding 48841), 49, 513, 56151, 56152, 562, 62191, and 92811	None**
Streetlighting	All electricity used for traffic control, street and highway illumination	Streetlights and traffic control devices
Industrial	All electricity and natural gas used in the process, extraction, and assembly industries included in NAICS 1133, 21, 23; 31-33, 511, and 516	Motors, thermal processes, lighting, heating, ventilation and air conditioning (HVAC); process steam, electrolytics, and cogeneration.
Agriculture	All electricity and natural gas used in crop production, livestock, and related commodities, included in NAICS 111, 112, 113, and 114	Irrigation pumping, building heating, crop drying
Water Supply	Water supply and wastewater agencies included in NAICS 22131	Water supply pumping and treatment for municipal water supply and wastewater

* North American Industry Classification System

** Consumption is estimated for aggregated of the ten NAICS codes, not for specific end uses

The Energy Commission forecasts energy demand for eight electric utility planning/service areas.

Forecasts for each utility planning area include the loads of the distribution utilities of select investor-owned (IOU) utilities, municipal utilities, and the energy deliveries of other electric service providers in these respective areas. These planning areas may differ somewhat from those used individually by the utilities in their own planning. Table 1-2 and Table 1-3 present the planning areas and their distribution utilities as defined by the Energy Commission for demand forecasting purposes.

Table 1-2

Electric Utilities within Forecast Planning Areas

Electric Utilities*		
Planning Area	Utility Name	
BGP	City of Burbank City of Glendale	City of Pasadena
DWR	Department of Water Resources	
LADWP	Los Angeles Department of Water and Power	
PG&E	Central Valley Project City of Alameda City of Lodi City of Lompoc City of Palo Alto City of Redding City of Roseville City of San Francisco City of Ukiah	Lassen Municipal Utility District Merced Irrigation District Modesto Irrigation District Pacific Gas & Electric Plumas-Sierra Rural Electric Co-op. Shasta Dam Area Public Utility District Silicon Valley Power Turlock Irrigation District
SCE	City of Anaheim City of Azusa City of Banning City of Colton City of Riverside	City of Vernon Metropolitan Water Department Southern California Edison Southern California Water Company
SDGE	San Diego Gas & Electric	
SMUD	Sacramento Municipal Utility District	
OTHER	Imperial Irrigation District PacifiCorp	Sierra Pacific Power Company Truckee-Donner Public Utility District

**Table only includes utilities with retail demand greater than 100 GWh.*

Table 1-3

Natural Gas Utilities within Forecast Planning Areas

Natural Gas Utilities	
<u>Planning Area</u>	<u>Utility Name</u>
PG&E	City of Coalinga City of Palo Alto Pacific Gas & Electric
SCG	Long Beach Gas Department Southern California Gas Company
SDGE	San Diego Gas & Electric
OTHER	Avista Energy Southwest Gas Corporation

The compilation of planning area forecasts requires the aggregation of county data to the planning area level. For example, county-level housing construction, population and income estimates form the basis of a planning-area residential consumption forecast. Each county is apportioned to one or more of sixteen climate zones; each climate zone is then assigned to a planning area. (This process is discussed in detail in Chapter 2.)

Since the 1970's, the Energy Commission's demand forecasting methodology has been based upon classes of energy users (households, business types, etc.) whose behavioral responses to key energy use determinants are reasonably homogeneous. Residential behavior, uses, and needs differ from those of commercial end users, just as they differ from those of industrial consumers. Table 1-1 shows the seven distinct consumer sector energy models used to project electricity and natural gas requirements.

The sectoral groups modeled balance the desire to capture end use detail with available data resources. Moreover, while the composition of sectoral consumption among the planning areas differs (see Tables 1-4 and 1-5), the same models are used to forecast electricity and natural gas demand. The models are implemented using individual planning area data to the extent possible.

At this time, the great majority of consumption is composed of utility sales, but self-generation is growing in importance. Private sales[4] and wheeling do not yet represent measurable components of overall consumption.

The aggregate demand for energy services increases with growth in economic activity and population and as new energy services (frequently possible due to the emergence of new technologies) become available. The Energy Commission's demand forecasts are driven by projections of the sector-specific economic variables outlined in Table 1-6. In addition, updated forecasts must reflect the penetration rates at which more efficient equipment and new energy services enter into use.

In addition to the energy and peak demand sectoral models that forecast final demand, the Energy Commission sometimes develops models that generate the values of economic variables used to drive the energy or peak sectoral models. This work has been necessary because the specific variables most natural for use have not been readily available. Similarly, certain economic regional forecasts are translated into utility planning area forecasts. Such translations are necessary because utility planning regions are not areas for which statistical data are commonly collected.

Table 1-4

California Historic 2003 Electric Consumption (GWh)

Planning Area	Residential	Commercial Building	TCU	Streetlighting	Industry	Mining	Agriculture & Water Pumping	Total
PGE	31,976	35,950	4,788	516	18,284	2,535	6,325	100,374
SMUD	4,361	3,921	476	80	780	125	181	9,924
SCE	28,488	35,602	4,371	700	18,947	2,750	4,051	94,909
LADWP	7,818	10,379	1,697	305	3,689	234	163	24,285
SDGE	6,745	8,142	1,587	105	1,672	207	231	18,689
BGP	891	2,079	82	15	154	46	16	3,283
OTHER	1,979	1,592	243	11	175	48	446	4,495
DWR							8,865	8,865
Statewide Total	82,257	97,665	13,245	1,732	43,701	5,946	20,278	264,824

Source: Energy Commission staff compilation of ENERGY COMMISSION 1304 and 1306 reports provided by electric utilities, energy service providers, and self generators.

Table 1-5

California Historic 2003 Natural Gas Consumption (million therms)

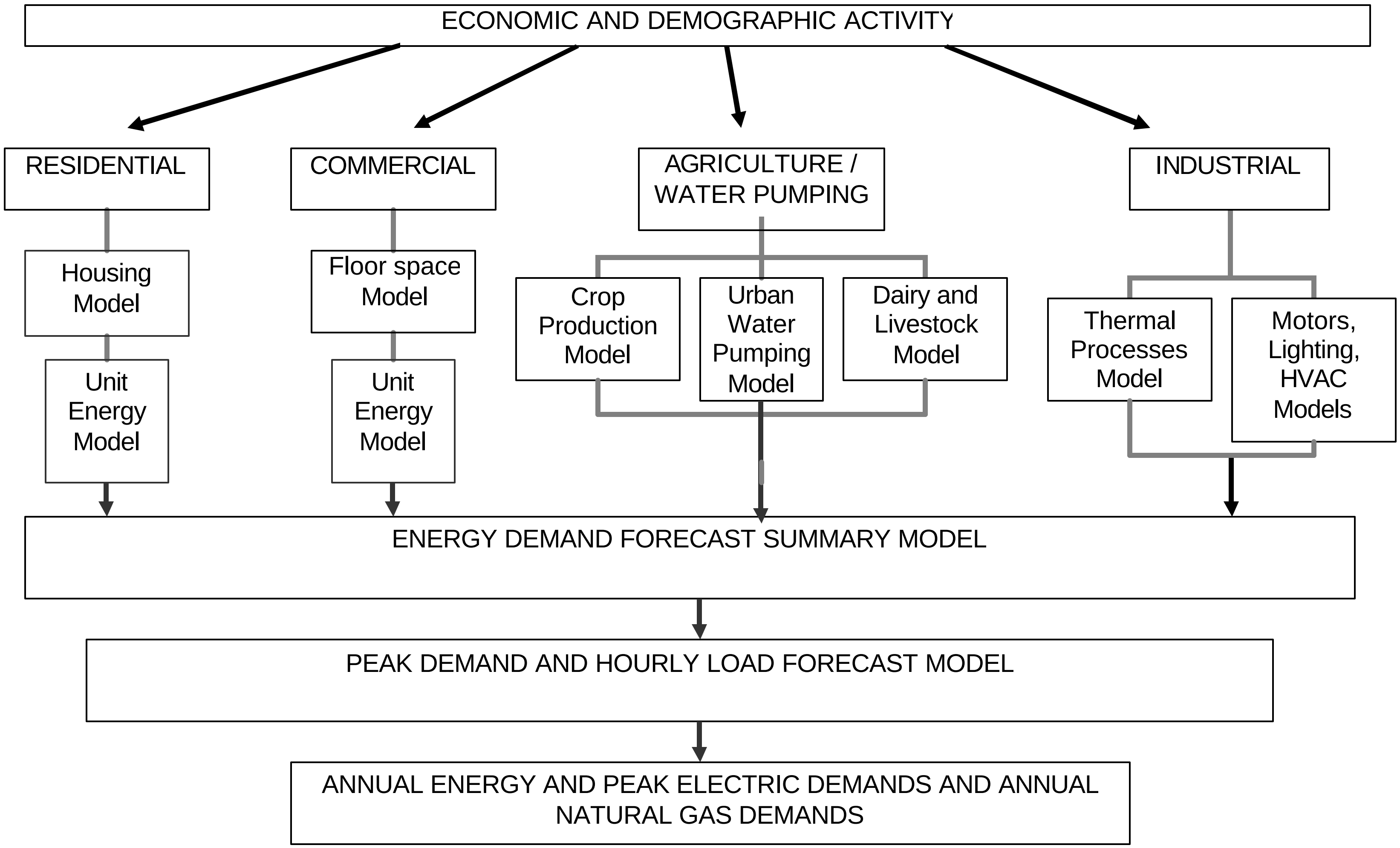
Planning Area	Residential	Commercial Building	TCU	Industry	Mining	Agriculture & Water Pumping	Total
PGE	2,075	877	48	1,447	308	83	4,838
SCG	2,558	924	75	1,504	2,652	101	7,814
SDGE	340	140	13	31	5	5	534
OTHER	84	19	3	18	5	0	130
Statewide Total	5,057	1,961	140	3,000	2,970	189	13,317

Source: Energy Commission staff compilation of ENERGY COMMISSION 1306 reports provided by natural gas utilities, energy service providers, and natural gas producers

Figure 1-1 provides a schematic diagram of the major elements of the energy and peak demand forecasting models. Note that the results from the energy forecasting models flow directly into the peak demand forecasting model.

Figure 1-1

Framework for Energy Demand Forecast Models



Source: California Energy Commission staff, May 2005

Sectoral Energy Demand Forecast Models

This section will provide a brief summary of each of the sectoral energy models: residential, commercial, industrial, and agricultural and water pumping. Also presented is the summary model, which aggregates the energy demand requirements from the sectoral models and prepares them for input to the final model in the forecast process: the peak demand and hourly load model. A discussion of how Demand Side Management (DSM) savings are forecasted and included in the forecast process is included in Appendix B.

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 single-family, multiple-family, and mobile homes are modeled; these are further grouped by climate zone. Sixteen climate zones are modeled; these are intended to capture differences in residential energy use for space conditioning across the state's microclimates.

Five vintages of housing construction are used to represent the eras in which building codes and revisions significantly influenced the thermal characteristics of residential buildings. These housing vintages are grouped by homes built before the standards were initiated in 1975 and those built in subsequent years as energy building standards became more stringent.

The residential model forecasts energy demand in three principal components. First, the number of households of each housing type is forecasted. Household projections are the main explanatory variable for the residential sector. Second, the saturation of appliances for each of three fuel types is projected. For example, the number of households having a gas space heating unit is determined. Finally, the model determines the amount of energy expected to be used by each end use appliance; this depends, in part, on the age profile of the appliance stock, as revised appliance standards have resulted in their increased efficiency over time. Total residential electricity consumption is the product of projected households, the fraction of households possessing a particular appliance, and the yearly average energy use for that appliance, summed over all end uses.

Commercial Energy Demand Forecast Model

The commercial energy forecasting model is similar to the residential model with respect to the degree of disaggregation. The model first forecasts the amount of building floorspace and vacancy rates for twelve different building types. Second, the model determines the fraction of floorspace 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 these three factors and summed for all end uses and building types. The model considers the effects on energy use of changes in floor space, vacancy rates, energy prices, the Energy Commission's building and appliance standards, and other major efficiency programs.

The commercial model relies heavily on end use intensities (EUIs), which are the energy use estimates per square foot by building type (given corresponding end uses and equipment). For staff's 2006 forecast, the impacts of three recent nonresidential building standards (1998, 2001, and 2005) were incorporated into the model. The EUIs for each of these sets of standards were developed based on prior analysis carried out to determine their impact.

Industrial Energy Demand Forecast Model

The industrial sector is divided into process and assembly groups. Process industries primarily involve the processing of raw materials; generally by chemical or physical transformations using thermal and electrical inputs. Individual process industries include food products, wood products, pulp and paper, petroleum refining, cement and glass. Also included in this group are the extraction industries which include petroleum and natural gas extraction and mining.

The assembly industry group includes industries whose primary activity is to shape and form materials and assemble components to produce final goods in a non-continuous production environment. Covering most manufacturing, these industries are relatively electricity intensive.

Projections of industrial energy demand for most sectors except extraction industries are driven by forecasts of output [added value of shipments or gross domestic product (GDP)]. For extraction industries forecasts of employment are used because the volatility of the prices of such commodities as oil, natural gas and precious metals leads to volatility in values of shipments or GDP.

To forecast annual electricity and natural gas demand, the Energy Commission uses the Industrial End use Forecasting Model (INFORM), developed by the Electric Power Research Institute (EPRI). The INFORM program can account for energy use trends, price effects, and exogenous improvement in efficiency by end use and industry.

The major end uses in the model are motors, thermal processes, lighting, heating, ventilation and air conditioning (HVAC) and miscellaneous. Energy Commission staff use the model to project demand for electricity, natural gas and other fuels for these five major end uses over a 12 year period. Demand for electricity, natural gas and other fuels for each of these five major end uses is forecast for each of ten process and 18 assembly industries, as shown in Chapter 4, Table 4-1.

Agricultural and Water Pumping Energy Demand Forecast Models

The agricultural sector is subdivided into three subsectors: crop production, dairy and livestock production, and urban water pumping. A separate forecasting model has been developed for each subsector, although the major focus is on water pumping for crop production as this consumes more electricity than other end uses.

The crop production model consists of two econometric equations, one for the amount of electricity used to pump ground water and the other to pump surface water. The equations are based on the economics of water usage in the agricultural sector. Demand for electricity to pump water depends on the level of crop production, the price of electricity, the price of diesel, and the amount of rainfall.

In the dairy and livestock subsector, the demand for electricity is forecast in three steps. First, econometric models are estimated relating energy consumption to levels of dairy and livestock production, as well as electricity prices. Second, the levels of dairy and livestock production are forecast using econometric models or trend analyses. Lastly, forecasts of these variables are used in the estimated energy equations to generate forecasts of energy consumption.

Urban water pumping requirements are forecast by estimating econometric equations in which energy consumption for water pumping is regressed on the determinants of urban water demand. These variables include total homes, persons per household, per capita income, and cooling degree days; the most important of them is the total number of homes in each planning area.

Energy Demands Summary Forecast Model

Individual sectoral model energy demand forecasts are processed by the Energy Demands Summary Forecast Model in order to calculate planning area total forecasts (see Figure1-1). The summary model adjusts the sectoral forecasts for weather and DSM program savings. The results are calibrated using recorded energy consumption. The adjusted forecast is then sent to the Hourly Electric Load Model (HELM) for use in preparing the peak demand forecast.

Weather adjustments are made to the residential and commercial model forecast results because these two models forecast (and backcast) on the basis of long-run normal weather. The sectoral model backcast and recorded energy consumption are not directly comparable due to the influence of abnormal weather on actual consumption. Energy demand for weather sensitive end uses is adjusted to accommodate the deviation between actual weather and normal weather for each climate zone in the planning area. After this step, the adjusted backcast and recorded consumption tend to match closely.

After the weather adjustment, minor adjustments are performed to account for DSM programs which have not been incorporated into the structure of or input data used in the sectoral models. The final adjustment to the forecasts is to calibrate the results using the recorded energy consumption. Calibration is a process of "scaling" the adjusted sectoral results based on the differences between the adjusted results and recorded energy consumption.

After calibration, the forecast is complete and ready for review. If the results are deemed reasonable, the adjusted forecast is provided to the HELM model for use in preparing the peak demand forecast.

Peak Demand Forecast Model and Hourly Electric Load

The Energy Commission staff employs the Hourly Electric Load Model (HELM) to directly use the end use electricity demand projections of the individual sectoral energy models. Projecting hourly peak load is more difficult than projecting energy consumption because the instantaneous demand for electricity changes constantly. Appliances are used more during the day than in the middle of the night (hourly change), lights are on more in the winter than in the summer (season), and refrigerators cycle more often in hot weather (temperature). Moreover, historical data on customer load consists mainly of system and sector load; relatively little customer type, or end use information is known with certainty.

HELM forecasts hour-by-hour end use demand for every day of the year. Peak days and peak hours on those days are then determined by locating maximum values from many individual hourly load forecasts. This method allows peak load to be directly determined from energy forecasts rather than constrained to follow past consumption patterns.

The residential and commercial portions of the hourly load model divide end uses into weather-varying (space heating and air conditioning) and season-varying (all others) groups. The estimates of average daily electricity consumption for each season-varying end use are based on analysis of past utility sales. Daily weather sensitive end use demand is distributed to each day and hour according to weather conditions and space conditioning equipment operating schedules. The summation of end use loads in any given hour produces a total load for that hour. Industrial, transportation, communication and utilities (TCU), agricultural, and streetlighting loads are forecasted by individual industry. Annual electricity sales are allocated to each day being forecast using utility billing data. Load curves, obtained from utility load research data, are then used to allocate the daily consumption over each hour of the day.

Peak calibration is needed to compensate for discrepancies between model results and recorded peak data. In calibration, the staff takes advantage of both data on the estimated coincident peak by sector and the historical system peak. The calibration procedure compares model estimates of peak demand with the recorded peak data from 1980 to 2003. The calibration factors for all utilities are estimated using regression. Using utility coincident peak estimates, independent calibration factors are estimated for the residential and nonresidential sectors for LADWP, SDG&E and SMUD. For PG&E and SCE, a four-sector calibration is performed; separate calibration factors are derived for the residential, commercial, industrial and agriculture sectors.

The methodology for hourly load calibration is designed to calibrate the HELM-simulated hourly loads against estimated sector loads or historical system loads submitted by utilities. It calculates the differences in these two values for each hour of the year, distributes this error over each of the end uses, and creates a new set of end use load shapes.

Data Sources for Energy Demand Forecast Models

Four classes of data are needed as inputs to disaggregated forecast models:

- consumer characteristics data such as end use appliance saturations, dwelling size and age, occupants' income and demographic makeup, utility bills for the residential sector, and equipment saturations, hours of operation, etc. for the commercial sector

- aggregated energy consumption data for the nonresidential sectors (most notably the industrial sector) classified by the North American Industry Classification (NAIC) codes devised by the federal government

- disaggregated economic and fuel price projections at a level of detail matching the customer sectors of the energy forecasting models

- characteristics of demand side management programs, either to allow quantification of savings endogenously within the models, or to subtract exogenous estimates from the results of the models (see Appendix B)

Consumer Characteristics

The principle source of information regarding consumer characteristics is customer survey data. Customer surveys collect data on customer electric and natural gas use that provides the core data needed for the Energy Commission's end use forecasting models, such as building and equipment characteristics and operation. These surveys, which until electric industry restructuring, were funded and managed by the utilities, are now funded through the Energy Commission's budget. In 2004, the Energy Commission completed a statewide survey of the residential sector which analyzed the characteristics of the residential population, saturation of residential appliances, characteristics of dwelling units, and energy use habits of their occupants.[5] As of this writing, a commercial survey which will provide similar data on energy use in the commercial sector is underway. As these surveys are completed the results can be used to revise forecasting model inputs and improve forecast results.

A major secondary data source also providing some consumer attributes are federal activities under the Bureau of the Census. 1970, 1980, 1990, and 2000 census data are used directly in the residential sector model. Similarly, the 1977, 1982, and 1987 Census of Manufacturers provides essential industrial production, employment, and fuels usage data. Unfortunately, the federal data gathering activities have not focused adequately on the commercial sector, leaving a major gap in the data. Acquisition of reliable commercial floorspace data remains a difficult and unresolved problem for forecasters.

Finally, the potential growth of various forms of private supply of energy, especially self-generated electricity, makes augmentation of utility derived data essential. The primary concern of the Energy Commission is energy consumption and forecasts utility sales forecasts are of secondary importance. Independent efforts to acquire reliable data on private supplies of energy (not connected to utility sales or wheeling) are of growing importance, especially in the industrial and large commercial sectors. Recent changes in regulations regarding the filing of *Quarterly Fuel and Energy Reports* (QFER) share this burden among large self-generators (who must report directly to the Energy Commission), and utilities that must report estimates of aggregate smaller scale self generation as part of routine QFER submissions.

Energy Consumption Data

Electricity and natural gas consumption data by Standard Industrial Classification (SIC) and NAICS code have proved to be a valuable source of information regarding basic energy usage for the nonresidential sector. The data is supplied by six-digit NAICS code on a quarterly basis for individual months by every electricity and natural gas retailer in the state. The data is processed by Energy Commission staff into various customer groupings, allowing staff to apply the sector models to groupings where no matches in rate classification would be possible. Tables 1-4 and 1-5 summarize electricity consumption for 2003 indicating the relative size of the customer sectors among the eight demand planning areas.

Beginning in 1990, electric generators began to report their self-generation to the Energy Commission. Growth of self-generation over time makes such data increasingly important. Several thousand GWh of self generation is consumed each year in California.

Conversion of SIC to NAICS Data Classifications

The federal Standard Industrial Classification (SIC) has been used as the key data collection unit for historical electric and natural gas sales from investor owned utilities (IOU) and energy service providers (ESP). This data, which was formally acquired through a process known as the Quarterly Fuel and Energy Report (QFER), is used to calibrate the models and perform backcasting. The Federal Office of Management and Budget (OMB) adopted a new industry classification system to replace the Standard Industrial Classification system (1987). The new system is called the North American Industry Classification System (NAICS). NAICS was created on a production-oriented or supply-based framework that groups establishments into industries according to similarity in processes used to produce goods or services.

Historically, data providers submitted consumption data to the California Energy Commission using the Standard Industrial Classification (SIC) system. A revision to the California Code of Regulations (CCR, Title 20, Division 2, Chapter 3, Section 1302) required data providers to provide NAICS coded data beginning January 1, 2003. Data providers are required to convert from SIC to NAICS coding to keep data on energy trends comparable to statewide and national economic data that are currently being transitioned to the new coding system.

Approximately half of the SIC codes convert directly to NAICS codes. The remaining SIC codes require analysis before a conversion to NAICS takes place. For example, only one SIC code exists for restaurants (5812), but NAICS categorizes restaurants into seven codes (full-service, limited-service, cafeterias, snack, food service contractor, caterers, and dinner theater).

NAICS was revised in 2002 for six of the twenty sectors. Construction and wholesale trade were substantially changed, but the revisions also modify a number of retail classifications and the organization of the information sector. Very minor boundary adjustments affect administrative and support services and mining.

Economic and Fuel Price Projections

Essential inputs into the Staff forecasting models are economic and fuel price projections for each planning area annually for 10 years into the future. The forecast framework in Figure 1.1 indicates the use of several translation models to convert available economic data into the actual "energy driver variables" which are used in the models to forecast energy usage (see Table 1-6). For example, in the commercial sector, the key energy driver is floorspace by building type, while the economic variables are employment of various types, taxable sales, and various groupings of population. Historic analysis of floor space additions and economic variables has indicated that a different mix of each of these economic variables has been found useful in projecting floorspace for each building type.

Electricity and natural gas price projections, which are a significant input into any energy demand forecast, are prepared by the Energy Commission staff and reported in various appendices of the *2005 Energy Report*.

Table 1-6

Economic Variables Used in Forecast Models

Sector	**Energy Driver**	**Economic Variable**	**Constructed Economic Variable**
Residential	• Fuel prices	• Population • Personal Income • Households	• Household population • Persons per household • Group quarters • Income per capita
Commercial	• Floorspace, by building type • Fuel prices	• Employment • Retail sales • Population	
Industrial	• Output, by industry • Fuel prices	• Output, by industry • Employment (extraction sectors only)	
Agriculture	• Crop production • Rainfall • Electricity price • Diesel price • Cooling degree days • Dairy and livestock production	• Personal Income • Population • Households	• Total households • Persons per household • Income per capita

Endnotes

[1] Because future demands for electricity drove the need for power plants, the forecast focus was on the demand for electricity. The projected demand for natural gas and other fuels were also forecast products. The emphasis on future natural gas consumption and efficiency savings is much greater in 2005 than in the early years of the Energy Commission.

[2] Public Resources Code, Section 25309

[3] "Dynamic pricing" entails a tariff under which the price may be changed with sufficient notice in response to external factors (e.g., system conditions); the tariff usually specifies the higher price, amount of notice required, number of times the higher price can be invoked and number of hours over which it can be charged. This high price is an incentive to reduce consumption during peak hours; it is offset by lower prices during other hours, leaving total costs to the consumer unchanged.

[4] Chapter 699, Statutes of 1984, allow private sales from a power generator to users immediately adjacent to the generator's property line.

[5] Residential Appliance Saturation Survey (RASS), California Energy Commission, Publication No. 400-04-009, June 2004

CHAPTER 2

RESIDENTIAL ENERGY DEMAND FORECAST MODEL

Introduction

A detailed end use model is used to develop energy forecasts for the residential sector. The three primary components of the model are households, appliance saturations, and average energy use per appliance; energy use for an end use category is determined by the product of total households, appliance saturation, and energy use per appliance. Total residential consumption is estimated by summing the projected consumption for 24 different end uses.

The data used in this forecast comes from utility surveys, engineering and manufacturer estimates, conditional demand analyses, the Department of Finance, the Los Angeles County Department of Regional Planning, and the National Oceanic and Atmospheric Administration (NOAA). These data sources are discussed in more detail below.

End use energy demand is projected by service or planning area, climate zone, housing type, housing vintage, fuel type, and appliance type. The Energy Commission divides California into service or planning areas for forecasting purposes. The residential model produces forecasts for the service/planning areas described in Table 1-2.[1]

Each service/planning area contains one or more of sixteen climate zones. The number of climate zones in a given area depends on the diversity of climate within the area and the existence of a sufficient number of weather stations in the area to capture this diversity. California climate zones and the percentage allocation of county populations to each zone are shown in Tables 2-1 through 2-9. Some allocations change over time, reflecting differential rates of growth in different parts of a county, but the majority of counties have fixed allocations.

Residences are classified as single-family, multiple family or mobile homes (housing types). No explicit distinction is drawn between owner and renter occupied dwellings.

Table 2-1

PG&E – Percent of County in Climate Zone

COUNTY/CLIMATE ZONE	1	2	3	4	5
ALPINE	63.4%				
AMADOR		100.0%			
BUTTE			100.0%		
CALAVERAS	100.0%				
COLUSA			100.0%		
FRESNO			100.0%		
GLENN			100.0%		
HUMBOLDT	100.0%				
KERN			70.8%		
KINGS			64.3%		
LAKE	100.0%				
LASSEN	18.2%				
MADERA			100.0%		
MARIN					100.0%
MARIPOSA	100.0%				
MENDOCINO	100.0%				
MERCED			100.0%		
MODOC	0.6%				
MONTEREY				100.0%	
NAPA				100.0%	
NEVADA	84.3%				
PLUMAS	94.1%				
SAN BENITO				100.0%	
SAN FRANCISCO					100.0%
SAN JOAQUIN		100.0%			
SAN LUIS OBISPO				100.0%	
SAN MATEO					100.0%
SANTA CLARA				100.0%	
SANTA CRUZ					100.0%
SHASTA			99.1%		
SIERRA	40.5%				
SISKIYOU	0.1%				
SOLANO				100.0%	
SONOMA				100.0%	
STANISLAUS			100.0%		
SUTTER			100.0%		
TEHAMA			100.0%		
TRINITY	100.0%				
TULARE			14.2%		
TUOLUMNE	100.0%				
YOLO		100.0%			
YUBA			100.0%		

Table 2-2

PG&E – Percent of County in Climate Zone by Year

COUNTY/YEAR	1970	1980	1993	2000	2007	2017
ALAMEDA						
Climate Zone /4	7.4	17.5	19.3	20.7	22.1	23.7
Climate Zone /5	92.6	82.5	80.7	79.3	77.9	76.3
CONTRA COSTA						
Climate Zone /4	69.8	64.3	66.1	67.5	68.9	70.5
Climate Zone /5	30.2	35.7	33.9	32.5	31.1	29.5
EL DORADO						
Climate Zone /1	72.3	69.3	74.7	78.9	80.8	83.1
PLACER						
Climate Zone /2	85.7	88.0	89.7	90.9	92.1	93.5
SACRAMENTO						
Climate Zone /2	1.5	1.5	0.0	0.0	0.0	0.0
SANTA BARBARA						
Climate Zone /4	43.4	46.0	48.7	50.8	52.9	55.3

Table 2-3

SMUD – Percent of County in Climate Zone by Year

COUNTY/YEAR	1970	1980	1985	2000	2007	2017
SACRAMENTO	98.5	98.5	100.0	100.0	100.0	100.0

Table 2-4

SCE – Percent of County in Climate Zone

COUNTY/CLIMATE ZONE	7	8	9	10
IMPERIAL				0.1%
INYO			58.2%	
KERN	29.2%			
KINGS	35.7%			
MONO			100.0%	
RIVERSIDE				91.6% (1)
SAN BERNARDINO				100.0%
TULARE	85.8%			
VENTURA		100.0%		

Table 2-5

SCE – Percent of County in Climate Zone by Year

COUNTY/YEAR	1970	1980	1993	2000	2007	2017
LOS ANGELES						
Climate Zone 8	37.6	33.4	32.4	31.1	30.8	29.8
Climate Zone 9	17.7	22.3	23.6	25.6	26.6	29.0
SANTA BARBARA						
Climate Zone 8	56.6	54.0	51.3	49.2	47.1	44.7
ORANGE						
Climate Zone 8	94.8	94.8	92.7	90.6	89.4	88.9

Table 2-6

LADWP – Percent of County in Climate Zone by Year

CLIMATE ZONE/COUNTY	1970	1980	1993	2000	2007	2017
Climate Zone 11						
LOS ANGELES	26.4	26.1	25.9	25.3	24.7	23.7
Climate Zone 12						
LOS ANGELES	13.6	13.6	13.5	13.5	13.5	13.1
INYO	41.8	41.8	41.8	41.8	41.8	41.8

Table 2-7

BGP – Percent of County in Climate Zone by Year

COUNTY	1970	1980	1993	2000	2007	2017
LOS ANGELES	4.8	4.6	4.6	4.5	4.5	4.4

Table 2-8

SDG&E – Percent of County Population in Planning Area by Year

COUNTY	1970	1980	1993	2000	2007	2017
SAN DIEGO	100.0	100.0	100.0	100.0	100.0	100.0
ORANGE	5.2	5.2	7.3	9.4	10.6	11.1

Table 2-9

OTHER – Percent of County in Climate Zone

COUNTY/CLIMATE ZONE	14	15
ALPINE	33.6%	
DEL NORTE	100.0%	
EL DORADO (1)	30.7%	
IMPERIAL		99.9%
LASSEN	81.8%	
MODOC	99.4%	
NEVADA	15.7%	
PLACER (1)	12.0%	
PLUMAS	5.9%	
RIVERSIDE (1)		8.4%
SHASTA	0.9%	
SIERRA	59.5%	
SISKIYOU	99.9%	

(1) percentage shown reflects 1980 allocation of population

Residences are further classified by vintage, determined by the California building standard in effect when the residence was built. The first state-wide residential building efficiency standard was developed in 1975 by the California Department of Housing and Community Development. Subsequently, the Energy Commission published revised energy efficiency standards for residential buildings in 1978, 1983, 1991, 2001 and 2005. The five residential vintages are accordingly classified as pre-1975, 1975-78, 1979-83, 1984-1991, and post-1991. For this most recent forecast, the post 1991 vintage of houses reflects the effects of the 1991, 2001 and 2005 standards revisions.

The residential model produces forecasts for electricity and natural gas demand by the residential sector. Other fuel types, such as wood heat and LPG, enter in the model's saturation equations to assure proper electric and natural gas fuel shares, but complete wood or LPG energy demand is not computed.

Finally, an end use may represent several appliance types. Electric space heating, for example, is comprised of baseboard, central, and heat pump units.

Model Structure

Figure 2-1 shows the three main components of the residential model: households, appliance stock, and average use per appliance (the “unit energy consumption” or UEC). Consumption for each end use is the product of households, appliance saturation, and unit energy consumption.

$$EUC_{e,t} = HOUSES_{t} * ASAT_{e,t} * UEC_{e,t} \qquad (1)$$

where:

EUC = end use consumption
HOUSES = households
ASAT = appliance saturation
UEC = average unit energy consumption for each end use
e = index of appliance end uses relevant to a particular fuel type
t = year index.

End use consumption is estimated for each combination of housing type, fuel type, and climate zone.

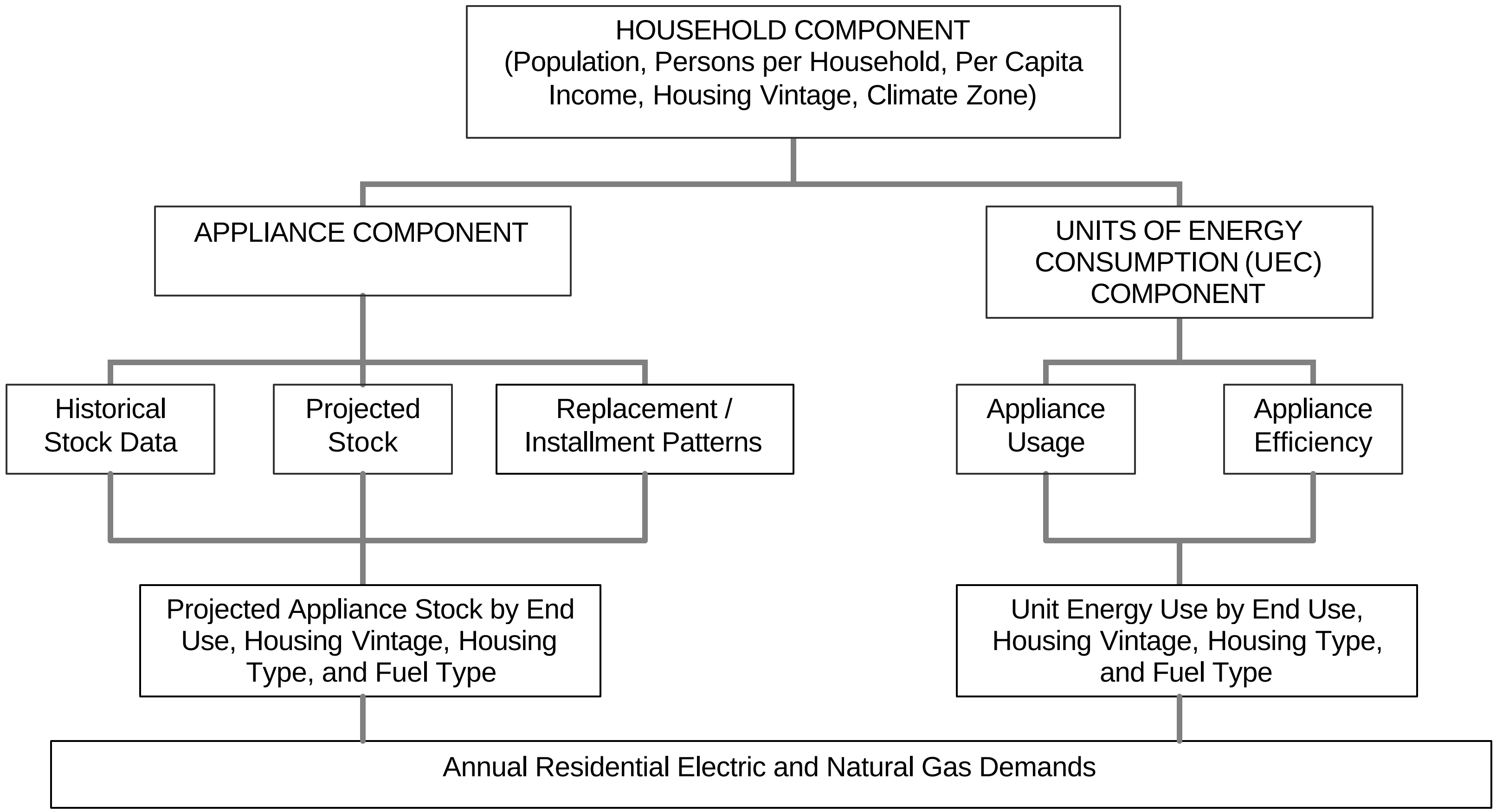
The household component provides projections of persons per household (PPHH), per capita income (PCI) by climate zone and housing stock by climate zone and housing type. Housing stock projections are used to calculate appliance stocks. Persons per household and per capita income are used to calculate unit energy consumption for some appliances.

The residential model features two methods for calculating appliance stocks. Historical stock calculations are based on census data and utility appliance saturation surveys. Projected stocks are based on computed retention factors and marginal saturations (purchases of new and recycled appliances; see page 2-14).

The UEC component estimates average UECs for each purchase year. These UECs are based upon average consumption in the base year, new equipment efficiencies, persons per household, and energy efficiency retrofit programs. For space conditioning end uses, the thermal integrity of dwellings is also taken into account.

Figure 2-1

Residential Energy Demand Forecast Model



Source: California Energy Commission staff, May 200

Household Component

The household component takes population and persons per household by county, plus recorded housing additions and projected housing stock decay rates, by county and housing type, and calculates housing stock, persons per household and historic decay rates by climate zone and housing type in a five step process.

First, the total housing stock for each county is calculated from population and persons per household projections (for the sources of these and all other data, see Table 2-11).

$$HOUSES_{t,c} = POP_{t,c} / PPHH_{t,c} \qquad (2)$$

where:

POP = population
PPHH = persons per household
c = county index
t = year index

The model then estimates net household additions in each year from the total housing stock.

$$NETADD_{t,c} = HOUSES_{t,c} - HOUSES_{t-1,c} \qquad (3)$$

where:

NETADD = net housing additions.

Second, projected housing construction splits (between single and multi-family residences and mobile homes), by county, are developed from recorded housing addition data. The splits from 2004-2016 are assumed to be constant and equal the mean of the observed values during 1977-2003.

Third, historical housing type decay rates are estimated with a procedure that makes use of the 1970 census housing stock as a base (t = 1), annual net housing additions (NETADD) and annual recorded new construction housing additions during 1971-2003.

$$CCSCAD_{c,l,t} = NETADD_{t,c} * PCT_{c,l,} \qquad (4)$$

$$CCSCHH_{c,l,t} = CCSCHH_{c,l,t-1} + CCSCAD_{c,l,t} \qquad (5)$$

$$CIRBHH_{c,l,t} = CCSCHH_{c,l,t-1} + HOUSE_{t,l,c} \qquad (6)$$

$$HRF_{c,l,t} = CCSCHH_{c,l,t} / CIRBHH_{c,l,t} \qquad (7)$$

$$DECR_{c,l,t} = 1 - HRF_{c,l,t} \qquad (8)$$

where:

CCSCAD = net housing additions by type

CCSCHH = housing stock
HOUSE = recorded housing additions
CIRBHH = estimated housing stock absent decay
PCT = housing construction shares
HRF = housing retention factor
DECR = housing decay rate
l = housing type index

Housing stock and decay rates are used to aggregate housing stocks into the five vintages defined above. A housing retention factor (HRF) is defined as the fraction of last year's housing stock remaining in the current year.

Fourth, projected households are calculated using the 1970 and 1980 Census households as a base plus the gross projected household additions, which are the sum of net additions plus replacements.

$$HOMES_{t,,c,l} = (HOMES_{l,t-1} * HRF_{1,t}) + (GROSSADD_{t,c} * PCT_{c,l,t}) \qquad (9)$$

$$GROSSADD_{t,,c} = [HOMES_{t-1,c,l} * (1 - HRF_{t-1,c,l,})] + NETADD_{t,,c} \qquad (10)$$

where:

HOMES = projected households
GROSSADD = gross additions
PCT = housing construction shares.

The final step is the aggregation of county data to climate zones.

Over the forecast, the housing stock is grouped into the five vintages described earlier, which are based on year of construction. Housing decay acts to decrease the households in each of the four older vintages. The most recent vintage, as a share of the total housing stock, increases over the forecast period.

Appliance Stock Component

The appliance stock component of the model maintains a disaggregate record of the appliance stock age distribution. The residential model uses two steps to calculate appliance stocks. First, the saturation of a given appliance in a given year is determined. Second, the number of appliances by purchase year surviving to a given forecast year is determined from the saturation rate and the decay of existing appliances.

Saturation Calculations

An appliance saturation is the percentage of households owning a particular appliance. Historic saturations are derived from the 1970 Census and appliance survey data provided by utilities.

For the forecast period, overall saturations are calculated from the previous year's overall saturation plus the current year marginal saturations. The most complex part of this procedure is the calculation of the four marginal saturation categories. For discussion purposes the following definitions will be used in describing saturation calculations:

end use - a process that uses energy for a particular purpose (i.e. cooking)

appliance - the specific type of appliance used in that process (i.e. gas stove, electric stove, etc.)

Marginal saturations (MS) are the percentage of households that buy a new appliance in a given year. These households comprise four categories of potential markets (PM) for new appliances:

PM1 = homes constructed in the current year
PM2 = Existing homes that as yet do not have the end use appliance
PM3 = Existing homes with an appliance that failed in the current year
PM4 = Existing homes that replace an operating appliance with a new appliance.

For some end uses PM3 and PM4 are split into the fuel types of the appliance that existed and the appliance that replaced it. Marginal saturation values, MS1 - MS4, are the saturation values corresponding to the potential markets, PM1 - PM4.

The primary advantage of the potential market approach for marginal saturations is that policy measures that affect only one or two of the potential markets may be modeled directly.

The marginal saturation values for each potential market can be calculated endogenously, but in practice most are determined and constrained using information from utility surveys or staff judgment. The marginal saturations used for new homes (PM1) are assumed to be the same as those in either the most recent or two most recent vintages of homes sampled in the most recent utility survey. The marginal saturations for existing homes that do not yet have the appliance (PM2) are endogenously determined, but the values are constrained such that plausible saturation levels are obtained. All failed appliances are assumed to be replaced (PM3), with a small amount of fuel switching allowed for appropriate end uses. Some fuel switching is also assumed for existing homes that replace an operating appliance (PM4).

Recycled appliances originate from two sources: when an existing appliance is replaced with a new model and when a house is “retired” and the appliance removed from it. The residential model assumes that recycled appliances are absorbed only by the PM2 and PM3 markets and that appliances are distributed between these two markets in proportion to their respective size. These assumptions have a small effect on the results because the pool of recycled appliances is small and limited to portable end uses such as refrigerators or freezers.

The manner in which marginal saturations are calculated varies depending on the saturation subroutine used. The current model uses two different saturation subroutines - CONSAT and DOLE.

The marginal saturations in CONSAT do not play any role and are only set for completeness. In CONSAT, base year overall saturations are read in and all future saturation values are set equal to the base year value. This subroutine is used in the case of end uses, such as miscellaneous, with constant saturations of 1.0 in all potential markets.

The determination of marginal saturations in the DOLE subroutine is a combination of marginal constraints input by the user and the calculation of a "free market marginal" used to fill in the gaps. This calculation is discussed below.

Most of the marginal saturations used in DOLE are constrained. The values for MS1 are constrained throughout the forecast period to be the same as the saturations which currently exist in new homes. The values for the replacement of failed appliances (MS3) are constrained to be 1.0 for appliances with only one fuel type and 0.99 for appliances with more than one fuel type (*i.*e., fuel switching is limited to 1 percent). The values of retrofit appliances (MS4) are constrained to 1.0 for appliances with only one fuel type and 0.95 for end uses with more than one fuel type (fuel switching is limited to 5 percent).

The only marginal saturation which is not completely constrained is MS2, which is calculated for those households that do not currently have the end use. Values for MS2 are a function of time and changing fuel prices; the staff does not allow these saturations to exceed reasonable limits for appliance purchases.

The calculation of the "free market saturation" is the combination of price and non-price factors. The non-price factor is determined by comparing an average price factor for the historical period with an overall marginal calculated for that same period. This "historic marginal" is calculated by dividing the total number of purchases by fuel type during the period in question by the sum of all potential markets existing in those years. The total number of purchases is calculated by taking the total number of appliances by fuel type existing in the reference year t (the last year for which an appliance survey is available) and subtracting from this appliances which have survived from the base year (1981). The latter is calculated using an overall retention factor which accounts for appliance lifetime, housing lifetime and appliance portability.

The sum of potential markets is calculated by taking the total number of households in year t and subtracting those with surviving appliances. The non-price factor then becomes the number by which the price factor must be multiplied to arrive at the overall "free market marginal" saturation.

Appliance Stock Calculations

Annual appliance saturations are converted into purchase year appliance stock arrays so that purchase year energy use may be estimated. This energy use then stays with the appliance through its entire lifetime; the model assumes no degradation of appliance efficiency over the life of the appliance. Because appliance use in year t is calculated by summing year specific use from years 1 to t, the average efficiency of the beginning stock needs to be known. This is not possible since historic appliance efficiency has not always been reported. Therefore, the simplifying assumption used by the residential model is that 1960 is the base year for computing appliance stocks. This assumption was made so that there would be a reasonable age mix of appliances available at the start of the forecast period (1970). It is also assumed that most, if not all, of the 1960 stock has decayed by the more recent period used for model calibration (1980-2003). The basic algorithm for estimating appliance purchases in year t (1960 < t < 1970) consists of the following equation:

$$PURCH_t = NAPPL_t - (NAPPL_{t-1} * ARF_a) \qquad (11)$$

where:

NAPPL = number of appliances as determined by the total housing stock and overall saturation
ARF = one-year appliance retention factor
a = age (of appliance) index

Total 1960 appliances stock is an input and the stock between 1960 and 1970 is determined by interpolation.

Purchases after 1970 are calculated directly from the saturations. Each of the potential markets contributes to the total number of purchases in a given year. After 1970 the calculation of new purchases is also dependent on the year. New purchases are essentially the sum of all of the purchases determined by the potential markets. Failed appliances for a given year are determined on a purchase year specific basis with older appliances failing at faster rates than new ones.

The yearly appliance stock profile can be thought of as a matrix with forecast year as rows and purchase year as columns. Table 2-10 provides such a matrix using freezers in single-family homes in the Sacramento Municipal Utility District planning area. The columns will monotonically decline as the appliances put into use in a given year slowly decay. The number of appliances in use in year t is the stock of appliances entering the year (the “TOTAL” column), plus the new purchases in year t (the intersection of row t and column t). New purchases take into account not only the purchase year specific retention factors of appliance lifetime but also the portability of appliances which can be recycled.[2]

Unit Energy Consumption Component

The third term in equation (1) is the unit energy consumption (UEC), which is the average energy use per appliance in a given year. The UEC depends on hours of operation, appliance efficiency and, for space conditioning end uses, the thermal characteristics of the dwelling unit. UEC values for an appliance purchased in a given year remain constant for the life of the appliance; this value is set as the average consumption of appliances purchased in that year. Appliance efficiency is introduced as a reduction in the UEC from a base year (1977) value. The exceptions to this are the space conditioning, water heating and miscellaneous end uses. The following discussion describes the methods used to calculate UECs for these end uses, as well as the general method used for the remaining end uses in the model.

Table 2-10

Appliance Stock Matrix for Single-family Freezers

(Purchase Year Across, Forecast Year Down)

	Total	1980	1981	1982	1983
1980	47329	2771	0	0	0
1981	48536	2769	2306	0	0
1982	49853	2766	2307	2445	0
1983	50271	2755	2305	2449	1881
1984	50871	2727	2287	2435	1887
1985	51359	2697	2268	2421	1881
1986	53773	2660	2239	2394	1863
1987	56065	2633	2222	2382	1858
1988	58462	2601	2201	2364	1849
1989	61191	2563	2174	2341	1836
1990	64073	2519	2142	2314	1819
1991	67026	2468	2104	2278	1796
1992	69968	2409	2060	2237	1768
1993	72885	2345	2010	2189	1736
1994	75782	2275	1956	2136	1698
1995	78656	2200	1897	2078	1657
1996	81258	2121	1834	2015	1611
1997	83925	2040	1769	1948	1562
1998	86621	1956	1701	1879	1511
1999	89367	1870	1631	1807	1457
2000	92126	1783	1560	1733	1402
2001	95327	1696	1488	1658	1345
2002	98623	1609	1415	1581	1286
2003	102015	1522	1343	1504	1227
2004	105417	1436	1270	1427	1168
2005	108960	1352	1199	1351	1108
2006	112322	1269	1129	1275	1049
2007	115761	1189	1060	1201	990
2008	119297	1111	993	1128	933
2009	122852	1036	929	1058	877
2010	126483	964	867	990	823
2011	130024	896	807	924	770

Space Conditioning UECs

Space conditioning UECs are a function of the thermal characteristics of the house, thermostat operating behavior and the efficiency of the equipment. Thermal load requirements are determined by housing type, housing vintage and climate zone. The housing vintages are meant to coincide with the periods in which specific state mandated building standards are in force (pre-1975, 1975-1978, 1979-1983, 1984-1991 and post-1991). For forecasting purposes, building standards revisions between 1983 and 1991 are assumed to be energy neutral. Estimates of the effects of the 2001 and 2005 standards are included within the post-1991 vintage.

For each end use (heating and cooling), a base thermal load value is calculated. This value is determined on a kBtu/sqft basis for a pre-1975 home.[3] This is then reduced by savings obtained from the addition of conservation measures. The conservation measures considered in the model are attic insulation, wall insulation, weather stripping/caulking, floor insulation, storm windows, thermal drapes, window shading, thermal mass and additional weather stripping/caulking upgrades. The penetration of conservation measures are tracked on a yearly basis to account for the continuing improvement in housing shell characteristics. Thus an annual average thermal load is created for each of the five housing vintages.

The base thermal load is adjusted for the effects of price and income changes on occupant behavior by adjusting the assumed thermostat setting. This is accomplished by using price and income elasticities to change the assumed thermostat setting for each housing vintage over the forecast period, thus adjusting the thermal load.

The adjusted thermal load is then multiplied by the efficiency of the appliance used to meet the load to determine the yearly average UEC. It should be noted that while the average thermal load of the house changes over time with the addition of conservation measures and changing economic factors, the efficiency of the appliance, determined by its purchase year, remains constant over its lifetime.

Water Heating UECs

The residential model distinguishes between basic hot water use, such as for bathing, and additional use for automatic dish- and clothes washing. The latter are considered independently because separate appliance saturations are estimated for these end uses.

Water heating energy demand is dependent on the volume of water used. Basic use, by housing type, is estimated with the following formula.

$$TWHA_{l,t} = [(1 - PENLF_{l,t}) * 10.5 * PPHH_{l,t}] +$$

$$[PENLF_{l,t} * 7.21 * PPHH_{l,t})] \qquad (12)$$

where:
TWHA = household basic hot water use in gallons per day
PENLF = penetration of low flow shower heads
PPHH = persons per household

The constants, 7.21 and 10.5, are the average number of gallons per person per day for households with and without a low flow shower head, respectively.

Additional hot water use for clothes washers becomes:

$$CWUSE_{l,t} = [(1 - PENCOLD_{l,t}) * 5.25 +$$

$$(PENCOLD_{l,t} * 1.05)] * PPHH_{l,t} \qquad (13)$$

where:

CWUSE = hot water used for automatic clothes washer
PENCOLD = penetration of cold water wash.

Additional hot water use for automatic clothes washers is related to the penetration of cold water wash. The constants, 5.25 and 1.05 are the average number of gallons per person per day of hot water use. A household that runs all wash loads in hot water uses 5.25 gallons of hot water per person per day. For households that run 80 percent of their loads in cold water, hot water use can be reduced from 5.25 to 1.05 gallons per person per day.

For an automatic dishwasher, the additional hot water use is

$$TDW_{l,t} = 3.5 * PPHH_{l,t} \qquad (14)$$

where the constant, 3.5, is the daily hot water use per person.

Water use differences between single, multiple, and mobile home types are reflected by differences in the persons per household in each of equations (12), (13) and (14). Average annual hot water use is the product of average daily use and the number of days in a year.

Energy consumption for basic hot water use, disregarding standby losses, is calculated as

$$EUSE_{l,t} = TWHA_{l,t} * [(PENSB_{l,t} * ECC120) +$$

$$((1 - PENSB_{l,t}) * ECC140)] \qquad (15)$$

where:

ECC120 = energy consumption coefficient for heaters with 120^{o}F temperature setting
ECC140 = energy consumption coefficient for heaters with 140^{o}F temperature setting
PENSB = penetration of 120^{o}F setback heaters

The additional energy use for dishwashers and clothes washers is simply the ratio of water use for the special purpose to that for basic water heating. For dishwashers:

$$INHWDW_{l,t} = EUSE_{l,t} * (TDW_{l,t} / TWHA_{l,t}) \quad (16)$$

A similar procedure is used to estimate additional water heating energy use for clothes washers.

Standby energy losses for water heaters purchased in year nnp are related to the water temperature set point, and the thermal integrity of the water storage tank. Two temperature set point options are considered: 120^{o}F and 140^{o}F. The thermal integrity of the hot water storage tank is determined by the presence or absence of a water heater blanket.

$$STNDBY_{l,t} = PENBL_{l,t} * PENSB_{l,t} * SLC120B +$$

$$(1 - PENBL_{l,t}) * PENSB_{l,t} * SLC120N +$$

$$PENBL_{l,t} * (1 - PENSB_{l,t}) * SLC140B +$$

$$(1 - PENBL_{l,t}) * (1 - PENSB_{l,t}) * SLC140N \quad (17)$$

where:

PENBL = percentage of appliance stock with water heater blanket
SLC120B = standby loss constant for heaters set at 120^{o}F with a water heater blanket
SLC140B = standby loss constant for heaters set at 140^{o}F with a water heater blanket
SLC120N = standby loss constant for heaters set at 120^{o}F with no water heater blanket
SLC140N = standby loss constant for heaters set at 140^{o}F with no water heater blanket

The basic water heating UEC is the combination of the energy use for the basic hot water load and standby losses for each fuel type.

$$UEC_{nn,nnp} = STNDBY_{nnp} + EUSE_{nn} \quad (18)$$

Miscellaneous UECs

Miscellaneous energy uses include, among others, lighting, small appliances, power tools, and black and white televisions. Changes in the overall UEC of miscellaneous appliances are assumed to be explained by fuel prices and income elasticities, and also variations in persons per household. The base year (1977) average annual household energy consumption by fuel type for miscellaneous end uses is:

$$UECM_{f,t} = CONST + PCOEF * PPHH_{l,t} + AINC_{l,t} * Y$$

$$+ PRCOEF * FUELP_{f,n} / 100 \quad (19)$$

where:

Y = average annual household income
FUELP = fuel price
PCOEF = persons per household coefficient
AINC = income coefficient

PRCOEF = price coefficient
CONST = constant
f = fuel type index.

Subsequent year UECs are dependent on the previous year's UEC, persons per household, fuel prices and household income as follows**:**

$$PRICEEFF = ((FUELP_{f,t} - FUELP_{f,t-1}) / FUELP_{f,t-1}) * PELAS * UECM_{f,t-1} \quad (20)$$

$$INCEFF = ((HINC_{f,t} - HINC_{f,t-1}) / HINC_{f,t-1}) * IELAS * UECM_{f,t-1} \quad (21)$$

$$PPHHEFF = PCOEF * PPHH_{f,t} + PCOEF * PPHH_{f,t-1} \quad (22)$$

$$UECM_{f,t} = UECM_{f,t-1} + PRICEEFF + INCEFF + PPHHEFF \quad (23)$$

where:

HHINC = annual household Income
PELAS = price elasticity
IELAS = income elasticity.

General UECs

Refrigeration, gas cooking, and gas dryer UECs are estimated with empirically-derived equations. All others are estimated with one general equation.

General

The general equation relates energy use to persons per household and the average efficiency of new appliances. For n $\geq$ np:

$$UEC_{t,np}=AEI_{np} * (CONST + PCOEF * PPHH_{t,l})) \quad (24)$$

where:

AEI = average energy intensity relative to base year of appliances purchased in year np
CONST = constant
PCOEF = person per household coefficient.

Refrigerators

The average UEC of refrigerators is a market-share-weighted-average of UECs for standard and frost free refrigerator models and changes in the efficiencies of these models. UECs based on standards, i.e., after 1987, are adjusted upward by 5 percent to account for higher levels of field performance compared to laboratory tests.

$UEC_{t,np} = BASUEC * [DS_{np} * 0.600 * STNDRD_{np} +$

$(1 - DS_{np}) * 1.144 * FRFREE_{np}]$ (25)

$DS_{np} = 1.145 * e^{-0.0766 * (np+3)}$

Np = 1 in 1960

where:

BASUEC = average UEC of refrigerators in 1977, both models
DS_{np} = fraction of standard refrigerators purchases
$STNDRD_{np}$ = AEI of standard refrigerator
$FRFREE_{np}$ = AEI of frostfree refrigerator.

The constants 0.600 and 1.144, for standard and frostfree models, are derived from UEC's estimated under test conditions and average market shares of refrigerator sales from 1972 through 1986. Base year UECs were found to be 1,551 kWh/yr for frostfree models and 903 kWh/yr for standard refrigerators.

Gas Ranges

Gas Ranges are divided into stove top and oven categories for cooking because the impact of intermittent ignition device standards differ for those two applications. The following assumptions are made in the calculation:

Stove Top

1. Average number of uses is 1.14 (4/3.5) uses/person/day
2. Average length of use is 0.25 hrs.
3. Energy use per burner is 10,900 Btu/hr.
4. Pilot light use 300 Btu/hr.

Oven

1. Average number of uses is (0.6/3.5) 0.17 uses/person/day
2. Average length of use is 41 minutes = 0.68 hrs.
3. Energy used is 21,925 Btu/hr. when the burner is on.
4. Burners are on one-third of the time the oven is being used.
5. Pilot light use is 175 Btu/hr.

Changes in the efficiencies of stove top and oven affect the pilot light loss only. Annual cooking energy use is:

$UEC_{t,np} = [3964 * PPHH_{t,l} + (24.0 - 0.28 * PPHH_{t,l}) * 300$ (26)

$* TOP_{np} + (24.0 - .039 * PPHH_{t,1} * 175$

$* OVEN_{np})] * (36 / 10^5)$

where:

TOP and OVEN are efficiency indicators for the existence of pilot light losses for stove tops and ovens, respectively. After 1978, the values for ovens are zero to reflect mandatory use of intermittent ignition devices in new appliances. For stove tops, the regulations permit replacement and consequently are set to 0.3.

Gas Dryers

The UECs for gas dryers equal the energy consumed by the pilot light plus a load factor that is proportional to persons per household. Efficiency changes affect only the pilot light loss and are set to zero after 1978 to reflect mandatory use of intermittent ignition devices:

$$UEC_{t,np} = PCOEF*PPHH_{t,l} + PL_{np} \qquad (27)$$

where:

PCOEF = persons per household coefficient
PL = saturation-weighted average annual pilot light loss

Total and Auxiliary Energy Demand

Having computed appliance stock and UECs by purchase year for each year of the forecast, the calculation of total energy use for each end use is straight forward. Each age-specific stock surviving to the present is multiplied by the appropriate UEC and the products are then summed across all purchase years.

$$Q_{l,t}=\sum_{nnp=1}^{nn} A_{l,t,nnp} * UEC_{l,t,nnp} \qquad (28)$$

where:

Q = total energy use of fuel type f for each end use among houses of type l in zone Z for year t.

The miscellaneous end use has one product because this stock is not purchase year specific. Space heating and central air conditioning end uses are summed separately for each housing vintage.

Certain auxiliary or indirect energy uses must also be taken into account. Such supplementary end uses include electric fans associated with many gas space heaters and additional water heating energy associated with the ownership of automatic dishwashers and clothes washers.

The fraction of gas space heaters that are assumed to have a furnace fan is multiplied by the average UEC. A simple reduction factor can also be used to account for gains in fan motor efficiency over time.

$$FFSAT_t=GSHSAT_t * FFRAC \qquad (29)$$

Q_t=$FFSAT_t$ * $HOUSE_t$ * $FUEC_t$ * $RDUCTF_t$ (30)

where:

FFSAT=saturation of furnace fans
GSHSAT=saturation of gas space heaters
FFRAC=fraction of gas heaters assumed to have fans
Q=total electricity consumed by furnace fans
FUEC=average UEC of furnace fans
RDUCTF=conservation factor, reflecting a reduction in average UECs
HOUSE=housing stock

Indirect water heating use is calculated similarly for dish washing and clothes washing. Gas and electric water heating saturations and energy use are combined with the demand ratios to arrive at the water heating use attributable to automatic dish washing and clothes washing.

$IXSAT_t$=$XSAT_t$ * $WHSAT_t$ (31)

$Q_{l,t}$=$IXSAT_{l,t}$ * $INHWXW_{l,t}$ * $HOUSE_{l,t}$ (32)

where:

IXSAT=fraction of homes that have automatic dish/clothes washers that are supplied with water heated with a specific fuel type

XSAT = saturation of automatic dish/clothes washers
WHSAT = saturation of ift-fueled water heaters
Q = incremental water heating energy use associated with automatic dish/clothes washers

INHWXW=indirect water heating UEC for automatic dish/clothes washer

Data Requirements and Sources

This section describes the data requirements and sources for the residential model. Table 2-11 summarizes the data and sources required to run the household, appliance saturation and unit energy consumption components of the residential model.

Table 2-11

Residential Energy Forecast Model Summary of Data Sources

Household Component	Data Sources
Population	1
Persons per Household	1
Per Capita Income	1
Historical Housing Type Construction Shares	2
Projected Housing Type Decay Rates	3
1970 Housing Stock	4
Historical Housing Additions (1971 - 2003)	2
Appliance Stock Component	
1960 Appliance Stocks	5
1970 Appliance Stocks	6
Decay Parameters Appliance Lifetime	7
Beta	8
Saturations and Marginal Saturations	9
Retrofit Parameters	8
Price Elasticities	8,10
Unit Energy Consumption	
Space Conditioning Attributes and Penetration of Conservation	11
Base Year Consumption and Savings	12
Average Square Footage	13
Water Heating Equations	12
Constants	12
General UECs Central Gas Furnace Fans Clothes Washing Dish Washing Clothes Dryers Refrigerators Freezers Cooking Natural Gas Swimming Pool Heating Miscellaneous and Lighting Pool Filters and Sweeps	14

Source Notes for Table 2-11.

1. California Energy Demand: 1995-2015, Volume XII, Economic and Demographic Projections, July 1995, California Energy Commission.

2. Annual Publications of California Construction Review, Construction Industry Review Board.

3. Memo from S. Levy, Center for the Continuing Study of the California Economy, Housing Model Inputs, November 30, 1988.

4. 1970 Census, U.S. Department of Commerce, Bureau of the Census.

5. CFM II, Technical Documentation of the Residential Sales Forecasting Model: Electricity and Natural Gas, Main Text October 1979, California Energy Commission, P102-79-028, Chapter 5, pgs. 4-115a through 4-116.

6. 1970 Census of Housing, Sixth Count U.S. Department of Commerce Bureau of the Census.

7. CFM II, Technical Documentation of the Residential Sales Forecasting Model: Electricity and Natural Gas, Main Text, October 1979, California Energy Commission, P102-79-028 Chapter 5, pg. 4-140.

8. California Energy Commission Staff Judgment.

9. See Table 2-13, Sources of Saturation Data, in this chapter.

10. Anderson, K.P., Residential Energy Use: An Econometric Analysis, Rand Report R-1297-NSF, October, 1973.

11. California Public Utilities Commission, State-wide Saturation Survey on Weatherized Dwelling Units, San Francisco, CA, May 1987. (Revised and expanded version of original report issued May 1986).

12. Schultz, D., Measurement and Evaluation of the Energy Conservation Potential in California's Residential Sector, California Energy Commission, P400-83-026.

13. Utility Residential Appliance Surveys: 1989 for SMUD and 1990 for SCE, LADWP, SDG&E, PG&E and BGP.

14. CFM II, Technical Documentation of the Residential Sales Forecasting Model: Electricity and Natural Gas, Main Text, October 1979, California Energy Commission, 102-79-028, Chapter 5 pg. 5-1.

Household Component

Data requirements for the household component include historical values for and projections of population, persons per household and per capita income. Additional data include the number of households from the 1970, 1980 and 1990 Census, household additions from 1971-2003, housing type construction shares, county to climate zone allocations, and housing decay rates.

Estimates and projections of population, persons per household, and per capita income for each California county are provided by Economy.com, tailored to staff's needs.[4] The household component aggregates these county projections to the appropriate climate zones within each planning area.

California's household population in 1970 is from the U.S. Census. Household additions from 1971 to 2003 are from annual reports on California's construction trends published by the Construction Industry Research Board. Estimates of household type construction splits are derived in the model and input decay rates have been provided by the Center for the Continuing Study of the California Economy (CCSCE).

Appliance Component

Data required to support the appliance component of the residential model include historic appliance stocks, estimates of appliance lifetimes, decay rates, fuel price projections, decay function coefficients, appliance saturations, and user-defined constraints on marginal saturation.

Historic appliance stocks are derived from the 1960 Census. The 1960 data provide the starting point for modeling the appliance stock. The year 1960 is the first Census prior to 1970 with comprehensive data on household appliance stocks.

The projected residential fuel prices used in the saturation equations are projected by the staff. Natural gas prices are provided by the Natural Gas Office and electricity prices are furnished by the Electricity Analysis Office.

Appliance decay rates are estimated using a Weibull probability density function.[5] The parameters of the function are chosen such that appliance mortality rates yield appliance life expectancies currently used by staff in the residential model.[6] These are reported in Table 2-12 and are based on manufacturer's estimates of appliance lifetimes.

Utility surveys are the primary source of appliance saturation data. Saturation estimates for 1970 are derived from Census data by California counties. Table 2-13 lists the sources for this and other key years.

Utility surveys historically have requested basic information on residence type, appliances and equipment, heating and cooling systems, conservation measures, and household occupants, and energy consumption behavior. For residence type, the surveys request data on single-family, multi-family, and mobile homes. The appliance and equipment section asks for data on appliance and fuel types, and also asks whether the appliance has been purchased as a replacement (PM3 and PM4), purchased as a new addition (PM2), or not purchased (NPM). The heating and cooling system section requests information on furnace equipment and fuel types. In the conservation section, respondents are asked to report consumption behavior and conservation activities. The household and residents section contains questions on attributes of the home and the economic and demographic characteristics of the residents.

Formerly, the five largest utilities (PG&E, SMUD, SCE, LADWP, and SDG&E) routinely conducted surveys.[7] New data regulations allow the utilities and staff to cooperate towards completion of a single statewide survey which is to be compiled on a regular basis. Data for new homes (PM1) are derived from separate surveys[8] or by analyzing responses from occupants of new homes found in the service area wide surveys.

The staff's current forecasts for PG&E, SMUD, SCE, LADWP, BGP, and SDG&E benefit from the inclusion of the recently completed 2002 California Statewide Residential Appliance Saturation Survey (RASS). The appliance saturation and end use consumption estimates, which are a main product of the survey process, were compared to the appliance introduction and consumption assumptions in the residential model. This procedure allowed for verification of assumptions and adjustment where necessary, in order that the model accurately capture appliance introduction and replacement behavior.

Constraints on projected saturations are needed to keep certain appliances from achieving unreasonable penetrations. Constraints in the current version of the model are set at 1.0 except for refrigerators. Refrigerators are constrained at 2.0 for single-family and at 1.5 for multi-family homes and mobile homes.

Price elasticities are used to reflect the effects of price changes on forecasted saturations. The original source for price elasticity estimates is K.P. Anderson [1975].[9] Since then, Energy Commission staff has revised the values based on more recent data and included additional end uses.

Table 2-12

Comparison of Equipment Lifetimes

Appliance	Lifetime (years)
Dishwasher	15.50
Clothes Washer	12.31
Water Heater	11.16
Stove	19.03
Pool Pump	22.39
Space Heater (all housing types)	22.39
Dryers	15.00
Color Television	12.00
Central AC	15.00
Room AC	15.00
Evaporative AC	15.00
Refrigerator	20.00
Freezer	25.00

Unit Energy Consumption

Data for the UEC component are derived from several sources. Data used in the space conditioning model are from survey data or results from DOE 2.0 heat load analysis. Data for water heating UECs are derived from reports or surveys. Other UECs are estimated using conditional demand analysis.

Table 2-13

Sources of Saturation Data

Planning Area	Starting Year	Subsequent Years
PG&E	1970 Census for principal counties in PG&E	1977,1981, 1986, 1990 and 1995 RASS - and also the 1985 New Homes Survey - for average and marginal saturations
SMUD	1970 Census for Sacramento County	1977,1979,1981,1986 and 1989 Residential Survey
SCE	1970 Census for principal counties in SCE	1977,1979,1981,1983,1985, 1987 and 1990 Residential Survey
LADWP	1970 Census for Los Angeles City	1977,1981,1983, 1986 and 1990 Residential Survey
SDGandE	1970 Census for San Diego County	1977,1981,1983,1985,1987, 1989 and 1993 Residential Survey
BGP	1970 Census for combined cities of Burbank, Glendale, and Pasadena	1977,1981,1983, 1986 and 1990 portions of LADWP Residential Survey

Data required to estimate space conditioning UECs include housing attributes, penetration of specific conservation measures, and consumption data. As discussed above, housing attributes and conservation measures are from utility surveys and the CPUC statewide insulation survey.

Consumption data and savings per conservation measure are determined from output of the DOE 2.0 heat load model. This model provides an engineering estimate of consumption based on building characteristics and hourly weather data. Energy use is first estimated for a house without conservation measures. Conservation measures are then added incrementally; DOE 2.0 is used to estimate the new energy requirement of the house after each addition. The difference in energy requirement between each successive run provides an estimate of incremental energy savings for each measure. These savings are expressed as saving per square foot.

The weather data consist of solar, wind, and temperature data for a typical meteorological year (TMY). TMY data were used for all weather stations except Burbank and San Bernardino, which used Climatic Thermal Zone (CTZ) data. The CTZ data are from the year that most nearly represents the climatic mean (1940-1970) for that station. Table 2-14 lists the weather stations used for each climate zone.

Much of the data for the water heating UECs comes from Energy Commission reports.[10] The equations for hot water consumption are taken directly from work performed by Lawrence Berkeley Laboratory.[11] Constants for the equations are derived from research undertaken by the Energy Commission's Energy Efficiency and Demand Analysis Division in developing building standards. Energy use for hot water is a function of inlet water temperature, ambient temperature, and thermal characteristics of the tank. The data for the penetration of low flow showerheads, hot water heater blankets, and other conservation measures has been augmented with data from utility surveys.

The general equation for other UECs is estimated using ordinary least squares.[12] Data used in this estimation comes from utility billing data and residential customer surveys for approximately 70,000 households. The generalized UEC regression equation is then adjusted for average energy intensities of each particular end use. The average energy intensity is defined as the inverse of the efficiency relative to base year stock. Appliance efficiencies are derived from appliance standards using conditional demand regression analysis of survey and utility billing data from 1977.[13]

Assumptions for gas cooking and gas clothes drying are based on a 1977 study.[14] Constants in the cooking UEC equations come directly from this study.

The equation for refrigeration UECs assumes the total UEC is a weighted average of the UECs for standard and frostfree models. Data for the analysis are contained in a 1976 report from the Lawrence Berkeley Laboratory. The UEC was validated in 1987 by comparing model results with national sales data from 1972, 1978, 1981, and 1983-1986 provided by the Association of Home Appliance Manufacturers.

Table 2-14

Stations Used for Each Climate Zone for DOE2 Heat Load Runs

Climate Zone	Station	Data Type
1	Arcata	TMY
2	Sacramento	TMY
3	Fresno	TMY
4	Sunnyvale	TMY
5	Oakland	TMY
6	Sacramento	TMY
7	Bakersfield	TMY
8	El Toro	TMY
9	Burbank	CTZ
10	San Bernardino	CTZ
11	Long Beach	TMY
12	Burbank	TMY
13	San Diego	TMY
14	Mt. Shasta	TMY
15	Daggett	TMY
16	Burbank	TMY

Conservation Program Characterization

Numerous conservation programs have been initiated to effect energy consumption in the residential sector. The model does not directly quantify effects of each specific program because of the excessive detail required for such an exercise. The largest portion of program savings, including all mandatory standards, are included in the model. Table 2-15 lists programs quantified directly by the model. Previously issued staff reports document the characteristics attributed to these programs.[15]

The programs listed in Table 2-15 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 program 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.[16]

Table 2-15

Conservation Programs Incorporated in Residential Model

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
Miscellaneous Retrofit*
OII-42 Solar Subsidies
Pool Pump Timers

*Includes audit programs, low and no interest loan programs, direct weatherization, conservation tax credits, Energy Bank, and multiple family housing rental programs. These are committed Demand Side Management program measures.

The building standards are incorporated as part of the space conditioning UEC calculations. The method consists of executing DOE 2.0 with each new conservation 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 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, newspaper articles, and expected impacts of incentive programs or other related conservation programs.[17] 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, nonspace 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 referenced in a Energy Efficiency and Demand Analysis Division report.[18]

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 conservation measures and the EIF.

Endnotes

[1] The 2005 residential forecast for PG&E and SCE is for their service areas, rather than planning areas. Accordingly, some of the municipal utilities and irrigation districts in these two planning areas are not included in the forecast.

[2] See Energy and Resources Group, University of California. Documentation of the California Energy Commission Residential Energy Demand Model, Report No. ERG-82-6, December 1982.

[3] See Schultz, D. "Measurement and Evaluation of the Energy Conservation Potential in California's Residential Sector," California Energy Commission, P400-83-026, June, 1983.

[4] See California Energy Commission, *California Energy Demand: 1989-2009, Volume XII, Economic and Demographic Projections*, June 1989. P300-89-014; and, California Energy Commission, California Energy Demand: 1989-2011, *Economic Projections in Support of The Preliminary ER 92 Electricity Forecast,* July 1991.

[5] See Hausman, J.A., "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," Bell Journal of Economics, Volume 10, No. 1, Spring, 1979.

[6] See California Energy Commission, CFM II, "Technical Documentation of the Residential Sales Forecasting Model: Electricity and Natural Gas", Main Text, October 1979.

[7] Data for the BGP service area are extracted from LADWP surveys.

[8] See Pacific Gas and Electric Company, Energy Research Section, Economics and Forecasting Department, Characteristics of New Homes and Catalog of Saturations, June 1986.

[9] See Anderson, K.P., "Residential Energy Use: An Econometric Analysis," Rand Report R-1297-NSF, October, 1973.

[10] See Schultz, D. "Measurement and Evaluation of the Energy Conservation Potential in California's Residential Sector," California Energy Commission, P400-83-026, June, 1983.

[11] See Wright, J., et.al., "Supplying Energy Through Greater Efficiency," Lawrence Berkeley Laboratory, January 1981.

[12] See California Energy Commission, "Technical Documentation of the Residential Sales Forecast Model: Electricity and Natural Gas," October 1979.

[13] See George, Stephen. "Short Run Residential Electricity Demand: A Policy Oriented Look," Ph.D. Dissertation, University of California, Davis, 1979.

[14] See Harbict Research, Inc., "Study of Gas Appliance Usage," Southern California Gas Company, December 1977.

[15]See California Energy Commission, "California Energy Demand: 1985-2005," Volumes III to IX, P300-85-008 - P300-85-014, August 1985.

[16] Jaske, M.R., D.K. Schultz, T.A. Gorin, and L.W. Baxter, "Integration of Conservation Program Savings in Long-Run Energy Demand Forecasts," Proceedings from the ACEEE 1986 Summer Study, Vol. 8:134-46.

[17] Documentation is in the November 23, 1987 staff working paper, Insulation in the Pre-1975 Housing Stock: Historic, Current and Future Trends.

[18]See California Energy Commission, "Local Energy Planning Handbook," P400-81-036, November 1981.

CHAPTER 3

COMMERCIAL BUILDING ENERGY DEMAND FORECAST MODEL

Introduction

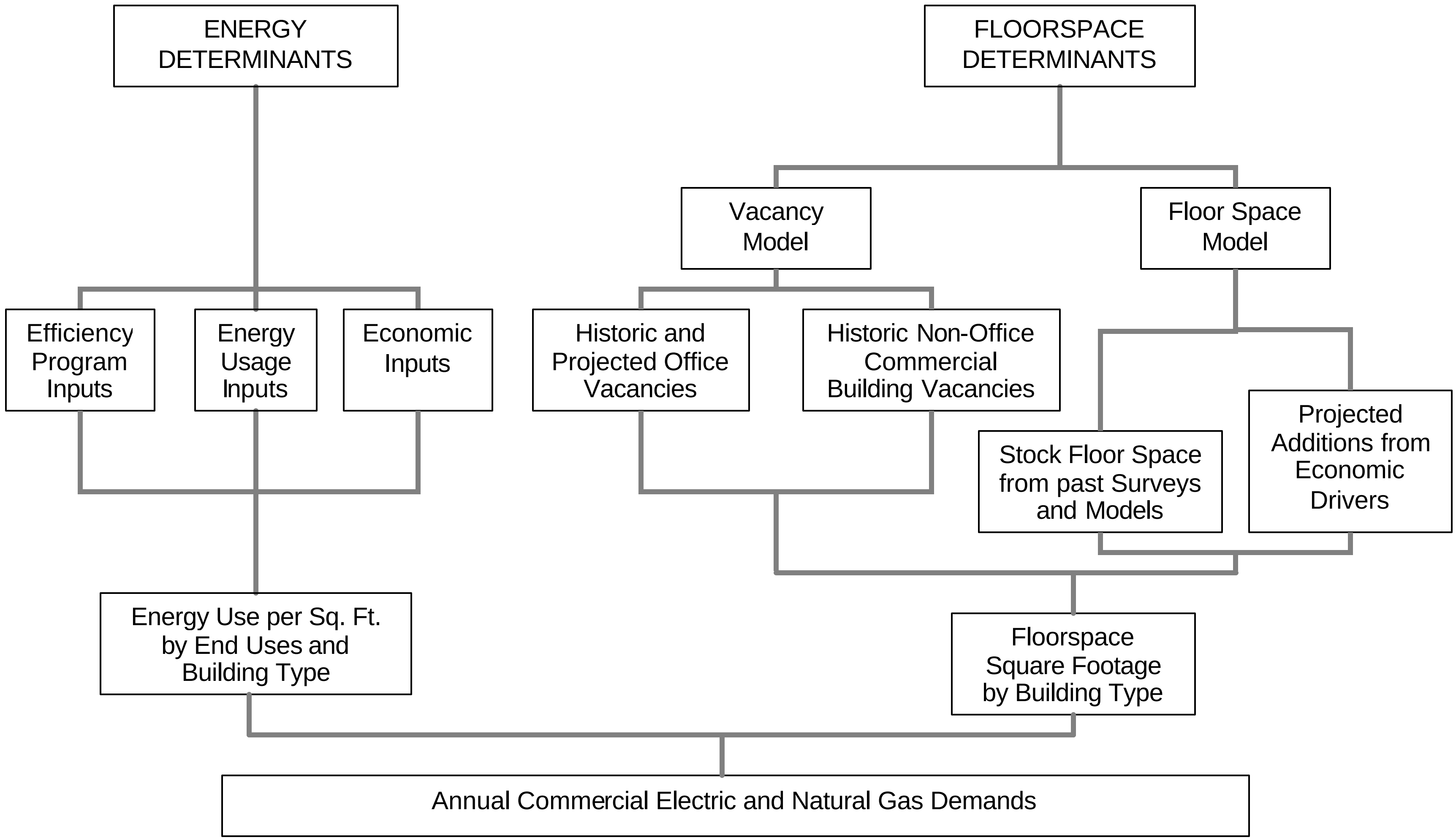
This chapter documents the Energy Commission's commercial sector forecast model (CECCFM). The commercial sector was responsible for more than 35 percent of total statewide electricity energy use in 2003, a share expected to grow slightly during the next two decades. Due to the sizable amount of electricity consumed and potential for energy conservation in the commercial sector, a substantial effort has been given to modeling its energy use characteristics. The effort began in 1978, when the Energy Commission staff adopted the theoretical structure of the J. Jackson commercial model developed at the Oak Ridge National Laboratory.[1] The Energy Commission staff subsequently modified the model to make it more applicable to the operating and policy environment of California's utilities. Particular emphasis has been paced on the model's ability to quantify building standard impacts and conservation program effects.

The CECCFM projects energy use for twelve building types, ten end uses, and three fuel types (Figure 3-1). As in previous cycles, a separate forecast is prepared for each of the seven major utility service/planning areas in California. Table 3-1 shows the breakdown of the twelve commercial building types by NAICS code. Table 3-2 shows the end uses which are modeled by fuel type within the CECCFM. The following section describes the key structural characteristics and modeling methodologies employed in the CECCFM. The treatment of energy prices, measurement of conservation, and the modeling of building and equipment decay are emphasized.

Data needed to run the model include economic data and engineering and statistical analyses. These data provide the basis for assessing trends in energy use and the penetration of new technologies and conservation measures in the commercial sector. Much of this data is obtained from surveys; the Energy Commission staff, in cooperation with the various utilities, regularly coordinates mail and onsite surveys of commercial buildings in each of the major California planning areas. These surveys, together with the above mentioned analyses, provide estimates of the parameters and input data utilized in the CECCFM. Additional data needs include electricity and gas retail rates, and consumption data. The specific data requirements and sources of these data are discussed throughout the chapter. Subsequent sections of this chapter discuss the data sources and estimation procedures for the floor space component of the model, review the energy use intensity (EUI) component, examine and document the fuel saturations, and review the estimation of fuel price elasticities.

Figure 3-1

Commercial Energy Demand Forecast Model



Source: California Energy Commission staff, May 2

Table 3-1

Commercial Building Types by NAICS Code

Building Type		NAICS Code*
1	Office-Small	115, 52, 531, 533, 5411-5412, 5414-5418, 55, 561, 6211-6213, 624 (6244), 813 (8131, 8134), 921, 923-927, 92812
2	Office-Large	
3	Restaurant	722
4	Retail Store	441-444, 446, 448, 451-454
5	Food/Liquor Store	445, 447 (44719)
6	Warehouse	421, 4221-4223, 4225-4229, 423, 4243, 4245-4249, 425, 493 (49312)
7	Refrigerated Warehouse	4224, 4242, 4244, 49312
8	School	6111, 6244
9	College/Trade School	6112-6114, 6116-6117
10	Health Care	6214-6219, 622-623
11	Hotel/Motel	721 (7212)
12	Miscellaneous	44719, 512, 514, 518-519, 532 (5324), 5413, 5419, 6115, 71, 7212, 811-812, 8131, 8134, 922

* Excluded NAICS codes in parentheses.

Table 3-2

End Use and Fuel Type Classifications

End use	Electricity	Natural Gas	Petroleum
Space Heat	X	X	X
Space Cooling	X	X	
Ventilation	X		
Water heating	X	X	X
Cooking	X	X	X
Refrigeration	X	X	
Indoor Lighting	X		
Outdoor Lighting	X		
Office Equipment	X		
Other	X	X	X

Theoretical Structure

The commercial building model used to produce the staff's 2005 forecast has the same basic structure as the one utilized in previous forecasts.

The work undertaken in support of the 2005 forecast continues to incorporate revisions to the forecasting methodology adopted for earlier analysis. For *Electrcity Report, 1994 (ER94)*, the major methodological change was the incorporation of vacancy rates into the model. This change resulted in improved backcasts for all planning areas. For the staff's 1995 forecast the major methodological change was the splitting of warehouses into refrigerated and non-refrigerated building types.

Vacancy rates were incorporated into the model used for *ER94* essentially as energy use modifiers. For previous *ER* cycles the basic structure of the Energy Commission's commercial forecasting model assumed that total energy consumption by building type was the sum of energy consumption of individual end uses. End use energy consumption was determined by the amount of floor space, the proportion of floor space receiving an end use energy service, and the type, efficiency and use of energy using equipment. The model computed energy use in forecast year "T" for a particular fuel, end use, and building type of vintage year "t", as:

$$Q_{T,t} = U75 * U_{T,t} * UTIL_{T,t} * F_t * A_t * d_{(T-t)} \qquad (1)^2$$

subject to

$UTIL_{T,t} > DLO$ (1a)
$UTIL_{T,t} < DHI$ (1b)
$U_{T,t} > EMAX$ (1c)

where

$Q_{T,t}$ = Energy use for a particular building, fuel, end use and vintage (t) in the current forecast year T.
U75 = Fuel use per square foot in 1975.
$U_{T,t}$ = Current EUI, relative to 1975, of equipment installed in year t in use in forecast year T.
$Util_{T,t}$ = Utilization rate of equipment installed in year t in use in forecast year T for a particular end use, fuel, building type and vintage.
F_t = Fuel share of equipment installed in year t.
A_t = Floor space of a particular building type added in year t.
$d_{(T-t)}$ = Fraction of floor space constructed in year t remaining in year T.

Total commercial building energy use is the sum of $Q_{T,t}$ across all buildings, fuels, end uses, and vintages. U75 are often termed the base year energy use intensities (EUI) and are fixed parameters. $U_{T,t}$ is the average efficiency for each end use, fuel, building type, and vintage.

Equation (1) is subject to a limit on the range of utilization rates; these are embodied in constraints (1a) and (1b); DLO and DHI are limited to 0.80 and 1.20, respectively. These limits had very little impact on the forecast results, as they were rarely reached.

Utilization rates are affected by both equipment efficiency and fuel price and will be discussed in this section below.

Constraint (1c) prevents equipment efficiency from reaching unrealistically low values. These limits differ by end use and fuel type. The model assumes the average equipment efficiency of a particular vintage to be a function of price, the rate of replacement of old equipment and the efficiency levels set by various building and equipment standards.

For *ER94* and subsequent forecasts, equation (1) was modified to reflect reduced energy consumption resulting from vacant buildings:

$$Q_{T,t} = U75 * U_{T,t} * UTIL_{T,t} * F_t * A_t * d_{(T-t)} * (1 - V_T) \qquad \text{(1 modified)}$$

where:

V_T = vacancy rate in the forecast year T.

This revision maintained full energy consumption due to outdoor lighting and 50 percent consumption due to indoor lighting within vacant or partially vacant buildings. For the 2005 forecast, these figures were revised to 50 percent and 5 percent, respectively.

Development of Vacancy Rates

There is no official historical record of vacancy rates. Reported vacancy rates are based on periodic surveys prepared for commercial leasing purposes; their scope and definition tend to vary from survey to survey. However, vacancy rates can be derived from employment data, creating a more consistently defined series.

The staff's vacancy rates were derived using the following methodology. First, building specific activity ratios were developed for each year of historical data. These included: office floor space per office employee, retail floor space per retail employee, warehouse floor space per wholesale employee, hotel floor space per employee, and miscellaneous floor space per employee. These activity ratios were then regressed against time and the results used to derive the average level of absorbed floor space. Finally, vacancy rates were derived as the deviation of absorbed floor space from total floor space plus a constant. The constant was added to prevent negative values and assumes that some floor space is held vacant as part of land managers' inventories. This methodology is illustrated in the following set of equations.

$$FS_t / EMP_t = C + b_1 * Year_t \qquad (2)$$

where

FS_t/EMP_t = activity ratio, expressed as square foot per employee.
$Year_t$ = trend variable (t = 1970 through 1993).

$$ABFS_t = FS_t / EMP_t * EMP_t \qquad (3)$$

where

$ABFS_t$ = absorbed (occupied) floor space.
EMP_t = employment.

$$VACY_t = (FS_t - ABSF_t)/ FS_t + k,\ 0.04 \_ k \_ 0.20 \quad (4)$$

where

$VACY_t$ = vacancy rate.
FS_t = floor space.

Treatment of Price Response

Energy prices affect energy use in two ways. In the short run, users' options are limited to reducing their uses of energy services, switching to different fuels (unlikely in the commercial building sector), and implementing low-cost conservation measures, such as insulation, solar films, shade screens, delamping, etc. In the long run, energy consumers in existing buildings can replace inefficient appliances with more efficient ones, in new buildings they can choose different energy service and/or commercial service technologies, switch fuels, and implement costlier conservation measures. The CECCFM keeps track of the retirement and replacement of buildings and equipment by vintage using decay functions. Thus, the energy use effects of the replacement of decayed equipment with newer and more efficient appliances can be estimated. Vintaging of equipment within vintages of buildings also permits the estimation of the effects of equipment efficiency standards. These two features of the model, short run and long run price responses, are discussed more completely below.

Price Responses of Utilization Rates

The utilization rate in the CECCFM, $UTIL_{T,t}$, is a usage index which is fuel, end use, building type and vintage specific. All utilization rates are initially set to 1 in the base year (1975). The utilization rate in subsequent years is assumed to vary depending on the levels of equipment efficiency, fuel price, and short run utilization (price) elasticities. For the forecast year T, the utilization rate of the equipment in buildings of vintage t is expressed as follows:

$UTIL_{T,t}$ = 1.0 for t = 1975, and (5)
$UTIL_{T,t} = U_{T-1,t}*[1.0-(P_T*U_{T,t}-P_{T-1}*U_{T-1,t})/P_{T-1}]*EU$ for t > 1975

where

P_T = fuel price at time T
EU = short-run utilization (price) elasticity.

The product of the energy price and efficiency is the cost of energy service at the end use level, and is often referred to as the "efficiency price." Since efficiency tends to improve when prices increase (see the discussion below), it is conceivable that an increase in price would lead to a decrease in the efficiency price and, thus, an increase in the demand for energy services.

Price Responses of Equipment Efficiency

The CECCFM tracks floor space for each building type, end use and vintage. Equipment is recorded in terms of floor space served rather than as discrete stocks.[3] Average efficiency is calculated for all equipment of a given end use. For example, space heating end use efficiency is determined for the composite of heat source, distribution and building shell elements. All $U_{T,t}$ values are bounded by zero and unity.

The ensuing discussion refers to equipment efficiency because this is the element most commonly improved. But, keep in mind that "equipment" is here regarded as the *composite* of factors governing consumption per square foot. To be specific, while the term "equipment" is used in discussion, this actually refers to floor space receiving an energy service.

Because equipment fails and is replaced by newer, more efficient models, the equipment (end use) efficiency [$U_{T,t}$ in equation (1)] is a weighted average efficiency of equipment installed in various years within a given building vintage. This vintaging of equipment within building vintages realistically calculates the effects of equipment decay, replacement, and the effect of price and equipment standards. The procedure for estimating the efficiency of equipment installed in new buildings differs from that used for older vintages. First, for a new building (vintage t = T), the efficiency of new equipment is affected by price and equipment standards. The two impacts are compared and only the higher impact is chosen. The impact of fuel price on the equipment efficiency is computed in a similar manner as the utilization rate:

$$UP_{T,t}=UP_{T-1,t}*[1.0-(P_T-P_{T-1})/P_{T-1}]*ee \qquad (6)$$

where

$UP_{T,t}$ = efficiency of new building equipment
ee = efficiency price elasticity.

The effect of efficiency standards (see discussion below) is then adjusted for noncompliance as follows:

$$US_{T,t} = (EUI79/U75)*PHASE_T+UP_{T,t}*[1.0-PHASE_T] \quad \text{for } t=T \qquad (7)$$

where

$US_{T,t}$ = efficiency of new commercial buildings due to the effect of the standard
EUI79 = efficiency specified in the 1979 standard
$PHASE_T$ = estimated standards compliance rate.

Equation (7) computes the average efficiency if a portion of the building stock of vintage T complies with the standards and the other portion follows market forces.

The CECCFM then selects the lower of the price and standard driven efficiencies:

$$U_{T,t} = \quad MIN[UP_{T,t},US_{T,t}] \qquad (8)$$

Thus, depending on the building vintage, the original equipment might be subject to a price impact or a standards impact. Once installed, it is assumed that the equipment efficiency, $U_{T,t}$ stays constant until it is replaced.

The treatment of the equipment efficiency of the older building vintages (buildings other than the vintage T) is more complicated as it considers both equipment decay and replacement. The equipment efficiency for any building vintage t (t < T) is the weighted average of the efficiency of the original and replacement equipment. The weights used are the fraction of the total stock of equipment that decays and is replaced in later years (see the section on Equipment Decay):

$$U_{T,t} = \sum_{i=t+1}^{T-1} W_{T,t,i} * EFF_{t,i} \quad 1964<t<T-1 \qquad (9)$$

where

I = equipment vintage (year of replacement);
t = building vintage;
T = current forecast year (1975 $\leq$ T $\leq$ Last Year);
$W_{T,t,I}$ = fraction of total equipment stock in building of vintage t being replaced in year i but still remaining at T
$EFF_{t,I}$ = efficiency of equipment replaced in year i in the building of vintage t.

For simplicity, we assume that all decayed equipment is replaced instantaneously and is of the same capacity and fuel type as the original equipment. Replacement equipment efficiency (EFF), however, can be different as it is subject to the equipment standards in effect in replacement years. Table 3-3 shows the seven vintages of equipment and buildings corresponding to the promulgation of standards in California. Building and equipment efficiency standards were initiated in 1979 and strengthened upon revision in 1984, 1992, 1998, 2001 and 2005. Replacement equipment efficiency is thus dependent on the year of replacement. Equipment replaced prior to 1979 in pre-1979 vintage buildings is subject only to the price effect. All other equipment replacements are subject to either a standards effect or the price effect, whichever yields the greater efficiency.

The treatment of replacement equipment efficiency thus is identical to that of new equipment in new buildings with additional computation for equipment replacement weights. However, for building shell related end uses, HVAC and lighting, replacement equipment efficiency is treated in a slightly different manner. For these end uses, replacement equipment installed in older buildings is not as efficient as it would be in newer buildings. For the building and equipment vintages not on the diagonal of Table 3-3, a separate replacement efficiency variable has been developed. For HVAC and lighting equipment replaced in the 1979-83 [1979<t<1983] period in a pre-1979 [t<1979] building, the replacement efficiency is calculated as follows:

$$EFF_{t,i} = R7579 * U_{T,t} * PHASE_T + U_{T,t} * (1 - PHASE_T) \qquad (10)$$

where

i = equipment vintage;
t = building vintage, i>t+1
T = current forecast year
R7579 = factor reflecting the increase in efficiency when installing equipment complying with the 1979 equipment standard in pre-1979 buildings
$U_{T,t}$ = efficiency of original equipment
PHASET = rate of compliance with the 1979 equipment standards.

Table 3-3

Energy Use Intensity of New and Replaced Equipment

By Building and Equipment Vintage

Building Vintage	Equipment Vintage			
	Pre-79	**79-83**	**84-91**	**92-97**
Pre-79	U75 reduced by price impacts	Smaller of price impact and 79 Stand adjusted for compliance rate and pre-79 bldg shell.	Smaller of price impact and 79 & 84 Stand adjusted for compliance rate and pre-79 bldg shell.	Smaller of price impact and 79, 84, 92, Stand adjusted for compliance rate and pre-79 bldg shell.
79-83		Smaller of price impact and 79 Stand adjusted for compliance rate.	Smaller of price impact and 79 and 84 Stand adjusted for compliance rate and 79-83 bldg shell.	Smaller of price impact and 79, 84, 92, Stand adjusted for compliance rate and 79-83 bldg shell.
84-91			Smaller of price impact and 79 & 84 Stand adjusted for compliance rate.	Smaller of price impact and 79, 84, 92, Stand adjusted for compliance rate and 84-91 bldg shell.
92-97				Smaller of price impact and 79, 84, 92 Stand adjusted for compliance rate.
98-00				
01-04				
Post-05				

Table 3-3 (Continued)

Building Vintage	Equipment Vintage		
	98-00	01-05	Post-05
Pre-79	Smaller of price impact and 79, 84, 92, 98 Stand adjusted for compliance rate and pre-79 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01 Stand adjusted for compliance rate and pre-79 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and pre-79 bldg shell.
79-83	Smaller of price impact and 79, 84, 92, 98 Stand adjusted for compliance rate and 79-83 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01 Stand adjusted for compliance rate and 79-83 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and 79-83 bldg shell.
84-91	Smaller of price impact and 79, 84, 92, 98 Stand adjusted for compliance rate and 84-91 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01 Stand adjusted for compliance rate and 84-91 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and 84-91 bldg shell.
92-97	Smaller of price impact and 79, 84, 92, 98 Stand adjusted for compliance rate and 92-97 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01 Stand adjusted for compliance rate and 92-97 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and 92-97 bldg shell.
98-00	Smaller of price impact and 79, 84, 92, 98 Stand adjusted for compliance rate.	Smaller of price impact and 79, 84, 92, 98, 01 Stand adjusted for compliance rate and 98-00 bldg shell.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and 98-00 bldg shell.
01-04		Smaller of price impact and 79, 84, 92, 01 Stand adjusted for compliance rate.	Smaller of price impact and 79, 84, 92, 98, 01, 05 Stand adjusted for compliance rate and 01-04 bldg shell.
Post-05			Smaller of price impact and 79, 84, 92, 01, 05 Stand adjusted for compliance rate.

An equation similar to (10) using variables R7584, R7592, R7984, R7992, R7998, R7901, R7905, R8492, R9801, R9805, R0105 computes changes for the other building and equipment vintage combinations not on the main diagonal of Table 3-3.

Treatment of Building and Equipment Decay

Decay of commercial buildings and equipment affects the energy forecasts in two ways. First, because the CECCFM keeps track of energy use by building and equipment vintages, and the energy efficiency and fuel shares differ by vintages, changes in decay rates affects the average energy efficiency and fuel share. Secondly, because California standards affect both new buildings and new replacement equipment in existing buildings, changes in building decay rates affect the construction of new replacement buildings and changes in equipment decay rates affect the rate of purchase of new replacement equipment. Thus, higher building and equipment decay rates would lead to faster introduction of newer and more energy efficient buildings and equipment and therefore a lower energy forecast.

Building and equipment decay are modeled with different functional forms in the CECCFM. Building decay is assumed to follow a logistic distribution function, while equipment decay is assumed to follow a Weibull distribution function.

Building Decay Function

As discussed in earlier sections, the CECCFM keeps tracks of all floor space vintages which make up the entire floor space stock at any forecast year T. For example, if the forecast year is 2010, the model keeps track of all floor space added from 1964 (the 1964 floor space represents all existing floor space in 1964) to the year 2010 adjusted for decay. Although commercial buildings vary widely in their decay characteristics, a simplified logistic function is assumed to be a reasonable representation of this decay behavior. Specifically, the fraction of commercial building still standing t years after construction can be approximated for 1964<t<last forecast year:

$$F_t = 1-(1/(1+\exp\{6.91-6.912/MNLIFE*t\})) \qquad (11)$$

where

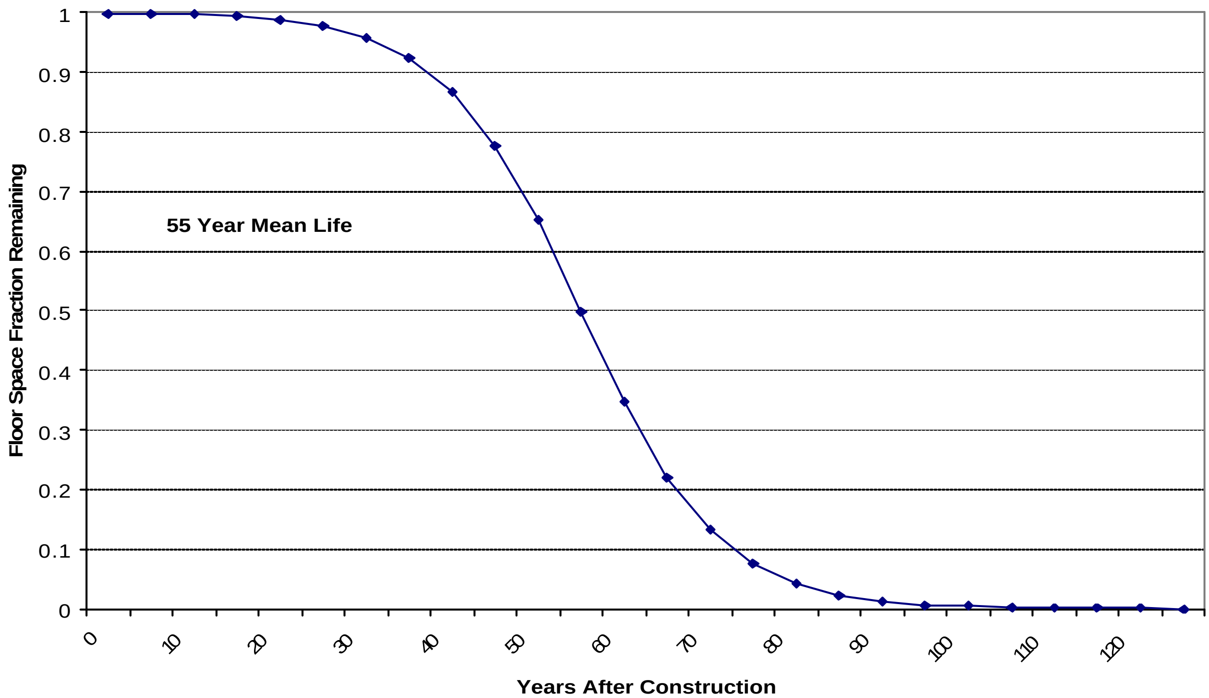
MNLIFE = mean life of a commercial building.

This is the same function chosen by Jackson[4] with the additional application of a mean life variable that is building type specific, rather than a constant 45 years. This function is graphically displayed in Figure 3-2 for a 55 and 75 year mean life. These graphs show a very low decay rate in the early years of building lifetime (less than 5 percent in the first 30 years) and a much faster rate in the latter years. The CECCFM is highly sensitive to changes in building decay rates. As such, the application of the decay equation and its interaction with the floor space regression equations is given a high degree of attention in the production of the floor space forecast.

In each forecast year, the fraction of 1964 vintage stock still standing t years after construction is also calculated utilizing equation (11), with the addition of an average age variable to t. The average age variable is defined as the average age of the 1964 stock in 1964. The mean life and average age of the stock in 1964 for the major California planning areas assumed in the staff's 2005 forecast are shown in Table 3-4.

Figure 3-2

Logistic Building Decay Function



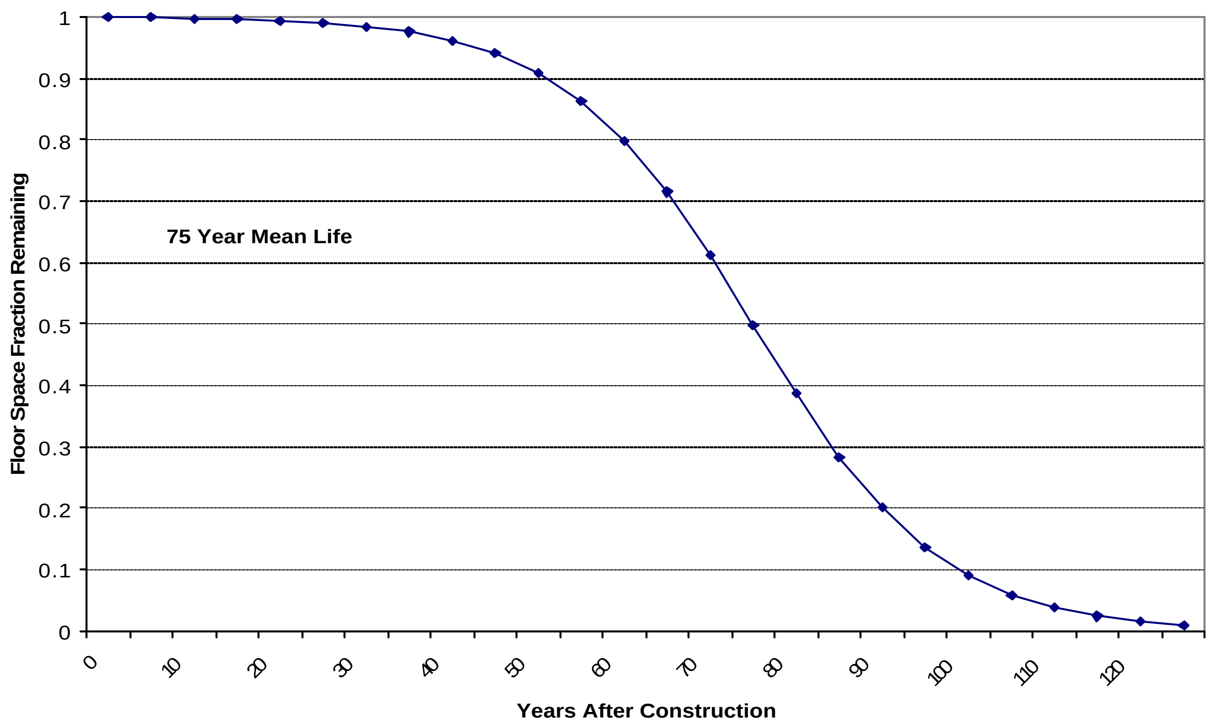


Table 3-4

Mean Life of Commercial Buildings and Average Age of 64 Stock for the Building Decay Equation

	PG&E						SMUD		SCE	
Building Type	Average Age					Mean Life	Average Age	Mean Life	Average Age	Mean Life
	z1	z2	z3	z4	z4	all zones	z6	z6	all zones	all zones
-------------	---	---	---	---	--	---------	-----------	---------	-----------	---------
Small Office	10	12	13	15	15	55	5	45	15	55
Restaurant	2	4	6	8	8	55	10	45	10	55
Retail	6	8	10	10	10	55	18	45	18	55
Food Store	6	8	10	10	10	55	18	45	18	55
Warehouse	6	8	10	10	10	55	20	45	20	55
Refr. Warehouse	6	8	10	10	10	55	5	65	20	55
School	5	5	5	5	5	65	10	65	10	75
College	6	6	6	6	6	65	10	65	10	75
Hospital	6	8	10	10	10	65	15	65	15	75
Hotel	6	8	10	10	10	55	5	45	20	55
Miscellaneous	6	8	8	8	8	55	5	45	16	75
Large Office	6	8	10	10	10	55	10	45	10	55

	LADWP			SDGE	
Building Type	Average Age		Mean Life	Average Age	Mean Life
	z11	z12	all zones	z13	z13
-------------	--------	------	---------	-------	---------
Small Office	15	15	55	15	55
Restaurant	10	10	60	12	55
Retail	18	18	55	20	55
Food Sto re	18	18	55	20	55
Warehouse	20	20	55	20	55
Refr. Warehouse	20	20	55	20	55
School	10	2	70	10	65
College	10	10	70	12	65
Hospital	10	10	70	20	65
Hotel	20	20	55	20	55
Miscellaneous	16	16	55	20	55
Large Office	10	10	55	10	55

Equipment Decay Function

Equipment decay adds an additional time dimension and complication to the above building vintage problem. Consider the forecasting year 2010. The total floor space stock in 2010 consists of floor space additions constructed between 1964 and 2000 and any stock constructed before 1964 still remaining. Equipment installed in each of these building vintages decays and must be replaced in subsequent years.

A major distinction between the structure of the CECCFM and its predecessor is the use of an end use specific equipment mortality algorithm. The average efficiency of appliances changes over time so that knowledge of the age distribution of the appliances is essential to accurately assess how efficiency changes affect aggregate energy use in both new and old buildings.

The CECCFM assumes that decayed equipment is replaced with a new model of the same fuel type and that total replacement equals total decay; i.e., owners will always opt to replace rather than do without.

The decay algorithm models equipment as probabilistic entities that fail through a random process. The curve representing percentage failure is assumed to be normally distributed with a mean life for each appliance and a standard deviation of one third (consistent with industry practice). Due to numerical difficulties in computing normally distributed characteristics, a more general probability density function, the Weibull, is used. Given the appropriate parameters this density function is a close approximation to the normal distribution.

The Weibull probability density function is defined as

$$p_t = bt^{b-1}\exp(-(t/L)^b)/L^b \qquad (12)$$

where b and L are generating parameters. The mean (M), variance (a^2), and median (m) are given by:

$$M = L*G((1+b)/b) \qquad (13)$$

$$a^2 = L^2*[G((2+b)/b)-(G(1+b)/b))^2] \qquad (14)$$

$$m = L(-\ln(0.5))^{1/b} \qquad (15)$$

where G is a gamma function G(v) = (v-1), and b is a dimension less positive number determining the shape of the distribution. For the special case b=1, the Weibull distribution is the simple exponential distribution. Equating mean and median, as for the normal distribution, then b = 3.25 with which the Weibull closely approximates the normal. Therefore, for appliances in buildings built after 1964, the appliance decay function takes the form:

$$g_{T-t} = \exp\{-((T-t)/L)^b\} \qquad (16)$$

where T-t reflects the age of the appliance, and g is the survival fraction (g = 1-Weibull cumulative distribution function).

The appliance decay process is different for the 1964 building stock because the 1964 floor space contains buildings of different vintages. We assume that the stock of appliances in 1964 is in equilibrium and normally distributed. This means that an identical amount x was purchased in every year t<1964 that just equaled the sum of decay from all years previous to the purchase year. Equation (17) represents the stock of appliances in 1964 according to these assumptions:

$$X_{1964} = x \int \exp\{-(-t/L)^b\}\, dt \quad (17)$$

$$= x*L*G((1/b) + 1)) \quad (18)$$

a population characterized by a mean age, M, determined as:

$$M = \frac{x \int t*\exp\{(-t/L)^b\}\, dt}{x \int \exp\{(-t/L)^b\}\, dt} \quad (19)$$

$$= (L/2) * G((2/b)+1) / G((1/b)+1) \quad (20)$$

which can be approximated:

$$= L/2 \quad (21)$$

To compute the total population at any arbitrary year 1964 + T requires that:

$$X_{(1964+T)} = \int x*\exp\{-((T-t)/L)^b\}\, dt \quad (22)$$

Solving equation (17) for x and substituting with equation (19):

$$X_{(1964+T)} = \int \frac{X_{1964}*\exp\{-((T-t)/L)^b\}}{L*G(1/b+1)}\, dt \quad (23)$$

This form of equation can be solved numerically using one of several alternative integration techniques. In this case, Simpson's Rule was followed, iterating until sufficient accuracy was achieved.

This subroutine develops a lower diagonal matrix of the following form for each building vintage floor space A_t.

In Table 3-5, Column 1 represents the decay of the original equipment purchased in construction year t. Moving down the column, we move through current years, moving across to the diagonal we move through purchase years. The decay of say W(t,t) to W(t+1,t) is represented as replacement purchases in year t+1 by W(t+1,t+1). This amount then follows its decay pattern down the column and adds to total replacement needs in subsequent years. In this manner, the diagonal elements represent the total replacement purchases for vintage floor space A_t. It is assumed that replacement is always opted in lieu of doing without, and furthermore that the same fuel type is retained; no fuel switching occurs when replacing units.

Table 3-5

Equipment Decay Rates

Years After Const.	Year of Equipment Purchase				
	0	1	2	...	M
0	W(t,t)				
1	W(t+1,t)	W(t+1,t+1)			
2	W(t+2,t)	W(t+2,t+1)	W(t+2,t+2)		
	. . . .	. . . .	. . . .		
m	W(t+m,t)	W(t+m,t+1)	W(t+m,t+2)	...	W(t+m,t+m)

The row values at T define the distribution of appliance stocks by purchase year for a given vintage floor space At (the elements of the row sum to 1.00). The efficiency (EUI) of each vintage floor space At estimated at the forecast year T is a weighted average of the efficiencies of the remaining original equipment and replacement equipment. The weights used are the cells of the Tth row of the above equipment replacement matrix.

$$U_{T,t} = \sum_{i=t+1}^{T-1} W_{T,t,i} * EFF_{t,i} \quad \text{for } 1964<t<T-1 \qquad (24)$$

where

U = average efficiency of floor space of vintage t
W = the cell of the Tth row of the replacement matrix above
E = efficiency of the equipment purchased in year i.

New HVAC equipment put in older buildings does not have the same characteristic consumption as new equipment installed in a new building. The difference is due to performance variations in the HVAC distribution system and the thermal integrity of buildings of different vintages. Therefore, E is adjusted by weighting the purchase year value with last periods average EUI. The weights are based on the effect that post standard (>1979 purchases) equipment has when installed pre-standard buildings. Buildings built after 1979 always utilize the same energy consumption characteristics for original and replacement equipment.

Conservation Program Savings

The conservation programs that affect the commercial building sector for the staff's 2005 forecast are listed in Table 3-6. Conservation program savings analysis must be closely coordinated with the specific fashion in which the CECCFM operates. A primary concern is with the pervasive nature of price response in the model. As discussed earlier, the CECCFM models a short-run price response affecting the utilization rate of existing equipment and longer-run price response affecting the choice of the efficiency of new and/or replacement equipment. Conservation program savings are measured as net savings in addition to price response. The remainder of this subsection provides a brief description of the methodological approaches utilized to estimate the net savings from these programs.

Table 3-6

Conservation Programs Quantified

2005 Forecast

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

1978 Title 24 Nonresidential Building Standards

Also known as the "first generation building standards", these applied to all commercial buildings for which permits were issued after July of 1978. These standards (and all subsequent building standards) were applied to the building in two ways, a prescriptive and a performance approach. The prescriptive approach specified certain minimum building characteristics, such as insulation levels, percent glazing, and building shading, which affect the energy efficiency of the envelope. Also specified were minimum equipment intensity levels for lighting, HVAC, and water heating. The performance method, on the other hand, allows the tradeoff of energy components within the building based on the achievement of a minimum overall building energy use per square foot index. This is accomplished by means of simulating the building's energy performance with an Energy Commission approved computer simulation model. This method is more flexible from a design perspective, allowing, for example, the tradeoff of additional glazing with a higher efficiency air conditioner.

1978 Title 20 Equipment Standards

These standards applied to air conditioners, heat pumps, refrigerators and freezers, water heaters, and gas space heaters. All buildings constructed after 1978 were required to install such equipment with minimum efficiencies in compliance with these standards. These standards also applied to the replacement of equipment stock in existing buildings.

1984 Title 24 Nonresidential Building Standards (offices)

Also known as the "second generation standards", these affected all commercial buildings classified as offices constructed after 1984. Regulations were voluntary until 1987, at which time they became mandatory. These standards affected the heating, cooling, ventilation, and lighting end uses and involved more stringent energy budget and minimum efficiency requirements for this building type than the 1978 standards.

1984 Title 20 Equipment Standards

These standards affected all residential size refrigerators, freezers, fluorescent lighting ballasts, and central air conditioners used in commercial buildings. Program savings are estimated as a function of equipment life, the total stock of appliances, the portion of the stock affected by the standards, and the per unit impact of the standards.

1985-1988 Title 24 Nonresidential Building Standards

These standards represent the balance of the "second generation" of the Title 24 standards initiated in 1984. These were phased in and applied to the conditioning, lighting, and water heating end uses in retail buildings, restaurants, and food stores.

1992 Title 24 Nonresidential Building Standards

This set of regulations can be considered as a consolidation and reorganization of the first and second generation nonresidential standards. They are intended to streamline and simplify the process of energy compliance for most building types. Both the prescriptive and performance methods are preserved; however, the concept of the energy budget in the performance method is replaced by an "allowable" budget which is calculated for each proposed building design independently. The allowable budget is obtained by simulating the energy characteristics of the proposed design and comparing the results with a simulation of the same building with the specifications of the prescriptive standards (insulation, glazing, equipment efficiency, etc.) applied instead. These simulations establish a "proposed" budget and an "allowable" budget for that building. To pass, the proposed energy budget must be equal to or less than the allowable budget.

This system is similar to the performance methodology employed for the residential standards. Energy compliance must be demonstrated with Energy Commission approved energy simulation programs.

1995 Title 24 Nonresidential Building Standards

The 1995 revisions to 1992 building standards were limited to compliance and implementation issues and correcting inconsistencies and typographical errors. Therefore, the 1995 Nonresidential Building Standards have not been included in the commercial forecast model.

1998 Title 24 Nonresidential Building Standards

The 1995 and 1998 standards mainly focused on compliance and implementation issues. The major change for 1998 standards was the reduction of Lighting Power Densities (LPD) from previously allowable values. This change was implemented to account for substituting T-8 lamps with electronic ballasts for T-12 lamps with magnetic ballast.

2001 Title 24 Nonresidential Building Standards

Following the 2000-2001 energy crisis, the legislature responded by passing AB 970, which mandated that the Energy Commission adopt updated standards. The main changes embodied in the 2001 standards include: the U-factor and SHGC for fenestration were updated; a credit for cool roofs was added that can be used with both performance and prescriptive approaches; the HVAC equipment efficiency requirements were updated to match the ASHRAE/IESNA Standard 90.1-1999.

2005 Title 24 Nonresidential Building Standards

The 2005 standards were adopted July 21, 2004 and will take effect October 1, 2005. The following is a list of the major changes in the 2005 Standards as they pertain to the commercial forecast model: the allowable Lighting Power Densities (LPD) for offices, retails, schools, colleges, and hotel/motel buildings have been reduced; energy efficient lighting requirements for unconditioned buildings (parking garages and warehouses); new federal air conditioner (residential sizes) and water heater standards; outdoor lighting power allowances are established for outdoor illumination applications. The lighting power allowances are established for four specific Lighting Zones (national and state parks, rural areas, urban areas, highly lit areas).

The adoption of the nonresidential building standards necessitates that their impacts be included and accounted for in the forecast. These standards supersede the 1975 (base year) building characteristics and affect all building types except health care facilities. Beginning with “first generation building standards" (1978), the impact on the forecast is assessed by means of applying an adjustment factor to the U75 value (base year EUI). The method employed is the same as that utilized for the adjustment due to the 1978 and 1984 standards.

The standards are assumed to primarily affect the heating, cooling, ventilation, indoor and outdoor lighting, water heating and refrigeration end uses. The values for the adjustment factors were obtained from various sources including: DOE-2 simulations, various Energy Commission publications and in consultation with the staff of the agency’s Buildings and Appliances Office. The adjustment factors are listed in the discussion on EUI's.

Federal Schools and Hospitals Program

The National Energy Conservation Policy Act of 1978 established a federal/state program of grants and low cost loans to assist schools, hospitals, and municipalities in the installation and retrofitting of energy conservation measures and cogeneration projects. Several cycles of grant applications and awards have already occurred in California. Each customer seeking to obtain assistance is required to have an initial audit conducted for their facility. Applicants for grants can seek funds for technical audits and for financial assistance to install cost effective conservation measures. Savings from this program are calculated by the Energy Commission's Energy Efficiency and Demand Analysis Division.

Commercial Load Management Audits

The Energy Commission Nonresidential Load Management Standard established a commercial building sector audit program for the five major electric utilities in California. The audit program provided for utility representatives to analyze the feasibility of and recommend cost effective energy conservation measures to commercial customers. Post-audit visits by utility representatives were utilized to determine what measures each customer has implemented.

Quantification of the effect of this program was based on initial audit and post-audit reports and data gathered from the utilities. Energy savings per square foot for each end use affected are multiplied by the amount of floor space to be audited in the future to yield annual estimates of gross audit savings.

Since customers are responding to price levels as well as audits, the gross savings are adjusted to take into account any reduction in energy use from price that would have occurred in the absence of the program. Audited customers were assumed to be representative of average customers and standard short-run price and efficiency elasticities are, therefore, used in these calculations.

Commercial Retrofit Incentives Programs

These programs affect all nonresidential customers classified as "commercial" served by the five major utilities. The programs are designed to offer financial assistance in the form of rebates to customers who install, or retrofit existing equipment with, energy efficient devices on their premises. Such programs are intended to target measures which involve high initial costs and/or long payback periods, which would discourage most customers from applying these measures on their own. The end uses affected include lighting, heating, air conditioning, ventilation, water heating, cooking, refrigeration, and other.

Although all commercial utility customers are eligible, participation is assumed to differ among the customer classes with more weight given to the high demand rate classes; limited to buildings constructed prior to 1980. Targeted floor space is estimated as portions of the eligible floor space participating in the incentives program.

In summary, the following considerations are taken into account when all the aforementioned conservation programs are quantified in the CECCFM.

- Each set of standards and each program affect specific building types and end uses.

- Title 20 appliance standards specify minimum efficiency levels for various types of equipment.

- Title 24 building standards generally specify minimum construction standards (prescriptive approach) or maximum/allowable energy budgets (performance approach) for different occupancy types (per the Uniform Building Code).

- The prescriptive approach is generally used to develop EUI modifiers which are then input into the CECCFM.

- EUI modifiers for most end uses are developed using building energy simulation models.

- 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 Energy Efficiency and Demand Analysis Division of the Energy Commission. These total savings are then shared equally among the end uses in these building types.

- Savings are quantified by iteratively executing the CECCFM and successively removing the effect of each standard and/or conservation program.

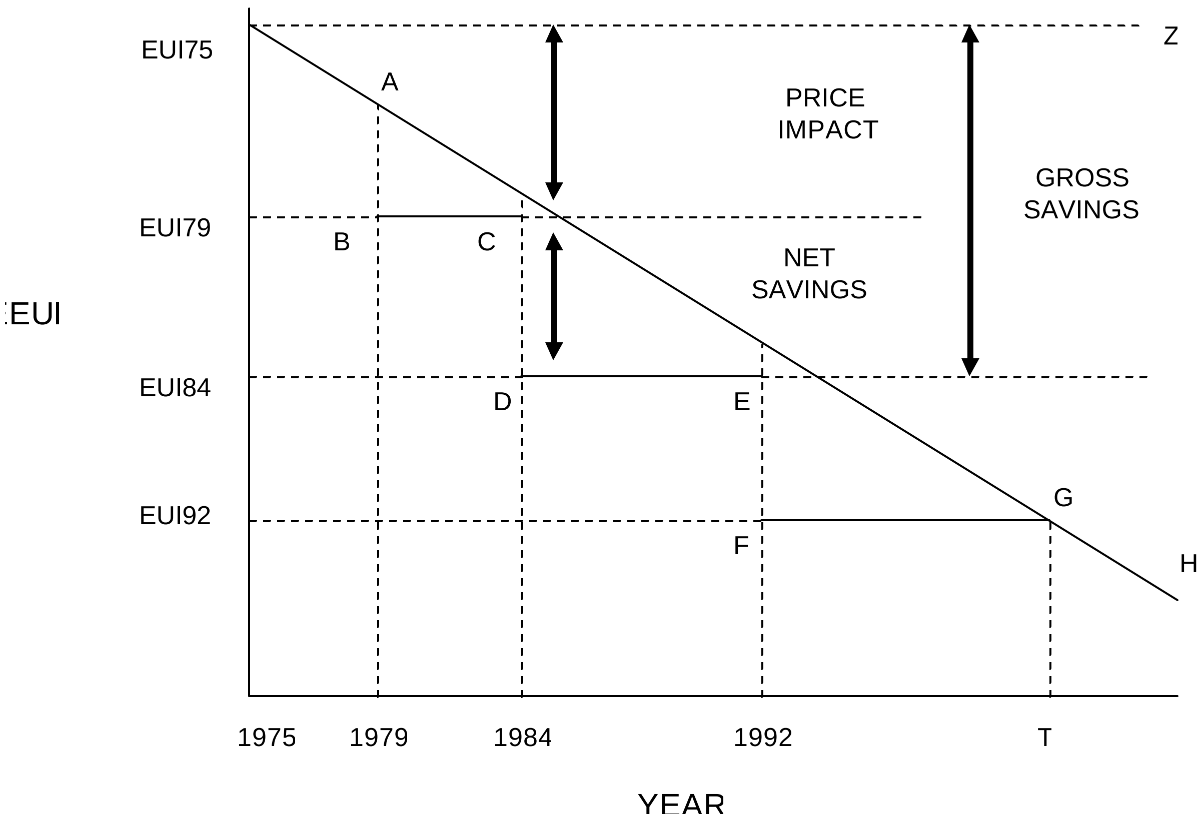
- The results of each run are then subtracted from the preceding one to obtain individual program savings estimates.

Figure 3-3 provides a qualitative view of the modeling technique employed within the CECCFM to capture the effect of the building and appliance standards. All post 1978 construction enters the energy equation with lower EUIs. Because price increases (or decreases) also induce changes in the EUI, a comparison is made between the standards and price effect and the lower of the two values is selected. Thus, conservation standards have an impact on the forecast only when the standards induce a greater efficiency than price increases.

Figure 3-3 provides an illustration of the methodology. With neither standard nor price impacts, the marginal EUIs for post standard construction (post 1975 in the model) are denoted by the EUI75-Z line. With increased prices, the marginal EUIs for 1975-1979 buildings would follow the U75-A line. Since the 1978-79 building standards (represented by the line EUI79-C) induce greater efficiency than price, the marginal EUI's for the 1979-1984 vintage buildings would follow line B-C. This pattern is repeated for the subsequent standards, with the actual value following the line EUI75-A-B-C-D-E-F-G-H.

Figure 3-3

Energy Use Intensity in Commercial Buildings



To summarize:

- All post 1978 floor space subject to the provisions of Title 24 enters the energy equation 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 CECCFM to keep track of both building and equipment vintages as well as equipment replacement rates.

Climate Zone Forecasts

The model and its inputs were modified to produce the commercial forecast at the climate zone level rather than the "regional" level employed for past *ER* cycles. This modification was made to match the output from the CECCFM with that of the residential model and more directly in line with the requirements of the peak model. As a result, the matrix employed to convert the previous regional output to the climate zones for use with the peak model is no longer necessary and has been eliminated.

Table 3-7 contains a listing of the climate zones by planning/service area as well as the weather station used to represent average climatic conditions in each zone. The county to climate zone share matrix utilized to apportion or aggregate economic data into the proper climate zones is the same one utilized by the residential model.

Office and Other Equipment Growth Rates

The growth of office equipment energy use emerged as a prominent factor in *ER90*. Consisting of all electronic data processing equipment, such as computers, copiers, fax machines, and printers, this end use is responsible for a large portion of the growth in energy use intensity in commercial buildings during the past twenty years. This trend is expected to continue and must be accounted for in the forecasts. As has been the case since *ER90*, the CECCFM allows for the modeling of office equipment energy use as a separate end use.

For each planning/service area, a growth rate matrix is applied to office equipment as a function of building type and time period. The historical growth rates are developed from consumption data, while the forecasted growth rates are estimated using staff judgment. The growth rate assumptions are high in the historical and early periods of the forecast followed by a slow down and leveling off of the EUI growth for both end uses as the forecast progresses. The underlying assumption for this trend is that as office equipment nears full penetration into the market, new equipment and equipment turnover will be characterized by higher efficiency technology and lower energy use per device. The application of a variable growth rate matrix by building type and period provides for much better control and limitation on the growth and impact of this end use.

Table 3-7

Climate Zones by Planning/Service Area

Planning Area	Climate Zone	Weather Station
PG&E	1	Arcata
	2	Sacramento
	3	Fresno
	4	Sunnyvale
	5	Oakland
SMUD	6	Sacramento
SCE	7	Fresno/Bakersfield
	8	LAX/Long Beach
	9	Burbank/Hollywood
	10	Norton AFB
LADWP	11	LAX/Long Beach
	12	Burbank/Hollywood
SDG&E	13	San Diego
OTHER	14	Mount Shasta
	15	Norton AFB
BGP	16	Burbank/Hollywood

The office equipment end use was previously included in a general miscellaneous end use category. For *ER92*, the miscellaneous end use was renamed "other" to differentiate between the more general miscellaneous category still employed by most utilities in their forecasts. The "other" end use includes escalators, elevators, pool heaters, laundry equipment, laboratory equipment, and any energy using device not included in the definition of the other nine end uses.

In previous *ER* cycles, the "other" end use was assumed to grow at a constant two percent for all building types during the entire forecast period. Beginning with the staff's 1995 forecast, a growth rate matrix similar to that utilized for office equipment has been applied to the "other" end use. Although the growth rates are much smaller for this end use, the initial EUI (U75) values are generally much larger.

Internal Heat Gain Impacts on Heating and Cooling

The growth of the office equipment and "other" end uses produces additional heat load into the conditioned space for all building types. To adjust for this additional load, the heating and cooling end use energy values are adjusted downwards and upwards, respectively. These adjustments are made by splitting the annual energy use due to the growth of office equipment and "other" end uses into a heating and cooling season portion based on the climate zone. Only the growth portion requires adjustments because the base level was addressed in preparation of base year HVAC end use EUIs. Following the split, the additional load is then converted to heating and cooling energy by means of dividing by an average heating and cooling equipment efficiency representing the stock of such equipment in each planning area.

Floor Space

The staff's commercial floor space projections for the CED 2006 forecast were derived utilizing regression analysis as well as historical averaging techniques. The equation specification process and data required to run the regressions that constitute the floor space model are discussed in this section.

Major characteristics of the staff's floor space methodology are:

- The model projects floor space stock values, while deriving projected additions as a residual.

- The model forecasts floor space stock for each of twelve individual building types in 16 climate zones.

- Economic and demographic data, as well as floor space additions data, is collected at the county level and aggregated to the climate zone level.

- This data, along with base year stock and assumed decay rates, is used to create historical floor space stock, which then becomes the dependent variable in the regressions.

The model forecasts building completions rather than starts.

Data Sources

Staff's floor space forecasting process requires several data inputs: base year floor space stock, economic and demographic data, and historical floor space additions

Base Year Floor Space Stock

Commercial surveys performed in 1982 by PG&E, SCE, and LADWP were the basis for the estimates of the base year floor space stock values for each of these utilities. SMUD's base year value is based upon its 1990 commercial survey; the value for SDG&E is based upon its 1991 survey. In each case, the base year for modeling purposes is the year the surveys were undertaken. Floor space stock base year values for the BGP and the OTHER planning areas were developed using data from Quarterly Fuel and Energy Reports (QFER) and comparison ratios of historical energy model runs; the base year for these planning areas is 1982.

Economic and Demographic Data

Population and sales data are the primary demographic and economic drivers, respectively, for the floor space model.

The source of demographic data used in the floor space model is Economy.com. School age population, ages 5 through 17 and the population of those 65 years of age and older are accompanied by personal income.

Total population is a descriptor of floor space need in general, and certain populations describe the need for specific building type floor space. For example, the population of ages 5 through 17 can be described as “school age” population, describing the current and future need for both schools at the kindergarten through high school and college levels.

Sales data restaurant sales, retail sales, and total sales are provided by the State Board of Equalization. These taxable sales data are used as a proxy for commercial output, signifying the relative strength of the commercial economy. Analogous to specific populations describing specific commercial floor space needs, certain sales data can describe specific needs as well; e.g., retail floor space stock is dependent upon retail sales data restaurant sales drive restaurant floor space.

Floor Space Additions

Floor space additions from 1965 through 2003 have been provided by the F. W. Dodge Company. These “Dodge additions” are based upon a record of county building permits issued for which construction has begun or is scheduled to begin within 90 days. The Dodge additions data are inputs to the floor space model as building completions, as Dodge has developed an algorithm with which to estimate the completion dates of floor space stock based upon the dates of permit issue and beginning of construction.

SIC, NAICS and Dodge Codes

The staff expended considerable effort mapping the Dodge Codes, which describe the economic purpose of the buildings for which permits are issued, to the Standard Industrial Classification (SIC) codes by which staff allocates building types. The use of North American Industrial Classification System (NAICS) codes in lieu of SIC codes requires an additional mapping; this effort is currently underway. An initial attempt is illustrated in Table 3-8.

Share Matrix

Both the Dodge additions and economic and demographic data are collected at the county level. Deriving floor space at the climate zone, and ultimately utility service area, levels necessitates an aggregation of this data. Fifty seven of California’s fifty eight counties are either wholly in one climate zone or split between two climate zones. Los Angeles County is split between five climate zones which represent three utility service areas climate zones 8 and 9 are in SCE’s service area; climate zones 11 and 12 comprise LADWP; and climate zone 16 is BGP. The splits of these counties are displayed in Table 3-9. The shares used to aggregate county level economic, demographic, and Dodge additions data to the 16 climate zones are presented in Table 3-10.

Los Angeles County Dodge additions were split among LADWP, SCE, and BGP in two steps. First, LADWP's share of Los Angeles County additions are based upon dollar valued nonresidential building permit data for the city and county of Los Angeles supplied to the Energy Commission staff by LADWP. The non-LADWP additions of the county were then split between SCE and BGP based upon California Department of Finance (DOF) regional population data for the cities in Los Angeles County. LADWP's climate zone 11 and 12 allocations are based upon regional population data provided by the County of Los Angeles Department of Regional Planning. The matrices developed from these sources are displayed in Table 3-11.

Los Angeles County economic and demographic data are allocated to LADWP, SCE, and BGP based upon the DOF population data used to split the non-LADWP portion of the Dodge additions. This method is consistent with the allocation of Los Angeles County population and housing data in the residential model. The shares used to divide LA county economic data between LADWP, SCE, and BGP are presented in Table 3-12. Also presented in Table 3-12 is LADWP's shares for climate zones 11 and 12.

Table 3-8

Staff's Building Type, NAICS Code, & Dodge Code

BUILDING TYPE	BUSINESS ACTIVITY	NAICS CODE*	DODGE CODE
Office	Administration	921	005-007
	Financial	52	005-007
	Real Estate, Legal	531, 55	005-007
	Public offices	923-927, 92812	100, 140
	Medical offices	6211-6213	5,007
	Agricultural Services	115	005-007, 118
	Other office	5411-5412, 5414-5418, 561, 624 (6244), 813 (8131, 8134)	005-007
Restaurants	Fast food, Self serve	7222-7223	2
	Table Service	7221	2
	Drinking establishment	7224	2
Retail Stores	General Merchandise	452	1,004,101
	Building Maintenance	444	1,004,101
	Home Furnishings	442	1,004,101
	Electronics and Appliances	443	1,004,101
	Apparel/Accessory	448	1,004,101
	Motor Vehicle Dealers	441	1,004,101
	Miscellaneous Retail	446, 44719, 451, 453-454	1,004,101
Food Stores	Grocery/Food/Liquor	445, 447 (44719)	1,004,101
Warehouses	Refrigerated	4224, 4242, 4244, 49312	203,303
	Non-refrigerated	421, 4221-4223, 4225-4229, 423, 4243, 4245-4249, 425, 493 (49312)	203,303
Hotel/Motel	Hotel	721 (7212)	69,072,073,079
Hospitals	Hospital	622, 6219	93,095
	Medical, Dental Labs	6214-6215	93,095
	Nursing Homes	6231	94,095
	Residential Care	6216, 6232-6239	95

BUILDING TYPE	BUSINESS ACTIVITY	NAICS CODE*	DODGE CODE
Schools	Nursery, Day Care	6244	44
	Elementary, High Schools	6111	041-043,048,049
Colleges	Colleges	6112-6113, 6117	45,046,057,074
	Vocational and Trade	6114, 6116	56,057,062
Miscellaneous	Library, Museums	712	140-143
	Church, Religious	8131	053-055,102,253
	Police, Fire Stations	922 (92211, 92215)	
	Correctional Facilities	92215	50
	Theater, Auditoriums	51213, 53223	59,256,060,058
	Sports Arena, Stadium	7112	104,105,257,262
	Park Facilities	7131	061,063-065
	Gas Stations,Auto Repair	44719, 8111	8
	Laundry, Cleaning	8123	109*
	Beauty, Barber Shops	8121	109
	Non Auto Repair	811 (8111)	109
	Construction Activities	5413	109
	Others	5122, 514, 518-519, 532 (53223, 5324), 5419, 6115, 711 (7112), 713 (7131), 7212, 8122, 8129, 8134, 92211	118*
	Theatrical Production	7111	118
	Motion Picture	5121 (51213)	118

* Miscellaneous (Dodge classification)

** Excluded AICS codes in parentheses.

Table 3-9

County to Climate Zone Splits

COUNTY	SPLIT to CLIMATE ZONES						COUNTY	SPLIT to CLIMATE ZONES				
Alameda	4	5					Orange	8	13			
Alpine	1	14					Placer	2	14			
Amador	2						Plumas	1	14			
Butte	3						Riverside	10	15			
Calaveras	1						Sacramento	6	2			
Colusa	3						San Benito	4				
Contra Costa	4	5					San Bernardino	10				
Del Norte	14						San Diego	13				
Eldorado	1	14					San Fransico	5				
Fresno	3						San Joaquin	2				
Glenn	3						San Luis Obispo	4				
Humboldt	1						San Mateo	5				
Imperial	15	13					Santa Barbara	4	8			
Inyo	9	12					Santa Clara	4				
Kern	3	7					Santa Cruz	5				
Kings	3	7					Shasta	3	14			
Lake	1						Sierra	1	14			
Lassen	1	14					Siskiyou	1	14			
Los Angeles	8	9	11	12	16		Solano	4				
Madera	3						Sonoma	4				
Marin	5						Stanislaus	3				
Mariposa	1						Sutter	3				
Mendocino	1						Tehama	3				
Merced	3						Trinity	1				
Modoc	1	14					Tulare	3	7			
Mono	9						Tuolumne	1				
Monterey	4						Ventura	8				
Napa	4						Yolo	2				
Nevada	1	14					Yuba	3				

Table 3-10

County Share Matrix

CNTY/YEAR	1970		1980		1987		1994		2001		2011	
ALAMEDA	0.074	0.926	0.15	0.85	0.178	0.822	0.198	0.802	0.214	0.786	0.228	0.772
ALPINE	0.634	0.366	0.634	0.366	0.634	0.366	0.634	0.366	0.634	0.366	0.634	0.366
AMADOR	1	0	1	0	1	0	1	0	1	0	1	0
BUTTE	1	0	1	0	1	0	1	0	1	0	1	0
CALAVERAS	1	0	1	0	1	0	1	0	1	0	1	0
COLUSA	1	0	1	0	1	0	1	0	1	0	1	0
CONTRA COSTA	0.698	0.302	0.65	0.35	0.661	0.339	0.664	0.334	0.669	0.331	0.672	0.328
DEL NORTE	1	0	1	0	1	0	1	0	1	0	1	0
ELDORADO	0.723	0.277	0.723	0.277	0.723	0.277	0.723	0.277	0.723	0.277	0.723	0.277
FRESNO	1	0	1	0	1	0	1	0	1	0	1	0
GLENN	1	0	1	0	1	0	1	0	1	0	1	0
HUMBOLDT	1	0	1	0	1	0	1	0	1	0	1	0
IMPERIAL	0.999	0.001	0.999	0.001	0.999	0.001	0.999	0.001	0.999	0.001	0.999	0.001
INYO	0.582	0.418	0.582	0.418	0.582	0.418	0.582	0.418	0.582	0.418	0.582	0.418
KERN	0.708	0.292	0.708	0.292	0.708	0.292	0.708	0.292	0.708	0.292	0.708	0.292
KINGS	0.643	0.357	0.643	0.357	0.643	0.357	0.643	0.357	0.643	0.357	0.643	0.357
LAKE	1	0	1	0	1	0	1	0	1	0	1	0
LASSEN	0.182	0.818	0.182	0.818	0.182	0.818	0.182	0.818	0.182	0.818	0.182	0.818
LOS ANGELES	0	0	0	0	0	0	0	0	0	0	0	0
MADERA	1	0	1	0	1	0	1	0	1	0	1	0
MARIN	1	0	1	0	1	0	1	0	1	0	1	0
MARIPOSA	1	0	1	0	1	0	1	0	1	0	1	0
MENDOCINO	1	0	1	0	1	0	1	0	1	0	1	0
MERCED	1	0	1	0	1	0	1	0	1	0	1	0
MODOC	0.006	0.994	0.006	0.994	0.006	0.994	0.006	0.994	0.006	0.994	0.006	0.994
MONO	1	0	1	0	1	0	1	0	1	0	1	0
MONTEREY	1	0	1	0	1	0	1	0	1	0	1	0
NAPA	1	0	1	0	1	0	1	0	1	0	1	0
NEVADA	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157
ORANGE	0.948	0.052	0.948	0.052	0.927	0.073	0.906	0.094	0.894	0.106	0.889	0.111
PLACER	0.857	0.143	0.857	0.143	0.857	0.143	0.857	0.143	0.857	0.143	0.857	0.143
PLUMAS	0.941	0.059	0.941	0.059	0.941	0.059	0.941	0.059	0.941	0.059	0.941	0.051
RIVERSIDE	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157	0.843	0.157
SACRAMENTO	0.985	0.015	0.985	0.015	1	0	1	0	1	0	1	0
SAN BENITO	1	0	1	0	1	0	1	0	1	0	1	0
SAN BERNARDINO	1	0	1	0	1	0	1	0	1	0	1	0
SAN DIEGO	1	0	1	0	1	0	1	0	1	0	1	0
SAN FRANCISCO	1	0	1	0	1	0	1	0	1	0	1	0
SAN JOAQUIN	1	0	1	0	1	0	1	0	1	0	1	0
SAN LUIS OB	1	0	1	0	1	0	1	0	1	0	1	0
SAN MATEO	1	0	1	0	1	0	1	0	1	0	1	0
SANTA BARBARA	0.434	0.566	0.434	0.566	0.434	0.566	0.434	0.566	0.434	0.566	0.434	0.566
SANTA CLARA	1	0	1	0	1	0	1	0	1	0	1	0

SANTA CRUZ	1	0	1	0	1	0	1	0	1	0	1	0
SHASTA	0.942	0.058	0.942	0.058	0.942	0.058	0.942	0.058	0.942	0.058	0.942	0.058
SIERRA	0.405	0.595	0.405	0.595	0.405	0.595	0.405	0.595	0.405	0.595	0.405	0.595
SISKIYOU	0.001	0.999	0.001	0.999	0.001	0.999	0.001	0.999	0.001	0.999	0.001	0.999
SOLANO	1	0	1	0	1	0	1	0	1	0	1	0
SONOMA	1	0	1	0	1	0	1	0	1	0	1	0
STANISLAUS	1	0	1	0	1	0	1	0	1	0	1	0
SUTTER	1	0	1	0	1	0	1	0	1	0	1	0
TEHAMA	1	0	1	0	1	0	1	0	1	0	1	0
TRINITY	1	0	1	0	1	0	1	0	1	0	1	0
TULARE	0.142	0.858	0.142	0.858	0.142	0.858	0.142	0.858	0.142	0.858	0.142	0.858
TUOLUMNE	1	0	1	0	1	0	1	0	1	0	1	0
VENTURA	1	0	1	0	1	0	1	0	1	0	1	0
YOLO	1	0	1	0	1	0	1	0	1	0	1	0
YUBA	1	0	1	0	1	0	1	0	1	0	1	0

Table 3-11

Dodge Additions Splits for Los Angeles County

LADWP SHARES OF LOS ANGELES COUNTY DODGE ADDITIONS

YR	SOFF	REST	RETL	WHSE	RWHS	SCHL	COLG	HOSP	HOTL	MISC	LOFF	PARK
64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.563	0.180	0.328	0.287	0.287	0.453	0.453	0.223	0.341	0.380	0.563	0.563
66	0.549	0.180	0.326	0.284	0.284	0.422	0.422	0.212	0.351	0.380	0.549	0.549
67	0.534	0.180	0.324	0.282	0.282	0.391	0.391	0.201	0.360	0.380	0.534	0.534
68	0.520	0.180	0.322	0.280	0.280	0.360	0.360	0.190	0.370	0.380	0.520	0.520
69	0.506	0.180	0.321	0.278	0.278	0.329	0.329	0.179	0.381	0.380	0.506	0.506
70	0.491	0.180	0.319	0.276	0.276	0.298	0.298	0.168	0.391	0.380	0.491	0.491
71	0.470	0.359	0.359	0.432	0.432	0.465	0.465	0.167	0.771	0.432	0.470	0.470
72	0.501	0.347	0.347	0.505	0.505	0.438	0.438	0.050	0.373	0.505	0.501	0.501
73	0.362	0.170	0.170	0.461	0.461	0.728	0.728	0.161	0.240	0.461	0.362	0.362
74	0.324	0.187	0.187	0.349	0.349	0.147	0.147	0.246	0.624	0.349	0.324	0.324
75	0.305	0.157	0.157	0.331	0.331	0.169	0.169	0.061	0.867	0.331	0.305	0.305
76	0.523	0.284	0.284	0.456	0.456	0.023	0.023	0.041	0.450	0.456	0.523	0.523
77	0.403	0.296	0.296	0.511	0.511	0.074	0.074	0.104	0.235	0.515	0.403	0.403
78	0.365	0.322	0.322	0.443	0.443	0.201	0.201	0.085	0.358	0.443	0.365	0.365
79	0.484	0.291	0.291	0.470	0.470	0.274	0.274	0.207	0.724	0.470	0.484	0.484
80	0.621	0.455	0.455	0.403	0.403	0.631	0.631	0.194	0.063	0.403	0.621	0.621
81	0.575	0.269	0.269	0.430	0.430	0.207	0.207	0.108	0.527	0.430	0.575	0.575
82	0.477	0.412	0.412	0.544	0.544	0.314	0.314	0.093	0.668	0.544	0.477	0.477
83	0.590	0.417	0.417	0.470	0.470	0.488	0.488	0.129	0.440	0.470	0.590	0.590
84	0.705	0.447	0.447	0.428	0.428	0.400	0.400	0.114	0.531	0.428	0.705	0.705
85	0.490	0.155	0.385	0.190	0.190	0.120	0.120	0.060	0.455	0.380	0.490	0.490
86	0.463	0.157	0.393	0.190	0.190	0.107	0.107	0.043	0.433	0.380	0.463	0.463
87	0.437	0.158	0.401	0.190	0.190	0.093	0.093	0.027	0.412	0.380	0.437	0.437
88	0.410	0.160	0.409	0.190	0.190	0.080	0.080	0.010	0.390	0.380	0.410	0.410
89	0.428	0.160	0.405	0.210	0.210	0.085	0.085	0.020	0.390	0.380	0.428	0.428
90	0.445	0.160	0.401	0.230	0.230	0.090	0.090	0.030	0.390	0.380	0.445	0.445
91	0.463	0.160	0.397	0.250	0.250	0.095	0.095	0.040	0.390	0.380	0.463	0.463
92	0.480	0.160	0.393	0.270	0.270	0.100	0.100	0.050	0.390	0.380	0.480	0.480
93	0.480	0.160	0.393	0.270	0.270	0.100	0.100	0.050	0.390	0.380	0.480	0.480

Table 3-11 (continued)

LADWP SPLITS FOR CLIMATE ZONES 11 & 12

SCE & BGP SHARES OF NON-LADWP DODGE ADDITIONS

YR	%CZ11	%CZ12	%SCE	%CZ8	%CZ9	%BGP
65	0.6300	0.3700	0.9185	0.6600	0.3400	0.0815
66	0.6290	0.3710	0.9190	0.6620	0.3380	0.0810
67	0.6280	0.3720	0.9195	0.6640	0.3360	0.0805
68	0.6270	0.3730	0.9200	0.6660	0.3340	0.0800
69	0.6260	0.3740	0.9205	0.6680	0.3320	0.0795
70	0.6250	0.3750	0.9209	0.6800	0.3200	0.0791
71	0.6282	0.3718	0.9213	0.6720	0.3280	0.0787
72	0.6314	0.3686	0.9217	0.6640	0.3360	0.0783
73	0.6346	0.3654	0.9221	0.6560	0.3440	0.0779
74	0.6378	0.3622	0.9225	0.6480	0.3520	0.0775
75	0.6410	0.3590	0.9228	0.6400	0.3600	0.0772
76	0.6442	0.3558	0.9232	0.6320	0.3680	0.0768
77	0.6474	0.3526	0.9236	0.6240	0.3760	0.0764
78	0.6506	0.3494	0.9240	0.6160	0.3840	0.0760
79	0.6538	0.3462	0.9244	0.6080	0.3920	0.0756
80	0.6570	0.3430	0.9248	0.6000	0.4000	0.0752
81	0.6564	0.3436	0.9250	0.5970	0.4030	0.0750
82	0.6558	0.3442	0.9250	0.5940	0.4060	0.0750
83	0.6552	0.3448	0.9249	0.5910	0.4090	0.0751
84	0.6546	0.3454	0.9252	0.5880	0.4120	0.0748
85	0.6540	0.3460	0.9254	0.5850	0.4150	0.0746
86	0.6534	0.3466	0.9259	0.5820	0.4180	0.0741
87	0.6528	0.3472	0.9264	0.5790	0.4210	0.0736
88	0.6522	0.3478	0.9261	0.5760	0.4240	0.0739
89	0.6516	0.3484	0.9250	0.5730	0.4270	0.0750
90	0.6510	0.3490	0.9247	0.5700	0.4300	0.0753
91	0.6501	0.3499	0.9247	0.5680	0.4320	0.0753
92	0.6493	0.3507	0.9247	0.5650	0.4350	0.0753
93	0.6493	0.3507	0.9247	0.5650	0.4350	0.0753

Table 3-12

Los Angeles County Population Shares

YEAR	%LADWP	CZ11	CZ12	%SCE	CZ8	CZ9	%BGP
1970	0.3993	0.6250	0.3750	0.5532	0.6800	0.3200	0.0475
1971	0.3989	0.6282	0.3718	0.5538	0.6720	0.3280	0.0473
1972	0.3985	0.6314	0.3686	0.5544	0.6640	0.3360	0.0471
1973	0.3981	0.6346	0.3654	0.5550	0.6560	0.3440	0.0469
1974	0.3977	0.6378	0.3622	0.5556	0.6480	0.3520	0.0467
1975	0.3974	0.6410	0.3590	0.5562	0.6400	0.3600	0.0465
1976	0.3970	0.6442	0.3558	0.5567	0.6320	0.3680	0.0463
1977	0.3966	0.6474	0.3526	0.5573	0.6240	0.3760	0.0461
1978	0.3962	0.6506	0.3494	0.5579	0.6160	0.3840	0.0459
1979	0.3958	0.6538	0.3462	0.5585	0.6080	0.3920	0.0457
1980	0.3954	0.6570	0.3430	0.5591	0.6000	0.4000	0.0455
1981	0.3948	0.6564	0.3436	0.5599	0.5970	0.4030	0.0454
1982	0.3932	0.6558	0.3442	0.5613	0.5940	0.4060	0.0455
1983	0.3933	0.6552	0.3448	0.5612	0.5910	0.4090	0.0455
1984	0.3941	0.6546	0.3454	0.5606	0.5880	0.4120	0.0453
1985	0.3949	0.6540	0.3460	0.5599	0.5850	0.4150	0.0452
1986	0.3959	0.6534	0.3466	0.5594	0.5820	0.4180	0.0447
1987	0.3946	0.6528	0.3472	0.5609	0.5790	0.4210	0.0445
1988	0.3942	0.6522	0.3478	0.5610	0.5760	0.4240	0.0448
1989	0.3935	0.6516	0.3484	0.5610	0.5730	0.4270	0.0455
1990	0.3927	0.6510	0.3490	0.5616	0.5700	0.4300	0.0457
1991	0.3924	0.6501	0.3499	0.5619	0.5680	0.4320	0.0457
1992	0.3921	0.6493	0.3507	0.5621	0.5650	0.4350	0.0458
1993	0.3918	0.6484	0.3516	0.5624	0.5630	0.4370	0.0458
1994	0.3915	0.6475	0.3525	0.5627	0.5600	0.4400	0.0458
1995	0.3913	0.6467	0.3533	0.5629	0.5580	0.4420	0.0458
1996	0.3910	0.6458	0.3542	0.5632	0.5520	0.4480	0.0458
1997	0.3907	0.6449	0.3551	0.5634	0.5490	0.4510	0.0459
1998	0.3904	0.6440	0.3560	0.5637	0.5470	0.4530	0.0459
1999	0.3902	0.6432	0.3568	0.5639	0.5440	0.4560	0.0459
2000	0.3899	0.6423	0.3577	0.5642	0.5420	0.4580	0.0459
2001	0.3896	0.6414	0.3586	0.5645	0.5390	0.4610	0.0460
2002	0.3893	0.6406	0.3594	0.5647	0.5370	0.4630	0.0460
2003	0.3890	0.6397	0.3603	0.5650	0.5310	0.4690	0.0460
2004	0.3888	0.6388	0.3612	0.5652	0.5280	0.4720	0.0460
2005	0.3885	0.6380	0.3620	0.5655	0.5260	0.4740	0.0460
2006	0.3882	0.6371	0.3629	0.5657	0.5230	0.4770	0.0461
2007	0.3879	0.6362	0.3638	0.5660	0.5210	0.4790	0.0461
2008	0.3876	0.6353	0.3647	0.5662	0.5180	0.4820	0.0461
2009	0.3874	0.6345	0.3655	0.5665	0.5150	0.4850	0.0461
2010	0.3871	0.6336	0.3664	0.5668	0.5130	0.4870	0.0462
2011	0.3868	0.6327	0.3673	0.5670	0.5110	0.4890	0.0462
2012	0.3865	0.6319	0.3681	0.5673	0.5090	0.4910	0.0462
2013	0.3863	0.6310	0.3690	0.5675	0.5070	0.4930	0.0462
2014	0.3865	0.6319	0.3681	0.5673	0.5090	0.4910	0.0462
2015	0.3863	0.6310	0.3690	0.5675	0.5070	0.4930	0.0462

Historical Stock Series

For the CED 2006 forecast, the historical floor space stock from 1964 through 2001 was estimated with the use of the 1965 through 2001 additions data, the base year floor stock values, and assumed floor space decay rates.

1964 floor space stock was estimated using equation (25). Equation (26) is used to estimate the 1965 through 2001 historical stock series.

$$S_{64} = [S_{BASE} - (\sum_{t=65}^{BASE} -1 A_t * F(BASE - t) + A_{BASE})]/F(BASE - 64) \qquad (25)$$

where:

S_{64} = derived stocks for the year 1964
BASE = Base year stock estimates from surveys
A_t = Dodge additions data for year t
F(BASE-64) = fraction of floor space built in year t that still remains in the base year.
F(BASE-64) = fraction of floor space built in 1964 and earlier that still remains in the base year. note: ($64 \leq t \leq BASE$).

$$S_T = S_{64} * F(T - 64) + \sum_{t=65}^{T-1} A_t * F(T - t) + A_T \qquad (26)$$

where:

S_T = stock at year T ($65 \leq T \leq 93$).
F(T-64) = fraction of floor space built in 1964 and earlier that remains in T.
F(T-t) = fraction of floor space built in year t that remains in year T.

Floor space stock for 2002 and 2003 was derived using the additions for these years and an assumed decay rate for existing stock of 0.5 percent.

Floor Space Projections

The floor space projections from 2004-2016, for each of the twelve building types, assume an annual floor space additions rate equal to the mean of additions from 1990 through 2003 for each building type. Again, the assumed annual decay rate for each building type is 0.5 percent. For example, restaurant floor space stock for 2004 is estimated by assuming additions in 2004 equal to the average of restaurant additions from 1990 to 2003. The 2004 additions are added to 99.5 percent of the 2003 restaurant floor stock (to account for 0.5 percent decay), resulting in the 2004 stock. This process is repeated through 2016 for each building type.

Energy Use Intensity (EUI)

This section provides a general description of the estimation method for base year (EUI75) and relative (1979, 1984, 1992, 1998, 2001, and 2005) EUIs. Base year EUIs reflect the average energy consumption of commercial buildings built and operated in 1975 while the relative EUIs are expressed as percentages of the base year EUIs. 1975 was selected as the base year by the staff because it was prior to the application of building standards and coincided with an onsite survey study conducted during that year from which the original staff EUI values were estimated.[5] The relative EUIs reflect changes to the base year value resulting from the impacts of the 1978, 1984, and 1992 building and appliance standards.

The general estimation method for Base Year EUIs include the following steps:

1. Development of representative (prototypical) commercial buildings by weather zone and utility planning area.

2. Simulation of the energy use patterns of the above prototypical buildings using building simulation models to derive preliminary estimates of base year EUIs.

3. Adjustment of these preliminary estimates for price impacts and equipment saturation to derive the final EUI75 numbers.

Prototype Development

A prototypical building is a thermodynamic representation of average existing buildings. The prototypes are designed to represent and model the specific heat gains and losses based on the following characteristics:

- physical characteristics
- thermal properties
- operating schedules
- HVAC equipment type
- non-HVAC equipment specifications

The development of prototypical buildings requires detailed data at the buildings/premises level. Of equal importance is how representative the buildings/premises are of the general population of similar building types. For this purpose, the Energy Commission requires all utilities to regularly conduct large-scale surveys of their commercial customers. These surveys are generally mail or on-site surveys and are supplemented by other available data, such as load research and/or class load data. The level of detail for these surveys is mandated to be sufficient to support the development of representative building prototypes for use in the forecasting models of the Energy Commission and the utilities.

For *ER92*, *ER94*, and the staff's 1995 forecast, the analyses and results of a project conducted by the Lawrence Berkeley Laboratory (LBL) were utilized to update the EUI values. The data used for this prototype development included the 1985-1986 commercial onsite survey, load research data, mail surveys, sub-metered loads and weather files, and prototypes developed from other sources modified for California.

Although this project was conducted specifically for Southern California Edison[6] (*ER92*) and Pacific Gas and Electric[7] (*ER94*), the EUIs were utilized for all planning areas and climate zones. For other climate zones, the HVAC EUIs for SCE and PG&E were modified using degree day ratios. LBL updated its PG&E study utilizing the 1985-1986 commercial onsite survey and other PG&E specific data for the staff's 1995 and subsequent forecasts.[8]

Impacts of Conservation Standards on EUI's

The impacts of mandatory conservation standards were determined through a variety of engineering calculations. Title 20 Appliance Standards and Title 24 Building Standards require commercial buildings to use energy more efficiently. EUIs for vintages from 1975 through 2005 must, therefore, reflect the impact of the standards at the end use level. The base year (1975) EUIs and the standards impact modifiers utilized in the CECCFM will soon be available from the Energy Commission website (www.energy.ca.gov).

Fuel Saturations

The percentage of the floor space stock using electricity, natural gas, or other energy sources for each end use are an important component of the Energy Commission's commercial building sector forecast. This section describes the procedures and data sources used to develop vintage specific fuel saturation estimates for the CECCFM.

Vintage-Specific Fuel Saturations

Planning area fuel share estimates are based on PG&E's 1982 commercial mail survey, PG&E's 1985 onsite survey, PG&E's 1988 mail survey, SCE 1985 mail survey, SMUD's 1990 onsite survey, and SDG&E's 1991 onsite survey. These surveys were used to identify fuel saturation by end use and to determine if there are significant differences in energy consumption between older and newer vintage buildings. The initial research confirmed the extent to which total energy use (electricity or gas) differs according to building age and helped to determine if fuel saturations were related to the consumption variations by vintage.

Data obtained from various utility commercial customer audits were also investigated for purposes of determining the building age/energy use relationship. The PG&E audit data has a large number of observations, considerable end use detail and records building size, but building age was not systematically recorded. Only a few hundred audit records contain the relevant age information. Audit data from other utility programs was either not available to the Energy Commission at the time or considered inferior to the PG&E mail survey as a source of data for these purposes.

Based on the mail survey, the following conclusions were reached:

- Total electricity and natural gas use per square foot varies significantly among commercial building types; the degree of variation and eras for which the variations occur differ significantly between building types

- A reasonably strong correlation exists between fuel saturations for space heating and cooling for most building types; these saturations alone, however, do not explain all of the energy use variations between vintages

- Additional factors, such as energy intensities for major end uses (such as lighting and cooling) and fuel shares for other end uses also contribute to the energy use variations between vintages, but the available data is insufficient to establish numerical estimates of these relationships.

More recent analysis of survey data concludes that it is reasonable to use the existing data to (1) establish only two vintages (pre-1979 and post-1979) and (2) estimate separate fuel saturations for each vintage for both heating and cooling. In previous ER cycles other periods of analysis were defined, but in staff's July forecast the pre- and post-1979 vintage was the predominant demarcation. This is because the more recent survey data do not contain enough data points for greater stratification.

Data Sources and Estimation Procedures

The use of the specific era demarcations shown on the saturation tables was primarily dictated by the sample size of the surveys used. For most building types, in more recent on-site surveys, the use of anything more a pre- and post-1979 demarcation would have meant relying on an extremely small number of observations. Because the most recent vintage establishes the fuel saturation estimates for construction during the forecast period, staff determined that a larger number of observations with a post-1979 vintage date would provide sounder estimates than a smaller number of observations with a more recent vintage date.

Even with the vintage definitions used, the available number of observations for several building types and vintages was relatively small and in some cases the results obtained from the survey appeared implausibly high or low. As a result, staff judgment was used to modify the saturation values for several vintages and building types.

The fuel saturation estimates for the PG&E planning area are primarily based on its 1988 mail survey. The SCE fuel saturations are based on its 1985 mail survey and the 1992 onsite survey. Fuel saturations for SMUD were based on its 1990 onsite survey. And fuel saturations for SDG&E were based on its 1991 onsite and mail surveys. Fuel saturations for the BGP planning area were not developed from survey data, but inferred from information in SCE's mail survey, SMUD's onsite survey, and iterative runs of the CECCFM. Fuel Saturations for the OTHER Planning area were also inferred in a similar fashion. Within the OTHER planning area there are two climate zones. Saturations for climate zone 14 were a duplication of PG&E's climate zone 1. Whereas, saturations for climate zone 15 (Imperial Irrigation District) were a duplication of the SMUD planning area, modified through iterative runs of the model. The saturation assumption utilized in the commercial model for each of the planning service areas will soon be available at the Energy Commission website (www.energy.ca.gov).

Price Elasticity

The price elasticities utilized in the staff's 2005 forecast are the same as those used in earlier cycles. In the previous two *ER* cycles, the staff used elasticities estimated by Nguyen and Chern (1985), who analyzed 1977-1981 energy use data as reported by the five major California energy utilities (PG&E, LADWP, SMUD, SDG&E, and SCE). These estimates were weakened by a time series of insufficient observations, poor data quality, and a lack of treatment of conservation programs. The staff improved the Nguyen and Chern study in the following ways: (1) adding additional observations to the time series (1977-1986); (2) using better quality electricity sales data, (3) accounting for conservation impacts; (4) improving cooling and heating degree day variables; and (5) respecifying the elasticity model to estimate electricity consumption per square foot rather than total electricity consumption.

Results of the analysis undertaken for *ER90* work indicated that the estimated price elasticities varied by building type. The elasticities were relatively more elastic for offices, retail buildings, food stores, and hospitals; and relatively less elastic for schools, warehouses, hotels/motels, and miscellaneous commercial buildings. Furthermore, all short run elasticity estimates were less than 0.25, indicating that the demand for energy for all commercial building groups is quite inelastic.

Model Structure

Electricity demand is a derived demand; i.e., electricity is not consumed directly, but is used in the production of various commercial services. Thus, the major determinants of commercial electricity demand are the level of commercial services (output), price of electricity, and prices of substitute or complementary goods, such as natural gas and oil. This relationship can be derived from a well-behaved commercial services production or cost function, such as translog functions, and is well explained elsewhere (e.g., see [Berndt and Wood, 1979]). The level of commercial electricity demand for a particular building type is assumed to be related to other variables as follows:

$$\ln(C_{b,t}/S_{b,t}) = a_{b,0} + (1-k_b) * \ln[C_{b,(t-1)}/S_{b,t}] + a_{b,1} * \ln(Q_{b,t}/S_{b,t}) + a_{b,2} * \ln PE_t + a_{b,3} * \ln PG_t + a_{b,4} * \ln CDD_t + a_{b,5} * \ln HDD_t + u_{b,t} \quad (31)$$

where:

b,t = subscripts denoting building type and year, respectively
C = electricity demand by a particular commercial building type
S = floor space square footage for a building type
Q = "commercial services" or output produced by a building type
PE = price of electricity at time t faced by a building type
PG = price of natural gas at time t faced by a building type
CDD = cooling degree days
HDD = heating degree days
k = Koyck-lag coefficient
u = random error term.

The model in equation 31 assumes a simple, geometrically distributed lag of the Koyck type. The Koyck-lag has been discussed in detail in many econometric text books (see [Maddala, 1977]). Different lag structures, such as Pascal, Almond, and Jorgenson, can be assumed; however, given only ten years of time series data (1977-1986) and research time constraints, estimation was limited to the Koyck-lag structure.

The Nguyen and Chern model specifies the dependent variable simply as the consumption of electricity, in which case the electricity price coefficient measures the relative change in the level of electricity consumption induced by electricity price fluctuations. In this study, the dependent variable has been specified as a ratio of electricity consumption over floor space square footage by building type. Accordingly, the price coefficient is now an indicator of the relative change in consumption efficiency that is induced by price fluctuations. The model was estimated at the utility planning area level both for the commercial sector as a whole and for each of 10 commercial building types. The price elasticities are derived as follows:

Short-run own-price elasticity: $e_{b,0} = a_{b,2}$ (32)

Short-run cross-price elasticity: $e_{b,c} = a_{b,3}$ (33)

Long-run own-price elasticity: $e_{b,0} = a_{b,2}/k_b$ (34)

Long-run cross-price elasticity: $e_{b,c} = a_{b,3}/k_b$ (35)

Since total commercial building sector electricity consumption is the sum of the consumption of individual building types, the aggregate sector price elasticities can be approximated from the building specific price elasticities.

Short-run aggregate own-price elasticity: $e_0 = s_b * e_{b,0}$ (36)

where s_b is the share of total electricity consumption for building type b, given as:

$b = C_{b,t}/C_t$ (37)

Long-run aggregate own and cross price elasticities may be derived similarly.

Data and Estimation Method

In order to estimate the above model, building type specific data on electricity consumption, fuel prices, and output, among other variables, are needed. Unfortunately, the data for nearly all the variables in equation 31 are not readily available at the utility planning area and building type levels, and, consequently, must be derived or approximated.

Six digit NAICS coded electricity sales data reported by California electricity retailers for the 1980-2003 period were aggregated to the proper commercial building type and planning area.

A major shortcoming of the reported sales data is the unwanted inclusion of the impacts of various utility and government mandated conservation programs. This is especially true for the years after 1979, when the California Nonresidential Buildings and Appliance Standards began to take effect. Use of such data to estimate equation 31 leads to biased estimates of price elasticities. Thus, the pure impact of various conservation programs must be removed from the reported sales data before estimation. As the key prerequisite for this calculation is knowledge of the price elasticity (which is being estimated), the following two-step procedure was implemented. First, the price elasticities estimated in 1985 by Nguyen and Chern were employed to estimate the price and pure conservation program impacts. Second, the estimated pure conservation program impacts were netted out from the reported sales. The modified sales data were then used to estimate equation 31.

Data on the level of commercial services are unavailable and were approximated using various economic variables. The proxy variables, selected after extensive testing, vary by commercial building type. Office employment is used as a proxy for the level of services provided by the office building type; population, for the restaurant building type; personal income, for the retail outlet and warehouse building types; and population, for all other commercial building types. Raw data for population, personal income, sectoral wage income, employment, and sectoral sales are measured at the county level. As a county may be served by one or more utilities, a share matrix was developed based on the historical commercial electricity sales data to distribute the county level economic data among the seven utility planning areas.

The impact of weather on commercial demand for energy is often estimated through the inclusion of cooling (CDD) and heating degree day (HDD) variables. HDD is conventionally defined as follows:

$$HDD = \sum_{i=1}^{365} \max(0, 65^{o} - (tmax_i + tmin_i)/2) \qquad (38)$$

where:

$tmax_i$ = maximum daily temperature
$tmin_i$ = minimum daily temperature.

CDD is defined analogously, except that 65^0 is subtracted from the parenthetic ratio, as opposed to the ratio being subtracted from 65^0.

Under this definition, only the maximum and minimum temperatures of the day are considered; the temperature profile, humidity, wind chill factor, etc. is ignored. As in other studies, the Nguyen and Chern study found the weather coefficients to be statistically insignificant. This may be due to the fact that weather has only minor impact on commercial electricity demand, and/or that the HDD and CDD as defined above are not appropriate weather variables to be used. To test the later hypothesis, staff defines new weather variables, annual cooling and heating degree hours (CDH and HDH), as follows:

$$HDH1 = \sum_{j=1}^{365} \sum_{i=1}^{24} Max(65^{o} - DB \;, 0) \qquad (39)$$

where:

i = hour of the day, 1 < i < 24
j = day of the year, 1 < j < 365
DB = dry bulb temperature,
HDH1= annual heating degree hours

Under this definition, hourly temperatures, rather than daily maximum and minimum temperatures are used to derive HDH1. Since commercial buildings are normally occupied for only part of the day, their heating and cooling loads are probably most affected by temperatures during certain periods of the day. For this reason, two other annual heating degree hour (HDH2 and HDH3) variables are derived. HDH2 is derived based on hourly temperature during the 7 AM - 5 PM period, HDH3, is derived based on the 10 AM - 9 PM period.

Annual cooling degree hour (CDH) variables are also derived similarly:

$$CDH1 = \sum_{j=1}^{365} \sum_{i=1}^{24} Max(DB - 70^{o} \;, 0) \qquad (40)$$

where I, j and DB are defined as in equation (39). Note that the base temperature is 70 instead of 65.

Weather data including cooling and heating degree days and hourly dry bulb temperatures were collected for ten weather stations in California. The weather station specific data were then mapped into the seven utility planning areas on the basis of the commercial electricity sales data.

Direct estimation of the above model for each of the commercial building types and planning areas is difficult because of the small sample size (1976-1986) and the presence of the lagged dependent variable. One way to overcome this difficulty is to increase the sample size by pooling cross section (planning areas) and time series data together. Such pooled data can be estimated by applying ordinary least squares to the data with cross-sectional dummy values (the LSDV method). Alternatively, as suggested by Nerlove, the dynamic equation may be estimated using a two stage least squares (TSLS) approach in which the LSDV method is used in the first stage to derive the residuals, and the generalized least squares (GLS) estimation method is used in the second stage. The SAS Parks procedure [SAS, 1982] employs this TSLS estimation method, and was used in the estimation of equation (31). The SAS Parks procedure explicitly corrects for autocorrelation problems in the time-series, and heteroscedasticity and contemporaneous correlation problems among the cross sections of the pooled data base.

Estimation Results and Demand Elasticities

Various versions of equation (31) were estimated; only the final results are listed in Table 3-13. As expected, empirical estimation of equation (31) encounters several problems. First, the weather variables as defined by CDD, HDD, CDH, and HDH often have incorrect signs and low t values. CDH3, defined based on hourly temperature between 10 AM and 6 PM, yields the best results. However, CDH3 has the correct sign and significant t statistics for only 3 of the 10 building types. Second, the gas price has been found to have a weak influence. As a result, the gas price variable has been dropped from the final function. This result is consistent with the results of earlier studies, as the opportunities for fuel switching in the commercial sector are rather limited. Third, due to poor sales data for the SMUD, BGP, and Other areas, the staff decided to exclude these areas in some regressions. This exclusion improves the estimation results for all building types except restaurants.

Table 3-14 presents the final estimation results. These final results have been subjectively chosen based generally on R^2 values and the signs and statistical significance of the estimated coefficients.

Some interesting observations can be drawn from the estimated results. First, the estimated coefficients are substantially different across building types. For instance, the estimated short run, own price elasticities range from the -0.10 for hotels/motels, warehouses, schools, and miscellaneous to -0.20 for offices, retails, food stores, and hospitals. These differences conform to the expectation of different patterns of electricity consumption for different commercial building types. Second, all estimated short run price elasticities are less than 0.25, indicating that the demand for electricity in the commercial building sector is quite inelastic. Third, in comparison with estimates from other studies, the elasticities estimated by the staff are generally lower. The estimated price and output elasticities from several studies of aggregated commercial electricity demand are compiled in Table 3-13. These results vary widely, with estimates of short run price elasticity ranging from -0.005 to -1.18, while estimates of long run price elasticities ranged from -0.05 to -2.10. Compared to these estimates, both short run (-0.17) and long run (-0.50) price elasticities estimated by the staff are relatively low. It should be noted that the staff estimates are not directly comparable to others since (1) the staff's demand variable is demand per unit of floor space, not total demand as in other studies, and (2) except for the Nguyen and Chern study, all other studies were based on aggregate total commercial sector data rather than regional and building specific time series data.

Table 3-13

Estimated Electricity Demand Equation by Building Type

Building	Dummy Variables						
	PG&E	LADWP	SDG&E	SCE	SMUD	BGP	OTHER
Office	-0.03 (-0.06)	0.02 (0.03)	-0.04 (-0.06)	0.01 (0.02)			
Restaurant	10.37 (16.22)	10.47 (16.32)	10.37 (16.21)	10.54 (16.32)	9.82 (16.38)	10.21 (15.93)	9.86 (16.19)
Retail	-0.82 (-3.21)	-0.83 (-2.96)	-0.65 (-2.38)	-0.77 (-2.86)			
Food store	1.59 (3.43)	1.59 (3.24)	1.51 (3.16)	1.61 (3.34)			
Warehouse	1.33 (1.60)	1.17 (1.52)	1.08 (1.38)	1.08 (1.54)			
School	-3.70 (-7.12)	04.06 (-7.18)	-3.85 (-6.92)	-3.83 (-7.19)			
College	4.27 (3.12)	4.12 (3.11)	4.90 (3.22)	4.45 (3.13)			
Hospital	-2.49 (-6.13)	-2.32 (-5.96)	-2.49 (-6.18)	-2.47 (6.08)			
Hotel/Motel	1.96 (2.72)	1.93 (2.61)	1.83 (2.61)	1.98 (2.67)			
Miscellaneous	-0.04 (-0.13)	-0.09 (-0.32)	-0.09 (-0.29)	-0.10 (-0.33)			

Table 3-13 (Continued)

Estimated Electricity Demand Equation by Building Type

Building	Independent Variables					
	Elec. Price	CDD3	Time	Output/ SF	Lagged Variable	R^2
Office	-0.20 (-6.87)		0.12 (6.17)	0.19 (2.44)	0.56 (7.05)	0.65
Restaurant	-0.14 (-7.74)		0.30 (22.44)	-1.29 (-12.04)	0.03 (0.62)	0.63
Retail	-0.21 (-8.18)		-0.27 (-8.12)	-0.57 (8.75)	0.52 (9.05)	0.74
Food store	-0.23 (-2.93)				.075 (5.80)	0.69
Warehouse	-0.12 (-1.86)		0.05 (1.48)	-0.07 (-0.40)	0.64 (7.70)	0.47
School	-0.13 (-5.17)	0.14 (8.21)	-0.01 (-1.34)	0.78 (5.60)	0.81 (10.33)	0.74
College	-0.17 (-2.22)	0.03 (0.71)	0.16 (4.23)	-0.87 (3.16)	0.91 (10.47)	0.83
Hospital	-0.18 (-3.90)	0.08 (2.51)	0.09 (3.78)	0.79 (6.81)	0.41 (3.83)	0.81
Hotel/Motel	-0.11 (-1.94)		0.10 (2.01)	-0.38 (-5.43)	0.68 (5.36)	0.19
Miscellaneous	-0.13 -3.45)		0.04 (7.09)	0.51 (6.88)	0.38 (5.18)	0.77

* R^2 is derived as follows: $R^2 = 1 - (RSS_i / TSS_i)$, where RSS is the residual sum of squares, TSS is the total sum of square, and i denotes utility planning area.

Table 3-14

Comparison of Previously Estimated Price Elasticities of Commercial Electricity Demand

Study	Price Elasticities		Output/Income Elasticities	
Mount-Chapman	-0.20	-1.60	0.10	0.80
Tyrrell	-0.17	-1.36	0.11	0.86
1973 (3 estimates)	-1.18	-1.45	0.72	0.88
Lyman (1973)		02.10[9]		N/A
Hudson Jorgenson (1974)	-.034	-0.85	0.79	1.98
FEA (1976)	-0.24	-0.38	0.73	1.63
Halvorsen (1976)		-0.92		1.25
Halvorsen (1978) (2 estimates)		-1.16 -0.56		1.38 1.15
Asher and Habermann (1978)	-0.25	-1.20	NA	NA
DOE (1978)	-0.30 to -0.66	-0.94 to -1.54	NA	NA
Beierlein-Dunn-McConnon (1981)	-0.005	-0.05	0.08	0.80
Nguyen and Chern (1985)	-0.14	-0.36	0.55	1.10
This Study	-0.17	-0.50	0.10	0.34[10]

As expected, the estimated price and output elasticities vary widely across building types. The differences in elasticities across building types implies that disaggregate commercial energy use models should use different elasticity values for different building types, rather than the same elasticity value for all building types. In addition, the wide variation in price elasticities across building types leads to the recommendation of using different elasticities not only for different building types, but also for different end uses. Although data are currently unavailable to support estimation of price elasticities at the end use level, the staff suggests the use of a priori information to approximate appliance use behavior in the face of changing prices. Such information may be used to infer end use price elasticities at the building type level.

Earlier studies indicated that the price effect of electricity demand is generally insignificant compared to the output effect. The staff uses commercial "output" per square foot, rather than "output" itself, as a proxy of the output or income effect. Hence, the results obtained by the staff are not directly comparable with those from other studies. The staff's results, however, show inconclusive income effects. In five building types - offices, retail stores, schools, hospitals, and miscellaneous - the "output" coefficients are positive. In the other five building types - restaurants, food stores, warehouses, colleges, and hotels - the "output" coefficients are negative.

Endnotes

[1] See J. Jackson [1978].

[2] The model keeps track of all building and equipment vintages (t) from 1964 to 2016. Note that Equation 1 suppresses indices for end use, fuel and building type.

[3] This convention works well for space heating, air conditioning and lighting but becomes more labored for refrigeration and water heating.

[4] See J. Jackson [1978].

[5] See Hittman Associates, Inc., 1980 - P300-80-014, and Weatherwax, R.K., July 1980 - P102-79-020.

[6] See LBL Final Report, "Integrated Estimation of Commercial Sector End Use Load Shapes and Energy Use Intensities", Phase I, January 1989 and Phase II, January 1991.

[7] See LBL Second Interim Report, "Integrated Estimation of Commercial Sector End Use Load Shapes and Energy Use Intensities in PG&E Service Area", June 12, 1993.

[8] See LBL Report 34263 UC-000, "Integrated Estimation of Commercial Sector End Use Load Shapes and Energy Use Intensities in PG&E Service Area", December, 1993.

[9] Combined short run and long run effect.

[10] Staff used commercial "output" per square foot as a proxy of income variable while other studies used commercial "output" directly.

CHAPTER 4
INDUSTRIAL MODEL ENERGY DEMAND FORECAST

Introduction

The industrial sector logically can be divided into process and assembly groups. Process industries primarily involve the processing of raw materials; generally by chemical or physical transformations using thermal and electrical inputs. Individual process industries include food products, wood products, pulp and paper, petroleum refining, cement and glass. Also included in this group are the extraction industries (NAICS sectors 211, 212 and 213). These industries include petroleum and natural gas extraction and mining of both metals and nonmetallic minerals. The majority of energy use in the extraction industries is for petroleum and natural gas extraction, the major continuous process industries in California.

The assembly industry group includes industries whose primary activity is to shape and form materials and assemble components to produce final goods in a non-continuous production environment. Covering most manufacturing (NAICS sectors 31-33 and 51), these industries are relatively electricity intensive; requiring large conditioned and lighted building spaces, motor drives, melting, coating, drying, curing, and process heating equipment, etc. Consequently, assembly industries in California account for almost 60 percent of industrial electricity consumption, but only about 30 percent of natural gas use.

Projections of industrial energy demand for all sectors except NAICS 211, 212 and 213 are driven by forecasts of output [added value of shipments or gross domestic product (GDP)]. For extraction industries classified within NAICS 211, 212 and 213, forecasts of employment are used because the volatility of the prices of such commodities as oil, natural gas and precious metals leads to volatility in values of shipments or GDP. This volatility distorts the empirical relationships between the value of production and the energy required in extraction.

The principal determinant of trends for all subsectors discussed above, excluding mining and crude oil extraction, is the forecast for gross state product (GSP) in that subsector. For mining and crude oil extraction, the driver is employment. These data come from Economy.com. Other data used in this analysis comes from the Quarterly Fuel and Energy Reports, Electric Power Research Institute, U.S. Bureau of the Census, and Energy Commission electricity and natural gas price forecasts.

Model Structure

To forecast annual electricity and natural gas demand, the Energy Commission uses the Industrial End Use Forecasting Model (INFORM), developed by the Electric Power Research Institute (EPRI). The INFORM program can account for energy use trends, price effects, and exogenous improvement in efficiency by end use and industry. The model offers the user the flexibility to define the number and type of industries, end uses, end use technologies (e.g., AC or DC motors, incandescent or fluorescent lighting, electric or natural-gas heating), and the time horizon for the forecast.

The major end uses in the model are:

- Motors
- Thermal Processes
- Other Processes
- Lighting
- Heating, Ventilation and Air Conditioning (HVAC)
- Miscellaneous

Energy Commission staff use the model to project demand for electricity, natural gas and other fuels for these five major end uses over a 12 year period. Demand for electricity, natural gas and other fuels for each of these five major end uses is forecast for each of ten process and 18 assembly industries, as shown in Table 4-1.

Table 4-1

Industrial Sector Definitions by NAICS Code

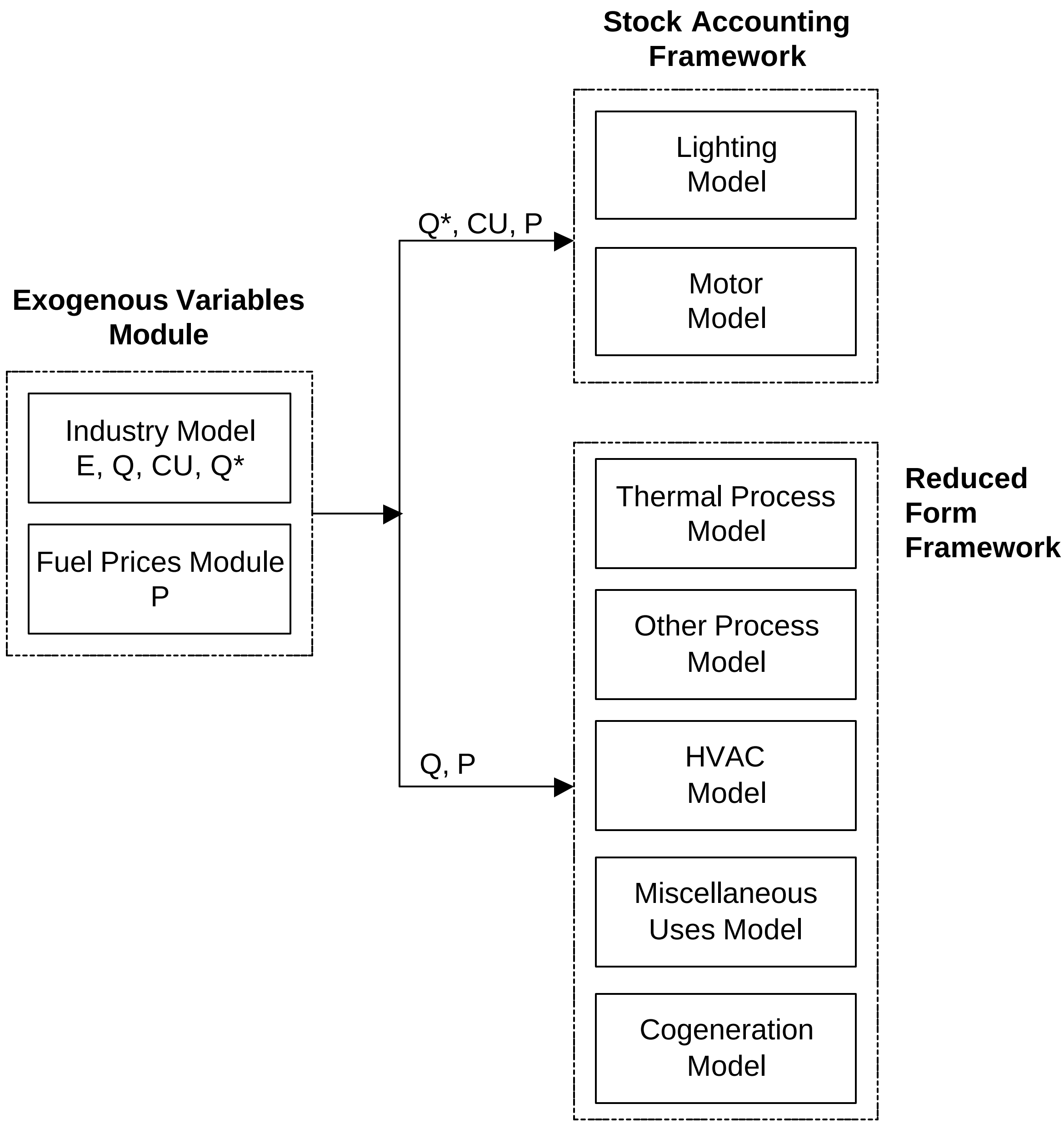
NAICS	Process Industries
1133, 321	Logging and Wood Product Manufacturing
211, 213	Oil and Gas Extraction & Support Activities
212	Other Mining
230	Construction
3113, 3114	Food Processing
322x	Paper Manufacturing (excluding 3221 – Pulp, Paper, and Paperboard Mills)
3221	Pulp, Paper, and Paperboard Mills
324	Petroleum and Coal Products Manufacturing
3272	Glass Manufacturing
3273	Cement
	Assembly Industries
311x, 312	Food and Beverage (excluding 3113, 3114 – Food Processing)
313	Textile Mills
314	Textile Product Mills
315, 316	Apparel and Leather Product Manufacturing
323	Printing and Related Support Activities
325	Chemical Manufacturing
326	Plastics and Rubber Products Manufacturing
327x	Nonmetallic Mineral Product Manufacturing (excluding 3272 – Glass Manufacturing and 3273 – Cement)
331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
334x	Computer and Electronic Product Manufacturing (excluding 3344 – Semiconductor and Other Electronic Component Manufacturing)
3344	Semiconductor and Other Electronic Component Manufacturing
335	Electrical Equipment, Appliance, and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing
511, 516	Publishing and Broadcasting Industries

Modular Structure Of the INFORM Computer Program

INFORM is organized into nine self-contained modules, each supporting its own database. These databases are composed of ten input files, two for the Exogenous Variables module and one for each of the eight models. Staff creates these files outside the INFORM program using a Microsoft Excel workbook, which is linked to twenty other spreadsheet files containing updated energy price and consumption data, capacity utilization data, employment data, added value of shipments or GDP, relationships amongst these parameters, shares of such parameters amongst industrial NAICS sectors and utility planning areas, etc. Macros and formulas within the Excel workbook use the updated information to prepare each of the ten input files required by the INFORM for a forecast for each utility planning area. INFORM's nine modules are:

- Exogenous Variables Module: This module has two sections. The Fuel Price section of the module is used to enter historical and forecast energy prices for each fuel. The Exogenous Variables section is used to enter data for all other variables that are used in the end use models.
- Industry Models: This component allows the user to select the industry model input file for use in the forecast. The user can then review forecasts of local employment, output, capacity utilization and output capacity.
- Motor, Thermal, Other Process, Lighting, HVAC, Miscellaneous Uses and Cogeneration models: These components each allow the user to select a respective model input file.

Figure 4-1
Industrial End-use Forecasting Model Structure



INFORM Forecast Structure

The forecast structure of INFORM is shown in Figure 4-1:

The key modeling elements in this structure are:

- Industry Model: provides for user defined economic activity equations that produce local projections of employment (E), output levels (added value of shipments or GDP) (Q), capacity utilization rates (CU), and output capacity (Q*).
- Fuel Prices Module: forecasts energy prices (P) for up to nine fuels.
- Motor Model: forecasts motor energy consumption.
- Thermal Process Model: forecasts melting, process heating, drying and curing energy consumption.
- Other Process Model: forecasts electrolytic, process steam generation, and other process energy consumption not accounted for by the motor and thermal process models.
- Lighting Model: forecasts lighting energy consumption.
- HVAC Model: forecasts space heating, cooling and ventilating energy consumption.
- Miscellaneous Uses Model: forecasts non-process miscellaneous energy consumption.
- Cogeneration Model: forecasts self-generated electricity.

The motor and lighting models are the most comprehensive, accounting for detailed equipment stocks, purchase and replacement decisions, and utilization factors. The forecast drivers are output capacity and capacity utilization rates. Capacity is the main driver for motor and lighting equipment stocks. Capacity utilization rates determine changes in operating hours. The remaining end use models are reduced-form models, which do not use equipment stock inputs and the model components that influence forecast outputs. The forecast driver for each of these models is industrial output, for which Energy Commission staff uses added value of shipments or GDP. Following are detailed discussions of each of the INFORM constituent models.

Industry Model

This model serves the following purposes:

- Defining industry segmentation. Energy Commission staff used the NAICS sectors in Table 4-1 to define this input.
- Defining base-year industry economic profiles. For each NAICS sector, the input file for this model provides base-year values for service area employment, output per employee, capacity utilization rate (held constant at 80 percent), and capacity.
- Developing output (Q), capacity utilization (CU) and output capacity (Q*) forecasts.
- Defining the time horizon of the forecast, in this case, 2003 to 2016.

The economic activity equations within INFORM evaluate each of these parameters as functions of U.S. variables for local conditions, and for industry i, in year t:

- E^t_i is employment;
- Q^t_i is output ($millions);
- CU^t_i is capacity utilization (%);
- Q^{*t}_i is output capacity ($millions).

These four parameters are calibrated within INFORM using the following four equations, where, for industry i, in year t:

$E^t_i = FE^t_i \times [E^{"}_i / FE^0_i]$;

where

FE^t_i = value of the employment activity equation
$E^{"}_i$ = control value base-year employment
FE^0_i = base-year value of the employment activity equation.

$Q^t_i = FQ^t_i \times [Q^{"}_i / FQ^0_i]$;

where

FQ^t_i = value of the output activity equation
$Q^{"}_i$ = control value base-year output
FQ^0_i = base-year value of the output activity equation.

$CU^t_i = FCU^t_i \times [CU^{"}_i / FCU^0_i]$;

where

FCU^t_i = value of the capacity utilization activity equation
$CU^{"}_i$ = control value base-year capacity utilization
FCU^0_i = base-year value of the capacity utilization activity equation.

$Q^{*t}_i = FQ^{*t}_i \times [Q^{*"}_i / FQ^0_i]$;

where

FQ^{*t}_i = value of the output capacity equation
$Q^{*"}_i$ = control value base-year capacity
FQ^0_i = base-year value of the capacity activity equation.

These four variables influence the forecast more than any other variables INFORM uses as inputs. Staff used the Industry Model input and exogenous variables files to define each of these variables for these equations. For an industrial NAICS subsector, two sets of inputs are required to define that subsector's set of economic activity equations. One set contains local base-year control values for:

- Employment;
- Labor productivity ($ output/employee);
- Capacity utilization;
- Output capacity.

The second set of inputs is calculated from the four economic activity equations given above.

Motor Model

The Motor Model serves the following purposes:

- Defining motor segmentation: motor use, size, and load type categories.
- Defining motor efficiency options and technology data.
- Defining base-year energy sales and market profiles.
- Developing motor energy sales forecasts.

Energy sales are derived from detailed motor stocks and utilization factors. The forecast drivers are output capacity and capacity utilization rates. Capacity is the prime indicator or the amount of plant and equipment available for production. In the model, capacity is used as the main driver for motor stocks. Capacity utilization rates determine changes in motor operating hours.

The Motor Model can be applied to any scheme of industrial aggregation. Energy Commission forecasts entail modeling the industrial NAICS categories in Table 4-1.

The Motor Model contains a component that adjusts forecasts to reflect motor purchase decisions due to a motor's physical decay, new plant construction, or expansion. Motor replacement due to physical decay is modeled using assumptions about motor life. Motor purchases due to new plant construction or expansion are modeled in part using change in capacity. This component determines the efficiency mix for new motor purchases.

Applications and Equipment Technologies

Motor use definitions are at the discretion of the user; staff disaggregates motor uses into three applications:

- Materials Handling;
- Materials Processing;
- Pumps, Fans and Compressors.

Specific Systems

For each application, the user defines a list of motor size categories. The staff forecast uses the nine categories in Table 4-2.

Table 4-2

Motor Size Categories

Reference Size (hp)	Reference Size Name	Category Description
0.26	Fractnl	Fractional horsepower motors
2	HP1to5	1 to 5 horsepower motors
10	HP6to20	6 to 20 horsepower motors
30	HP21to50	21 to 50 horsepower motors
75	HP51t100	51 to 100 horsepower motors
160	HP101t200	101 to 200 horsepower motors
250	HP201t500	201 to 500 horsepower motors
800	HP501t1000	501 to 1000 horsepower motors
1200	Large	1000-plus horsepower motors

Motor workloads can be categorized by three general load types: constant or intermittent load applications, or variable-speed or variable-torque applications. INFORM condenses these into constant- and variable-load categories.

Motor efficiency design options are also a user-defined component of the model. Staff uses the four designs outlined in Table 4-3.

Table 4-3

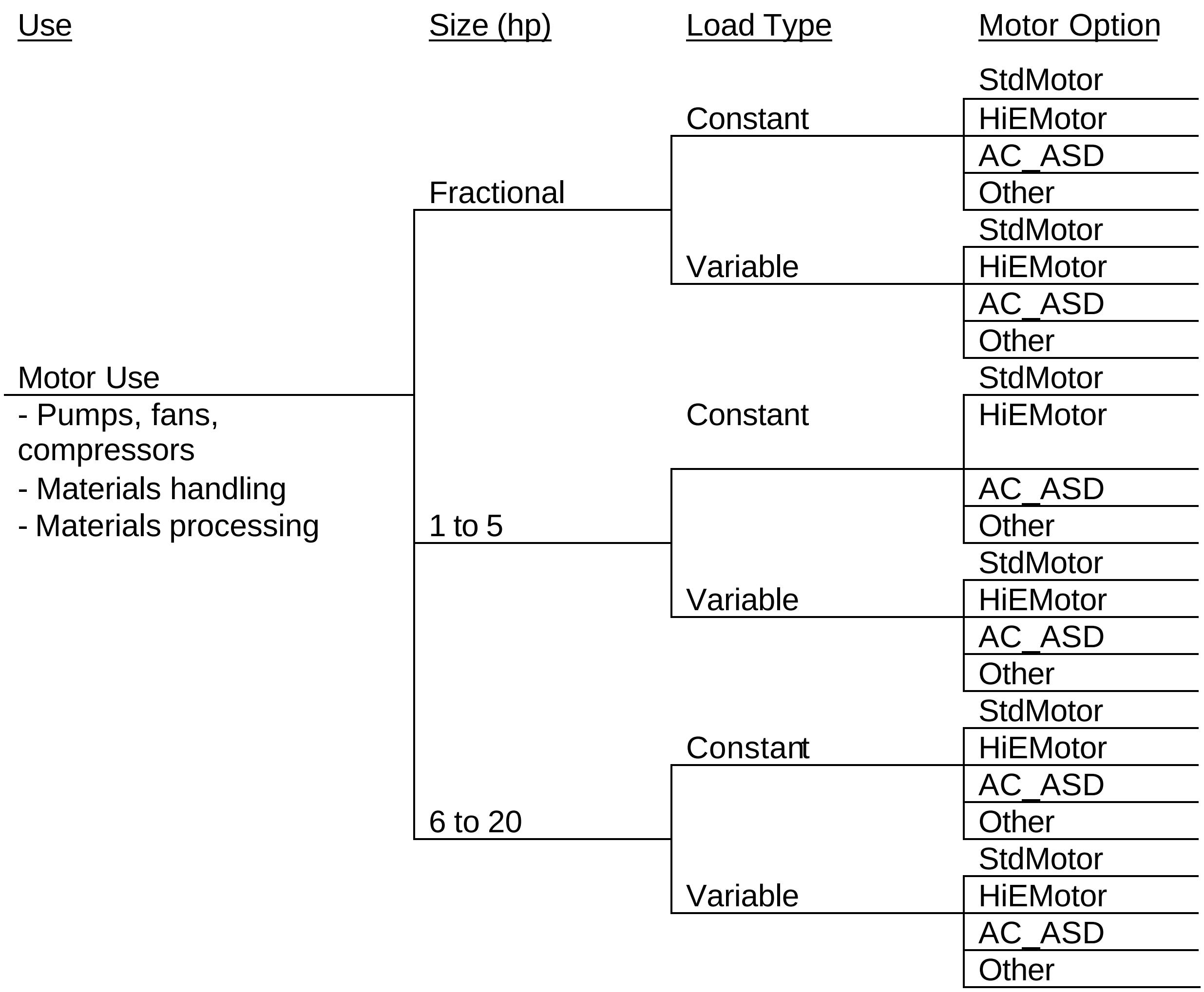
Motor Efficiency Design Options

Design Option Name	Description
StdMotor	Standard Efficiency AC Motors
HiEMotor	High-Efficiency AC Motors
AC_ASD	AC Motor with Electronic ASD Controls
Other	DC, Synchronous, Single-Phase Motors

These dimensions produce the level of detail depicted for the three smallest motor sizes in Figure 4-2:

Figure 4-2

Motor Model Level of Detail



Motor Model Central Energy Equation

Motor electricity use is calculated using the central energy equation:

$$kWh_m = \frac{HP \times Hours \times 0.746 kWh / Hp \times SHARE \times LF^{a_m}}{EFF_m}$$

where

kWh_m = annual electricity consumption for motors with efficiency option m in a specific application category (use, size and load-type), expressed as kilowatt-hours (kWh)

HP = sum of the rated capacity of the stock of motors in the application categories of use, size, and load-type (hp)

Hours = average number of annual operating hours for the application category

SHARE = share for an efficiency option, expressed as percent (%)

LF = load factor, or average value of the duty-cycle distribution during operating hours, expressed as percent (%)

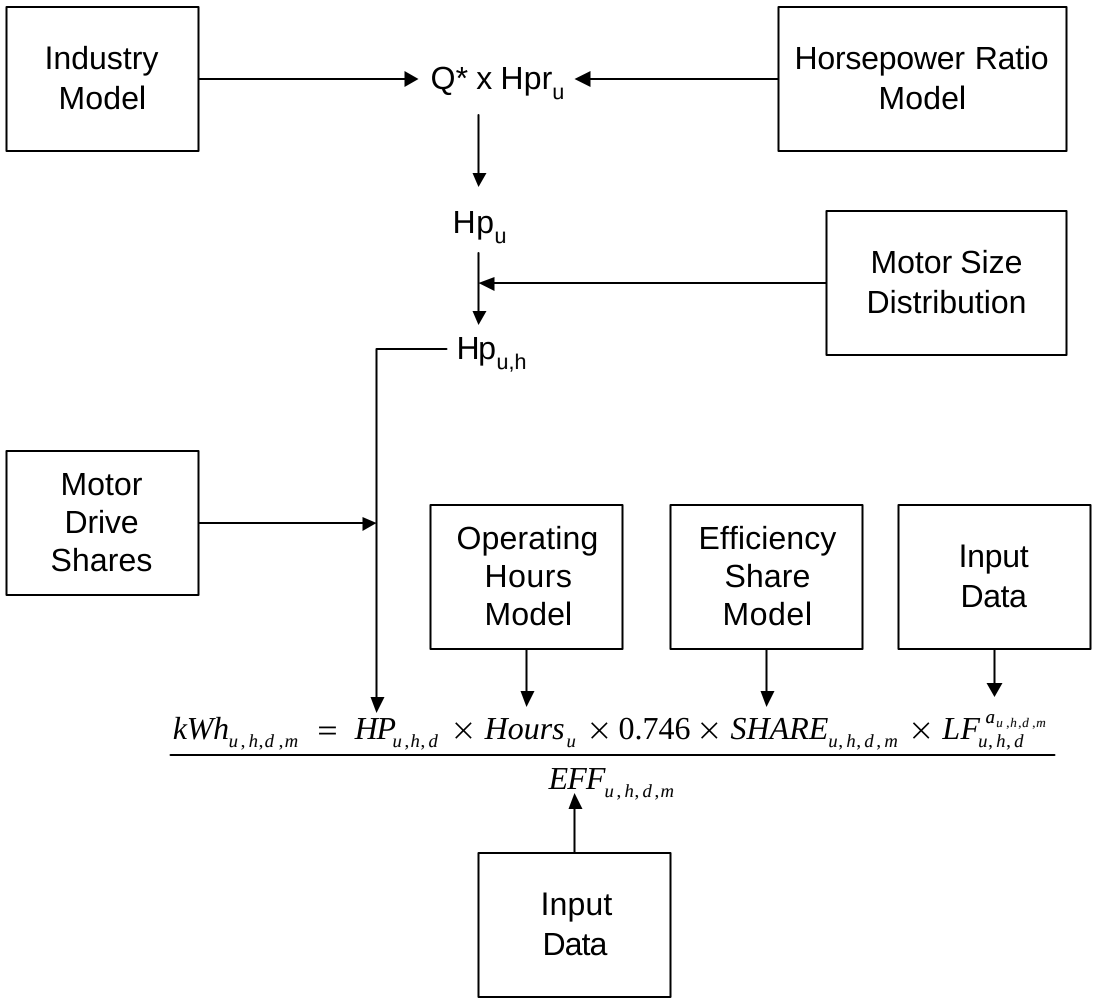
α_m = part-load elasticity describing the slope of the power curve for efficiency option m in this type of application (no units)

EFF_m = an option's rated efficiency, expressed as percent (%).

Electricity consumption is calculated separately for each industry (i), motor use (u), horsepower size category (h), load variability category (v), and motor efficiency option (m). All subscripts except the motor efficiency option have been suppressed for simplicity.

The Motor Model forecast structure is shown in Figure 4-2:

Figure 4-3
Motor Model Structure



The key modeling elements in this structure are:

- The economic activity equations, used to determine local output levels (Q), local capacity utilization (CU), and local capacity (Q*). Capacity is the main driver for equipment stocks.
- The capacity utilization model, used to estimate changes over time in hours of operation.
- The horsepower ratio model, a measure of total horsepower divided by industry capacity; used to compute the ratio over time of horsepower requirements per unit of capacity (hp/$million).
- The size and load-type distribution parameters. The load-type fractions give the fraction of motors of each size used in constant and variable load applications; the motor size distribution gives the fraction of motor horsepower in each size category.

- Input data used to describe motor option efficiency levels and power requirement curves for each option. This includes:
    - Average load factors; the average percentage motor loading during operating hours;
    - The operating hours model, which uses changes in capacity utilization to determine changes in motor operating hours.
    - Part-load elasticity; a measure of input power requirements to percent load. As a motor's load increases, controls are used to increase input power requirements or output slows.
- The Efficiency Share Model, used to estimate the share over time of motor efficiency options. Motors are replaced as a result of physical decay or at the time of new plant construction or expansion. The former is modeled using assumptions about motor lifespan; the latter is modeled using changes in capacity or production processes that change horsepower ratios.

Thermal Model

The Thermal Model serves the following purposes:

- Producing energy forecasts for each defined thermal process in the end use model.
- Forecasting emissions levels associated with a process energy use. Exogenously specified sets of emissions factors associated with certain energy uses can be used to project emissions in pounds per Btu of energy input.
- Forecasting emissions associated with production levels independent of energy usage levels; for example, emissions levels from solvent vapors associated with an industrial process. These forecasts are driven by changes in output.
- Forecasting the energy and emission level impacts of technology substitution. For each process, the user defines a set of equipment options. Exogenously-specified equipment share equations determine the allocation of energy sales across competing equipment options.
- Forecasting the energy and emission level impacts of operating efficiency and emission factor improvements. For each equipment option, the user defines a base-year operating efficiency and set of emission factors.

Applications and Equipment Technologies

Equipment options are controlled in a user-defined list that should include the main options used today and emerging options that are expected to capture a significant share over the forecast horizon. The options for the thermal model chosen by staff include the following:

- Melting: Direct arc, indirect resistance, and cupola.
- Heating: Induction heating, indirect resistance heating, fossil fuel-fired furnace.

- Drying and Curing: Microwave processing, radio frequency drying, fossil fuel-fired ovens.

The resulting level of detail is illustrated in Figure 4-4:

Figure 4-4

Thermal Model Level of Detail

Industry	Thermal Use	Equipment Options
		Direct Arc Melting
	Melting	Indirect Resistance Melting
		Cupola
NAICS		
		Induction Heating
	Heating	Indirect Resistance Heating
		Furnace
		Microwave Processing
	Drying and Curing	Indirect Resistance Drying
		Ovens and Dryers

Thermal Model Central Energy Equation

The central energy equation for the thermal model is:

$ENERGY^{t}_{i,u,e,f} = Q^{t}_{i} \times PHR^{t}_{i,u} \times SHARE^{t}_{i,u,e} \times FRR^{t}_{i,u,e,f} \times k_{i,u,f}$

where, for year t, industry i, thermal use u, equipment option e, and fuel f:

$ENERGY^{t}_{i,u,e,f}$ = annual energy use (GWh or bBtu).

Q^{t}_{i} = annual output ($billions).

$PHR^{t}_{i,u}$ = process heat ratio; the amount of heat input required to produce a dollar of output (1000 Btu/$). This represents the amount of heat delivered to the target substance; not the fuel input to the process:

- o $PHR^{t}_{i,u} = HEAT^{t}_{i,u} / Q^{t}_{i}$
  - $HEAT^{t}_{i,u}$ = amount of process u heat required (bBtu)
  - Q^{t}_{i} = industry i output

$SHARE^{t}_{i,u,e}$ = share of the heating requirement for use u, that is delivered by equipment option e (%). As with the process heat ratio, this share represents the share of delivered heat, not the share of fuel input

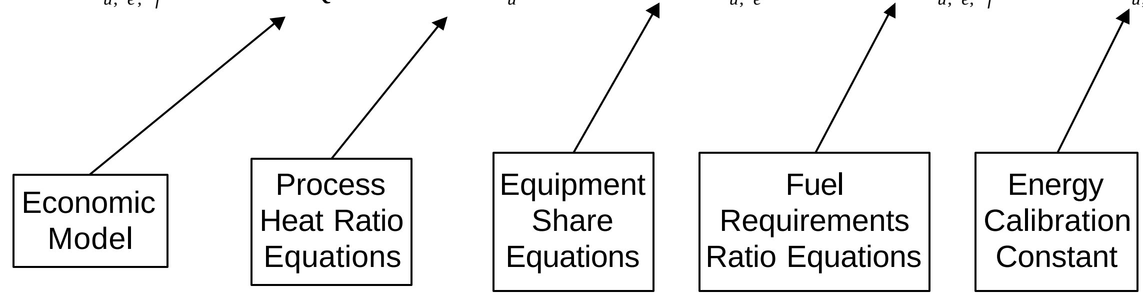
$FRR^{t}_{i,u,e,f}$ = fuel requirement ratio for a specific fuel used by option e (Wh/Btu or Btu/Btu) This ratio gives the input fuel requirement per Btu of delivered heat

$k_{u,f}$ = calibration constant.

The Thermal Model forecast structure is shown in Figure 4-5:

Figure 4-5
Thermal Model Structure

$$ENERGY_{u,e,f} = Q \times PHR_{u} \times SHARE_{u,e} \times FRR_{u,e,f} \times k_{u,f}$$



The key modeling elements in this structure are:

- The economic model, used to determine local output levels (Q).
- The process heat ratio equations, which determine temporal changes in process heat requirements ratios. Therefore, process efficiency improvements are modeled in this ratio as a decreasing function over time.
- Equipment share equations, which forecast process equipment shares over time. Electrification of an industrial process powered by gas or some other fuel is modeled as an increase in the share performed by electric equipment.
- Fuel requirements ratio equations, which project temporal changes in these ratios. Equipment efficiency improvements produce reductions in these ratios.
- Energy calibration constants, which are calculated to insure that the control total estimates of energy sales by industry, thermal use and fuel are obtained.

Lighting Model

The Lighting Model serves the following purposes:

- Defining lighting segmentation (light use and light source categories).
- Defining lamp and ballast efficiency options and technology data.
- Defining base-year energy sales and market profiles.
- Developing lighting energy sales forecasts.

Energy sales are derived from detailed lighting equipment stocks and utilization factors. The forecast drivers are output capacity and capacity utilization rates. Capacity is the prime indicator of the amount of plant and equipment available for production. In the Lighting Model, capacity is used as the main driver for new lighting system purchases. Capacity utilization rates determine changes in lighting operating hours.

Lighting data are categorized by lighting use, lighting technologies, and specific systems. Lighting use categories include outside lighting and inside categories such as area lighting and task lighting for offices, warehouses, and production areas.

Applications and Equipment Technologies

Staff uses the following lamp types in its modeling:

- 4-foot, 32-watt fluorescent;
- 4-foot, 34-watt fluorescent;
- 4-foot, 40-watt fluorescent;
- 8-foot, 60-watt fluorescent;
- 8-foot, 75-watt fluorescent;
- 200-watt high-pressure sodium vapor;
- 400-watt mercury vapor;
- 250-watt metal halide;
- Standard incandescent.

Staff uses the following ballast types in its modeling:

- Fluorescent lamps with standard magnetic ballast (SMAG), high-efficiency magnetic ballast (HMAG), electronic ballast (ELEC);
- High-intensity Discharge ballasts (HIDB), for high-pressure sodium (HPS), metal halide, and mercury vapor (MV) lamps.

Specific Systems

Each of these lighting source types is applied in a broad variety of systems using many different loads (lamp kW plus ballast kW). Table 4-4 is a complete list of systems specified by staff in the model:

Table 4-4

Lighting Model Level of Detail

System Identifier	Ballast	Lamps /Fixture	Watts /Fixture	System Description
F40-SMAG	SMAG	4	175	4-ft Fluor Standard
F40-HMAG	HMAG	4	161	4-ft Fluor Hi-Eff
F34-SMAG	SMAG	4	156	4-ft Fluor Standard
F34-HMAG	HMAG	4	139	4-ft Fluor Hi-Eff
F32-HMAG	HMAG	4	131	4-ft Fluor Hi-Eff
F34-ELEC	ELEC	4	119	4-ft Fluor Elec
F32-ELEC	ELEC	4	107	4-ft Fluor Elec
F75-SMAG	SMAG	2	151	8-ft Fluor Standard
F75-HMAG	HMAG	2	143	8-ft Fluor Hi-Eff
F60-SMAG	SMAG	2	121	8-ft Fluor Standard
F60-HMAG	HMAG	2	113	8-ft Fluor Hi-Eff
F60-ELEC	ELEC	2	108	8-ft Fluor Elec
HID-HPS	HIDB	1	235	Sodium HID
HID-MV	HIDB	1	454	Mercury HID
HID-MH	HIDB	1	295	Metal Halide HID
OTHER	NONE	1	100	Generic System

Lighting Model Central Energy Equation

To model end use energy consumption, the central energy equation is applied:

$kWh^{t}_{i,u,s} = Q_{i}^{*t} \times LCR^{t}_{i,u} \times SHARE^{t}_{i,u,s} \times HOURS^{t}_{i,u} \times (1/EFF^{t}_{i,u,s})$

where, for industry i, year t, lighting use u, and light source s:

$kWh^{t}_{u,s}$ = electricity sales (GWh);

Q^{*t} = production capacity ($ million);

LCR^{t}_{u} = lumen capacity ratio (lumens/$);

$SHARE^{t}_{u,s}$ = share of lighting (lumens) provided by the light source (%);

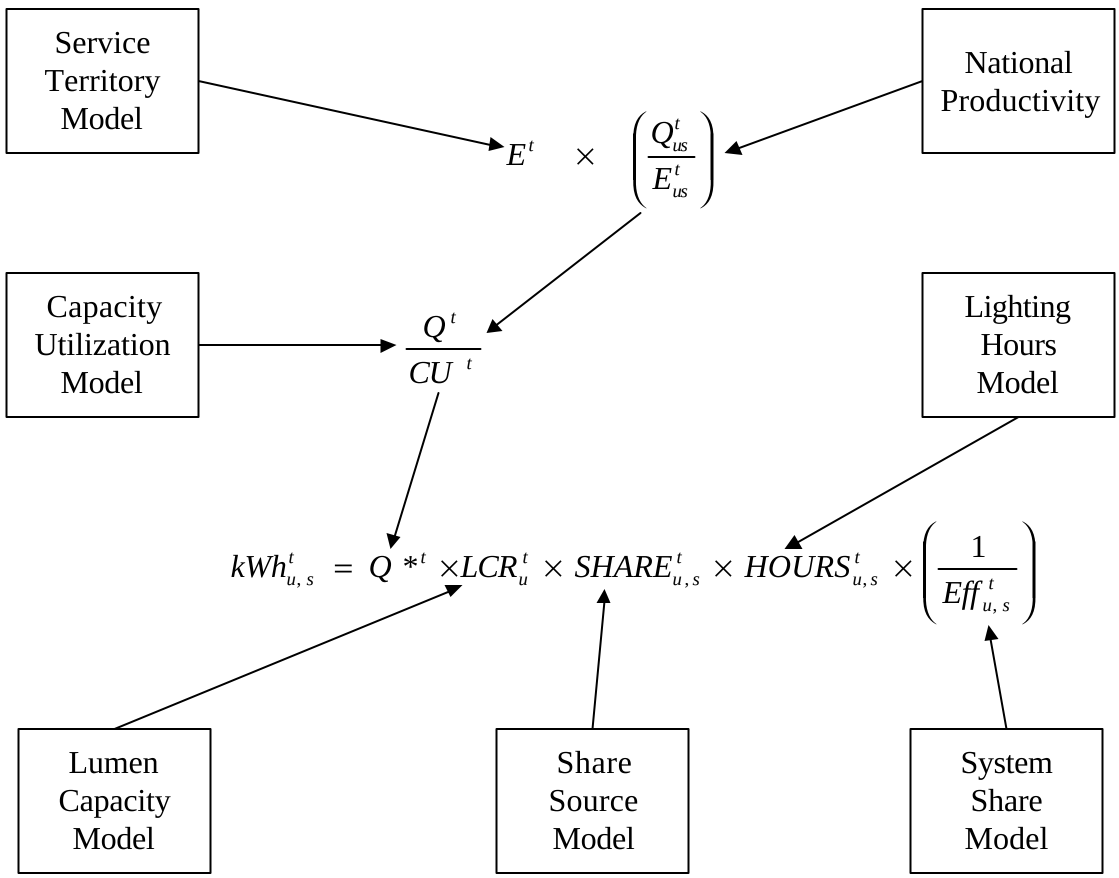
$HOURS^{t}_{u}$ = annual operating hours;

$EFF^{t}_{u,s}$ = average option efficiency for the light source (lumens/watt).

Average option efficiency is equal to the system efficiency when a single lighting system represents one lighting option. For lighting options that are represented by multiple systems, an average efficiency is computed from the individual system values.

The Lighting Model forecast structure is shown in Figure 4-6:

Figure 4-6
Lighting Model Structure



The key modeling elements in this structure are:

- The economic activity equations, used to determine local capacity (Q*). These equations are discussed in the Industry Models section.
- The lumen capacity ratio model, used to calculate the ratio over time t of lumen requirements per unit of capacity u. More simply, this is the ratio of total lighting capacity to industry production capacity, providing a measure of the importance of lighting in the production process.
- The light source share model, used to estimate changes over time in the share of lighting capacity for each of the light sources.
- The lighting hours model, used to estimate changes over time in hours of operation. As capacity utilization increases, so will operating hours, and therefore so will lighting usage. This relationship is not proportional, however.

- The system share model, used to estimate the change in specific system shares resulting from decay and replacement of lighting fixtures or ballasts, or adding such equipment due to new plant construction or other capacity expansion.

Heating, Ventilation and Air Conditioning (HVAC) Model

The HVAC model serves several purposes, namely:

- Defining heating, ventilation, and cooling uses.
- Defining equipment options and option shares.
- Forecasting HVAC energy sales.

Energy sales in the HVAC module are driven by changes in output. Exogenously specified fuel shares determine the allocation of these sales across competing fuels.

Applications and Equipment Technologies

The module is applied at the level of industrial aggregation specified in Table 4-1. The number of HVAC applications and technologies is user defined. Staff has defined the following applications and technologies for this forecast:

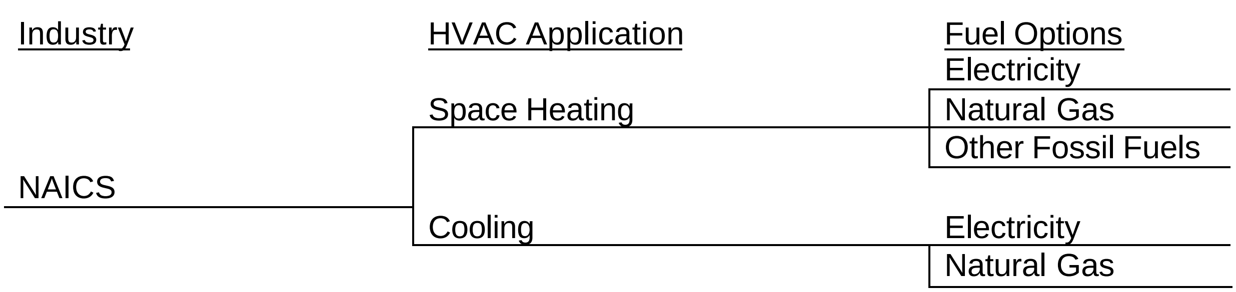
- Applications: space heating and cooling;
- Technologies: electric heating and cooling; gas heating and cooling; other fuel heating.

The HVAC module permits specification of equipment options such as electric, natural gas, or other fossil-fueled furnaces, or electric and natural gas chillers. Staff has declined to define these in the model inputs.

The resulting level of detail is illustrated in Figure 4-7:

Figure 4-7

HVAC Model Level of Detail



This level of detail implies modeling of energy sales for a total of 140 categories, calculated as 28 industries x 3 heating technologies + 28 industries x 2 cooling technologies.

HVAC Model Central Energy Equation

HVAC energy use is calculated using the central energy equation:

$ENERGY_{i,u,e,f} = Q_i \times HRR_{i,u} \times SHARE_{i,u,e,f} \times FRR_{i,u,e,f} \times k_{i,u,f}$

where, for industry i, HVAC use u, equipment option e, and fuel f:

$ENERGY_{i,u,e,f}$ = annual energy use (GWh);

Q_i = economic activity equations used to determine local output levels ($millions);

$HRR_{i,u}$ = heat requirements ratio (Btu/$). For space heating, this is the ratio of heat input required per dollar of output. For space cooling, this is the ratio of heat removed required per dollar of output.

$SHARE_{i,u,e,f}$ = an exogenously provided forecast of fuel shares over time (%);

$FRR_{u,e,f}$ = fuel requirement ratio for each equipment option (no units);

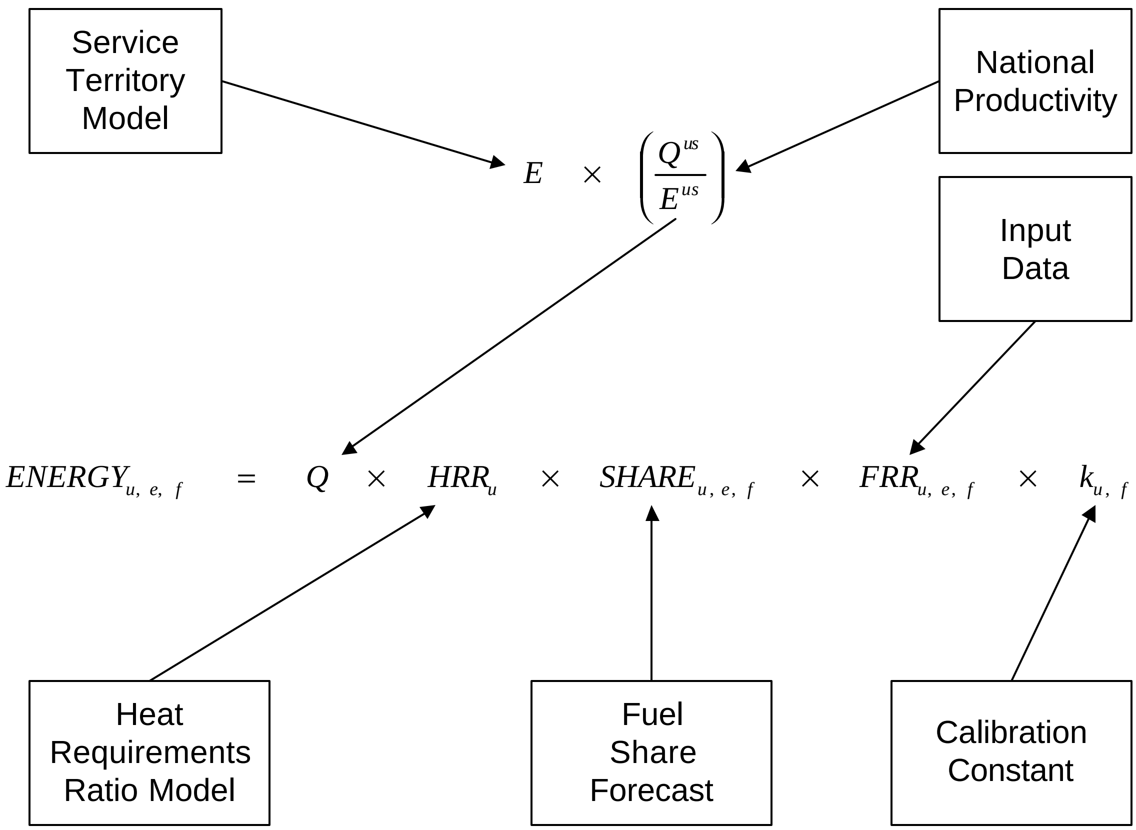
$k_{u,f}$, = calibration constants computed to insure that control total estimates of energy sales by HVAC use and fuel are realized.

Each of the five components of the central energy equation is itself a function of specified parameters:

- $HRR^t_{i,u} = HEAT^t_{i,u} / Q^t_i$, where:
  - $HEAT^t_{i,u}$ is the amount of HVAC use u heat delivered/removed in year t (mmBtu);
  - Q^t_i is the output in year t ($ millions).
- $SHARE^t_{i,u,e,f}$, is the share of HVAC heating requirements in year t (%).
- $k_{i,u,f}$ is a calibration constant to insure that estimated energy use by use and fuel is equal to control total values that are input for each industry. The constant is the ratio of the target energy usage $TARGET_{i,u,f}$ to the total energy usage $TOTAL^0_{i,u,f}$:
  - $k_{i,u,f} = TARGET_{i,u,f} / TOTAL^0_{i,u,f}$, where
    - $TOTAL^0_{i,u,f} = Q^0_i \times HRR^0_{i,u} \times SHARE^0_{i,u,f} \times FRR_{u,f}$

The HVAC model structure is shown in Figure 4-8:

Figure 4-8
HVAC Model Structure



The key modeling elements in this structure are:

- The economic activity equations, used to determine local output levels (Q). These equations are discussed in the Industry Models section.
- The heat requirements ratio equations, which give the amount of heat required in an industry per dollar of output for each HVAC application.
- An exogenously generated fuel shares forecast.
- Fuel requirements ratios for each equipment option.
- Calibration constants calculated to insure that control total estimates of energy sales by HVAC application and fuel are obtained.

Other Processes Model

This model serves several purposes, namely:

- Producing energy forecasts for processes defined by the user that are not captured in the other INFORM models.
- Forecasting emissions levels associated with process energy usage. The staff forecast defined nitrogen oxides, sulfur oxides, and carbon dioxide emissions

types. Exogenously specified emissions factors (lbs/MMBtu) and changes in energy consumption are used to determine these values.

- Forecasting emissions levels associated with production levels. The model provides the flexibility to project emissions levels that are direct by-products of production processes independent of energy consumption levels, such as solvent vapors produced by some industrial processes. These levels are driven by changes in output.
- Determining the energy and emission level impacts of technology substitutions. The user defines a set of equipment options for each process. Exogenously specified equipment share equations determine the allocation of energy sales across competing technology options.
- Determining the energy and emission level impacts of operating efficiency and emission factor improvements. For each equipment option, the user defines a base-year operating efficiency and set of emission factors. The model uses these to estimate the energy and emission impacts of market adoption of more efficient equipment and emissions control technologies.

Applications and Equipment Technologies

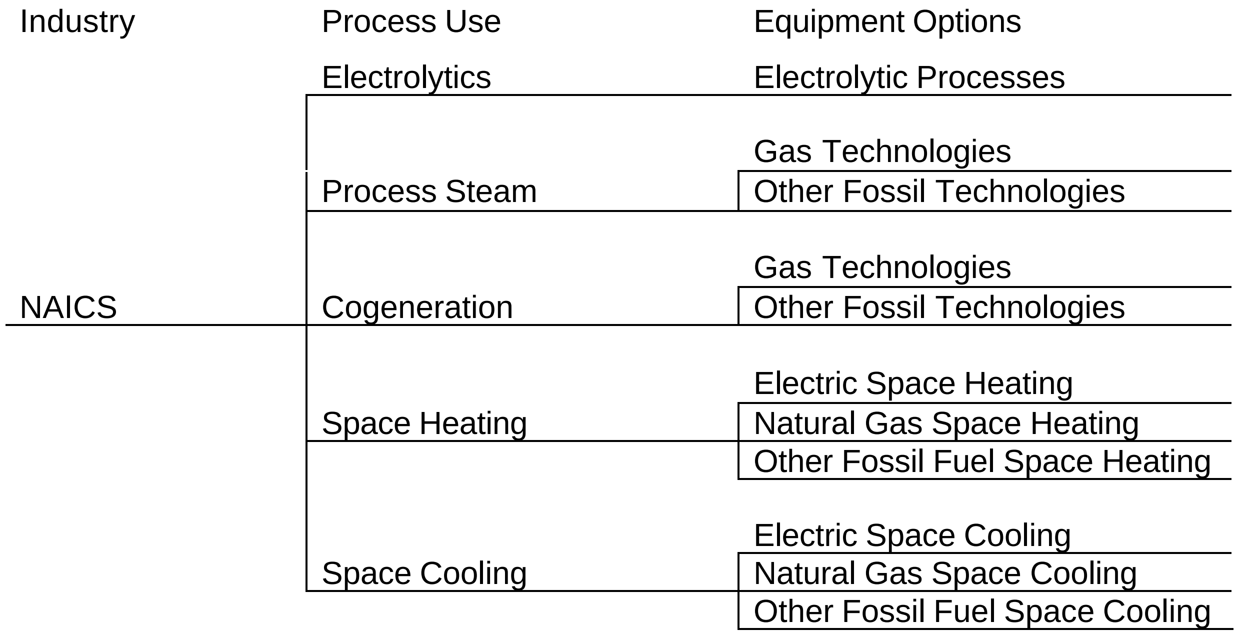
The Other Process Model can be applied to any scheme of industrial classification or aggregation. Energy Commission forecasts entail modeling the industrial NAICS categories in Table 4-1. The model also has the flexibility to allow the user to define the number of process uses. Typically, these process uses require energy to transform raw materials into intermediate and final products. Staff has defined the following process uses for the model:

- Electrolytics
- Process Steam
- Cogeneration
- Space Heating
- Space Cooling

For each process use, the user defines a list of current and emerging equipment options. The list defined by staff, when applied to the above process uses, produces the level of detail depicted in Figure 4-9:

Figure 4-9

Other Processes Model Level of Detail



Other Processes Model Central Energy Equation

The central energy equation, emissions equation and process heat ratio model appear to use the same components as the respective thermal model equations, but vary for different processes, technology options, etc.:

$$ENERGY^{t}_{i,u,e,f} = Q^{t}_{i} \times PHR^{t}_{i,u} \times SHARE^{t}_{i,u,e} \times FRR^{t}_{i,u,e,f} \times k_{i,u,f}$$

where, for year t, industry i, thermal use u, equipment option e, and fuel f:

$ENERGY^{t}_{i,u,e,f}$ = annual energy use (GWh or bBtu).

Q^{t}_{i} = annual output ($billions).

$PHR^{t}_{i,u}$ = process heat ratio; the amount of heat input required to produce a dollar of output (1000 Btu/$). This represents the amount of heat delivered to the target substance; not the fuel input to the process:

- $PHR^{t}_{i,u} = HEAT^{t}_{i,u} / Q^{t}_{i}$
  - $HEAT^{t}_{i,u}$ = amount of process u heat required (bBtu);
  - Q^{t}_{i} = industry i output.

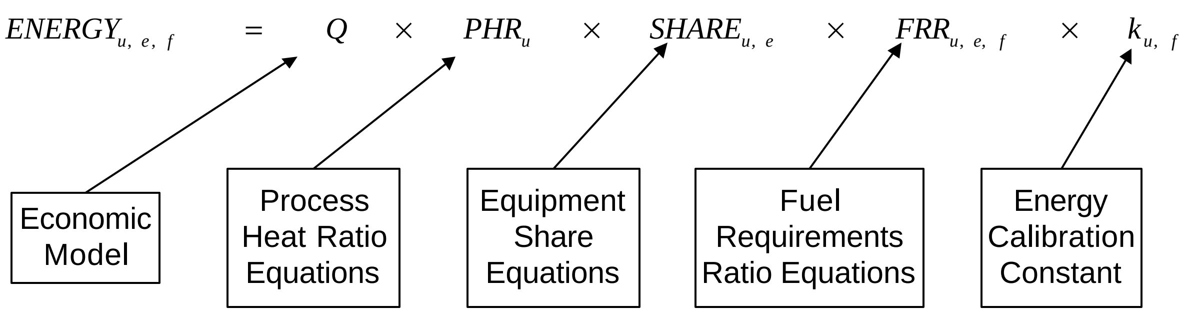
$SHARE^{t}_{i,u,e}$ = share of the heating requirement for use u that is delivered by equipment option e (%). As with the process heat ratio, this share represents the share of delivered heat, not the share of fuel input.

$FRR^{t}_{i,u,e,f}$ = fuel requirement ratio for a specific fuel used by option e (Wh/Btu or Btu/Btu). These ratios give the input fuel requirement per Btu of delivered heat.

$k_{u,f}$ = calibration constant.

The Other Processes Model forecast structure is shown in Figure 4-10:

Figure 4-10
Other Processes Model Structure



The key modeling elements in this structure are:

- The economic model, used to determine local output levels (Q).
- The process heat ratio equations, which determine temporal changes in process heat requirements ratios. Therefore, process efficiency improvements are modeled in this ratio as a decreasing function over time.
- Equipment share equations, which forecast process equipment shares over time. Electrification of an industrial process powered by gas or some other fuel is modeled as an increase in the share performed by electric equipment.
- Fuel requirements ratio equations, which project temporal changes in these ratios. Equipment efficiency improvements produce reductions in these ratios.
- Energy calibration constants, which are calculated to insure that the control total estimates of energy sales by industry, other use and fuel are obtained.

Miscellaneous Uses Model

The purpose of the Miscellaneous Uses model is forecasting miscellaneous fuels usage. In this model, energy sales are driven by changes in output.

Applications

This model is, like the others, applied at the level of industrial aggregation specified in Table 4-1. There is no limitation to the number of miscellaneous uses one can specify, but only one fuel type can be assigned to each use. Staff specified electricity, natural gas, and other fossil fuel for this forecast, resulting in the simple tree structure depicting the level of detail in Figure 4-11:

Figure 4-11

Miscellaneous Uses Model Level of Detail

The central energy equation is simpler than the equivalent equations for the other models. With the calibration constant $k_{i,f}$, detailed energy usage estimates for each fuel can be modeled.

$$ENERGY_{i,u,f} = Q_i \times HRR_{i,u} \times FRR_{i,u,f} \times k_{i,f}$$

where, for industry i, use u, and fuel f:

$ENERGY_{i,u,f}$ = annual energy use for miscellaneous use u and fuel use f (GWh or bBtu);

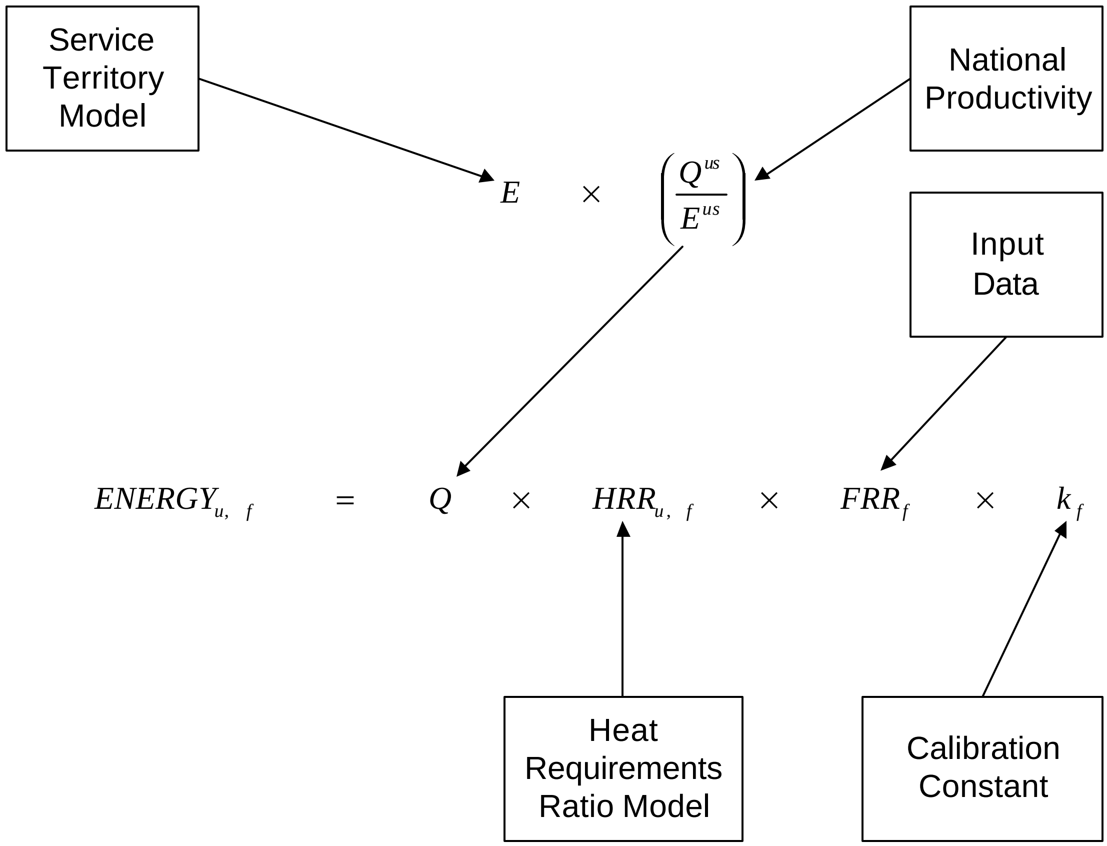
Q_i = economic activity equations used to determine local output levels ($millions);

$HRR_{i,u}$ = the miscellaneous use heat input requirements ratio for use u (Btu/$);

$FRR_{i,u,f}$ = fuel requirement ratio for specific use u and fuel f (Wh/Btu or Btu/Btu);

The Miscellaneous Uses Model forecast structure is shown in Figure 4-12:

Figure 4-12
Miscellaneous Uses Model Structure



The key modeling elements in this structure are:

- The economic activity equations (Q), which determine local output levels.
- The heat requirements ratio equations, used to determine temporal changes in heat requirements ratios per dollar of output.
- The fuel requirement ratios for each fuel; that is, the input fuel requirement per Btu of delivered heat.
- Calibration constants computed to insure that control total estimates of energy sales by fuel are obtained.

CHAPTER 5

AGRICULTURAL AND WATER PUMPING ENERGY DEMAND FORECAST MODELS

Introduction

The agricultural sector is divided into three subsectors: (1) crop production/irrigation water pumping, (2) dairy and livestock production, and (3) domestic water pumping. Irrigation water pumping for crop production is the most significant electricity using sector, therefore three separate models have been developed with the major focus on electricity consumption for water pumping in crop production.

In the crop production sector in the PG&E and SCE service areas, energy used for irrigation water pumping is forecast using econometric models based on the economics of water usage in the agricultural sector. For the remaining service areas a combination of econometric and trend analysis is employed.

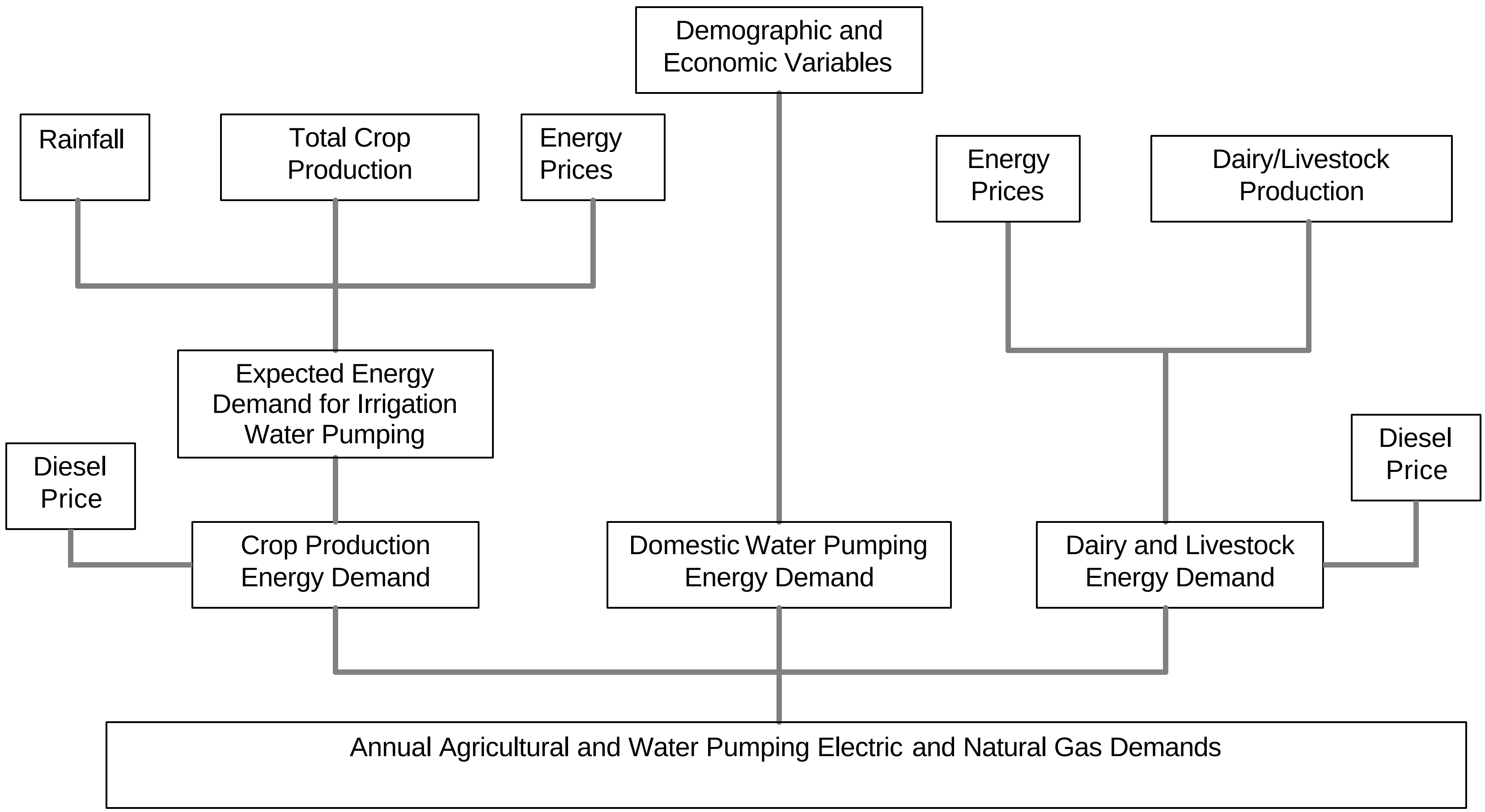
In the dairy and livestock sector, energy demand forecasts for the PG&E and SCE areas are generated using econometric models relating energy usage in this sector to the levels of dairy and livestock production, as well as to electricity prices. For the remaining areas, a combination of trend and time series analysis is used to forecast energy demand.

Domestic water pumping requirements are forecast using econometric models in which energy consumption is regressed on the total number of homes.

The explanatory variables used in each of the subsector models are illustrated in Figure 5-1. The data used in this analysis comes from the California Energy Commission, California Department of Water Resources, California Department of Food and Agriculture, California Department of Finance, and the utilities. A more detailed listing of the data sources can be found in Table 5-7 at the end of the chapter.

Figure 5-1

Agricultural and Water Pumping Energy Demand Forecast Models



Source: California Energy Commission staff, May 2005

Irrigation Water Pumping

Theoretical Structure

The econometric models for the PG&E and SCE service areas are based on the following theoretical framework. Electricity is predominantly used in this subsector to pump ground water or surface water for irrigation purposes. A description of the model for ground water pumping energy usage follows. That for surface water pumping is quite similar.

The amount of electricity used to pump ground water is affected by the amount of ground water pumped, and the prices of electricity and diesel in the agricultural sector. This last variable accounts for fuel substitution possibilities in the long run. We have

$$E_t = \varphi_0 + \varphi_1 GW_t + \varphi_2 PE_t + \varphi_3 DIESELP_t \qquad (1)$$

where

E_t = electricity consumption for ground water pumping (GWh)
GW_t = amount of ground water pumped
PE_t = price of electricity in the agricultural sector ($/kWh)
$DIESELP_t$ = price of diesel in the agricultural sector ($/gallon)

A similar equation is written for the surface water by replacing GW_t with SW_t in the above equation, where

SW_t = the amount of surface water pumped.

This model could be easily estimated if reliable data on ground water pumping were available. Unfortunately this is not the case; therefore an indirect method of estimation was adopted. This method relates ground water pumping to its driving factors using economic theory, and substitutes the result into the above equation.

The starting point in the development of an economic model for water usage is the equilibrium condition that the supply of groundwater pumped must equal total demand for water by the agricultural and urban sectors minus the supply of surface water.

$$GW_t = ADW_t + UDW_t - SW_t \qquad (2)$$

where

ADW_t = demand for water by the agricultural sector
UDW_t = demand for water by the urban sector

The *conditional* agricultural demand for water is assumed to be a linear function of the form[1]

$$ADW_t = \alpha + \beta PW_t + \gamma Q_t \tag{3}$$

where

PW_t = water price
Q_t = quantity of crop produced

The amount of water needed to produce any type of crop depends on the quantity of the crop to be produced as well as the price of water. Water demand will depend on the amount of land needed to produce one unit of a given crop, and the amount of water needed to irrigate one unit of land. Over time, both of these ratios will change due to technological progress. A linear trend is a simple way of capturing this phenomenon.

The next equation specifies the supply of ground water pumped as a function of the prices of water and electricity. The electricity price enters the equation to capture the electricity cost of pumping ground water

$$GW_t = \lambda_0 + \lambda_1 PW_t + \lambda_2 PE_t + \lambda_3 RAIN_t \tag{4}$$

where

$RAIN_t$ = rainfall

The supply of ground water is expected to increase following an increase in the price of water or an increase in the rainfall, and a decrease in the price of electricity.

The supply of surface water can similarly be modeled in terms of the price of water, the price of electricity (to pump surface water) and the amount of rainfall (to account for drought conditions):

$$GW_t = \theta_0 + \theta_1 PW_t + \theta_2 PE_t + \theta_3 RAIN_t \tag{5}$$

Urban water demand is treated as an exogenous variable in this model.

The four equations of the economic model, i.e., equations (2) through (5), are solved to obtain the equilibrium values of the four endogenous variables ADW, GW, SW and PW as linear functions of the exogenous variables of the model. Of these four functions only those for GW and SW are needed, the former to be substituted in (1) and the latter in the corresponding function for the surface water energy usage. These functions take the following reduced forms:

$$GW_t = a_0 + a_1 PE_t + a_2 Q_t + a_3 RAIN_t + a_4 UDW_t \tag{6}$$

$$SW_t = b_0 + b_1 PE_t + b_2 Q_t + b_3 RAIN_t + b_4 UDW_t \tag{7}$$

Note that the price of water does not appear in these equations since, being endogenous, it has been "solved out."

Substituting equation (6) into (1) we obtain the final forecasting equation for groundwater pumping, GW:

$$E_t = B_0 + B_1PE_t + B_2CROP_t + B_3RAIN_t + B_4DIESELP + B_5UDW_t \quad (8)$$

where

$CROP_t$ = quantity of crops produced (tons)

A similar equation obtains for SW by substituting (7) in the corresponding equation.

In the empirical equations some proxy variables, such as urban population and urban employment, were used in place of UDW to capture the effect of this variable on electricity usage. They did not perform well, however. We therefore dropped this variable from the regressions. Moreover, the diesel price was not deemed important in the SW regressions and, thus, was dropped from these equations.

The QFER data for SIC 01 (Crop Production) was used as the dependent variable (E) on the left hand side of (8). This is the energy used for crop production, most of which is for water pumping. For surface water regressions, the QFER data for SIC 497 (Irrigation Systems) was used as the dependent variable.

The data used for crop production are the total tons of agricultural products, published by the California Department of Food and Agriculture. These are simple sums of all the crops produced in California. The main advantage of this index is that it is subject to a lesser amount of measurement error. Moreover, it is intuitively clear that an increase in the quantity of any crop produced will increase the demand for water and hence electricity. The rainfall data for the PG&E area are the inches of precipitation and for the SCE are the amounts of water runoff. The prices of electricity (¢/kWh) and diesel fuel ($/gallon) for the agricultural sector are provided by the Energy Commission's Electricity Analysis Office and Transportation Fuels Office, respectively.

Estimation Results for SCE

Table 5-1 presents the results for both Crop Production (SIC code 01) and Irrigation Systems (SIC Code 497) for the SCE service area. In the Crop Production model the diesel price was insignificant and was, therefore, dropped from the equation. All the other coefficients had the right signs and all but the crop variable were highly significant. The time variable is excluded from the regression since it was insignificant and its inclusion caused some of the other variables to have the wrong signs. The crop variable is statistically insignificant. There might be several reasons for this. First, this could happen in general if the independent variable is less volatile than the dependent variable, which is the case for the crop variable. Second, the amount of crop production is affected by RAIN which is already included in the regression. And, finally, it is a state-wide variable. Nevertheless, since it has a correct sign, it is deemed important as a determinant of energy consumption.

In the Irrigation Systems regression all the coefficients have the right signs. Note that the RAIN variable enters with a negative sign and is significant. This can be explained as follows. An increase in the rainfall will increase the supply of surface water and lower the price of water, everything else the same. This will induce a higher demand for surface water and higher electricity usage to pump the surface water. At the same time the increase in the rainfall will reduce the need for surface water delivered from distant places. The final equilibrium quantity of the surface water pumped will depend on which effect is stronger; electricity consumption in this sector could rise or fall as a result of an increase in rainfall.

The electricity price is not statistically significant. It was kept in the equation due to its correct sign. Lagged energy usage significantly improved the R^2 and the forecasts. This could be because this variable picks up the effect of crop production which is slow-moving, as mentioned above. The crop variable itself was not significant and, was, therefore excluded from the equation.

Estimation Results for PG&E

Table 5-2 presents the results for the PG&E Service Area. The coefficients for both sectors have the right signs. In the Crop Production regression electricity price and rain have a statistically significant effect on energy consumption. The diesel price is not statistically significant but its inclusion improved the overall fit.

For the Irrigation Systems regression, the coefficients have the expected signs but are not very significant. Nevertheless the crop production is significant at a 10 percent significance level. The reasons for the insignificance of the coefficients are the same as those discussed in the SCE case. A dummy variable for 1991 was included to account for the unusual behavior of energy consumption in this year.

Other Service Area Modeling

For the remaining service areas a combination of time series and trend analyses was used to forecast water pumping energy consumption in the agricultural sector.

Table 5-1

Regression Results for SCE

Groundwater Pumping Model Results			
Variable	**Coefficient**	**t-Statistic**	**R^2**
Constant	1197.28	5.25	
Electricity Price	-41.28	-2.96	
RAIN	-0.68	-5.63	
CROP	2.27E-06	1.26	0.70
Surface Water Pumping Model Results			
Constant	40.03	0.91	
Electricity Price	-0.11	-0.03	
RAIN	-0.08	-2.88	
Lagged Energy Consumption	0.71	6.70	0.71

Table 5-2

Regression Results for PG&E

Groundwater Pumping Model Results			
Variable	**Coefficient**	**t-Statistic**	**R^2**
Constant	4363.63	7.31	
Electricity Price	-103.10	-3.66	
RAIN	-47.23	-3.50	
DIESELP	2.53	1.26	0.54
Surface Water Pumping Model Results			
Constant	1316.87	2.51	
RAIN	-16.18	-1.52	
CROP	1.29E-05	1.82	
Dummy for 1991	-895.76	-3.29	0.43

Dairy and Livestock Sector

The following describes the Dairy and Livestock (SIC code 02) energy forecasting models. The models estimated for the PG&E and SCE areas are different from the rest of the planning areas since these two planning areas account for about 80 percent of total SIC 02 energy consumption.

The amount of energy used in the Dairy and Livestock sector in any planning area is a function of the level of dairy and livestock production in that area. However a breakdown of the dairy and livestock variables by county or planning-area is not available. For this reason the planning area Dairy and Livestock energy consumption was directly correlated with the state-wide values of the driving variables. The underlying assumption was that an increase in the state-wide level of any of the driving variables will result in an increase in the level of the same variable in the service area.

The econometric models for PG&E and SCE have two components:

1. The energy consumption in the Dairy and Livestock sector is forecast on the basis of the total amounts of different products produced in this sector, and the energy prices faced by the producers in each planning area.

2. Forecasts of dairy and livestock production levels are generated in order to generate forecasts of the total energy usage.

The models start with a conditional demand function for energy. Conditional demand models assume that producers minimize their total costs for given levels of output subject to their technology constraints, represented by a production function. Such a minimization results in the demand functions for different resources as functions of input prices and production levels. For estimation purposes we assume that the conditional demand for energy is a linear function of the production levels and energy prices.

$$E_t = a + b_1Q_1 + b_2Q_2 + \ldots + cPE \qquad (9)$$

where

E_t = electricity consumed in dairy and livestock production in the service area
Q_i = state-wide production of product i

At the estimation stage, various forms of this model were evaluated to obtain the most plausible results. With regards to the production level variables, aggregate data on several products are available for California. As we cannot have very many explanatory variables in our regression equation, staff had to aggregate them further. Since different products have different units of measurement, staff opted for the following aggregation:

Category 1. Cattle, calves, hogs, pigs, sheep, and lambs produced; in thousand pounds.
Category 2. Feedlot cattle marketed; in thousand heads.

Category 3. Milk produced, in million pounds.
Category 4. Eggs produced, in millions.
Category 5. Broilers, turkeys, and chickens produced, in thousand pounds.

The data for these variables were obtained from the California Agricultural Statistics Service.

Estimation Results for SCE

After numerous trials, Staff selected a model in which Dairy and Livestock energy consumption is regressed on the levels of milk produced (category 3) and broilers, turkeys, and chickens produced (category 5). The electricity price turned out to have a statistically significant effect on energy usage. However, its inclusion resulted in non-intuitive forecasts. It was therefore excluded from the regression. Table 5-3 presents the regression results.

Table 5-3

Estimated Model for SCE

Dairy and Livestock Energy Model Results			
Variable	**Coefficient**	**t-Statistic**	**R^2**
Constant	35.12	1.19	
Milk Produced	0.005	7.31	
Broilers and Turkeys	0.0001	4.72	0.88

The R^2 is quite high and all the coefficients have the right signs. The independent variables are highly statistically significant.

Estimation Results for PG&E

A similar procedure was employed for the PG&E service area. The following table presents the regression result.

Table 5-4

Estimated Model for PG&E

Dairy and Livestock Energy Model Results			
Variable	**Coefficient**	**t-Statistic**	**R^2**
Constant	45.77	0.29	
Cattle and Calves Marketed from Feedlots	0.22	2.98	
Milk Produced	0.012	6.37	
Broilers and Turkeys	0.0001	2.10	0.75

The dairy and livestock production variables were forecast using a combination of econometric and time series analyses.

Remaining Service Areas

The remaining service areas together account for only about 20 percent of the total Dairy and Livestock energy consumption. For these areas, Staff used more ad hoc models for projection purposes. Table 5-5 summarizes the models estimated for these service areas.

Table 5-5

Estimated Models for Other Planning Areas

SMUD	Sample Mean = 30.43 (1980-2003)
LADWP	Forecast = 2003 electricity consumption (2.15)
SDG&E	Forecast = 2003 electricity consumption (11.95)
BGP	Sample Mean = 0.12 (1980-2003)
OTHER	Regression of energy consumption on cattle and calves marketed from feedlots and milk produced Energy Consumption = 17.32 + 0.009 Feedlot + 0.0009 Milk t-statistics (2.51) (1.97) (5.76) $R^2 = 0.71$ Sample period: 1980-2003

Urban Water Pumping Requirements

Electricity is used to deliver water to urban areas; any model developed to forecast energy usage in the Water Supply sector (SIC code 494) should consider 1) the amount of water demanded in the area, and 2) the amount of energy used to deliver that amount of water.[2]

Demand for Water

In urban areas water is used in four different sectors: 1) residential, 2) commercial, 3) industrial and 4) government.

Residential Water Demand

In general, the residential demand for water depends on a host of variables, both economic and non-economic in nature. These variables include climate, landscape irrigation, housing density, persons per household, water prices, water conservation programs, and so on.[3]

One can postulate a linear time series equation of the form

$$W_R = a_0 + a_1 TEMP + a_2 PPHH + a_3 PW + a_4 HOUSE + a_5 INCOME \quad (10)$$

where

W_R = water use in the residential sector
TEMP = temperature
PPHH = persons per household
PW = price of water
HOUSE = number of households
INCOME = an appropriate measure of household real income

One such model can be written for each planning area.

Commercial Water Demand

Commercial water use includes the amount of water used in office buildings, restaurants, filling stations, and other business establishments. Commercial water use is also divided into indoor and outdoor usages, and landscape irrigation is a significant part of total commercial demand.

The demand for water in the commercial sector is greatly influenced by the state of the economy. During booms, when the level of aggregate demand is high due to high household incomes, the demand for water in the commercial sector increases. Conversely, in an ailing economy characterized by many bankrupt businesses and vacant office buildings, commercial water use diminishes.

It, therefore, seems that some of the variables in equation (10), such as household income and the number of households are also the driving variables in the commercial sector. We can thus write

$$W_C = b_0 + b_1 TEMP + b_2 PW + b_3 HOUSE + b_4 INCOME \quad (11)$$

where

W_C = commercial demand for water.

Industrial Water Demand

In the aggregate, the amount of water consumed in this sector will depend on the amount of output produced by the firms, as well as climate and the cost of water. We may, therefore, postulate

$W_I = c_0 + c_1TEMP + c_2PW$ (12)

where

W_I = industrial water demand

Ideally, one would want to estimate equations (10) through (12) separately. However, a breakdown of total urban water demand into different components is not available. We, therefore, have to estimate an aggregate function. To this end, we add both sides of the above three equations to get

$W = d_0 + d_1TEMP + d_2PPH + d_3PW + d_4HOUSE + d_5INCOME$ (13)

where

W = total urban demand for water.

We note that the coefficients in equation (13) are the sum of the coefficients in equations (10) through (12).

Energy Consumption

The QFER data for electricity consumption in the Water Supply sector can be related to the amount of water demand using a simple model of the form

$E = e_0 + e_1W$ (14)

Where

E = electricity consumed in urban water pumping

Staff combined regression equations (13) and (14) into one, relating SIC 494 energy usage in each area to the determinants of urban water demand. This is because consistent county level data on water usage is not available. DWR publishes county level data every ten years. However, data for some years and counties are missing. Various trials indicated that the total number of homes in each planning area had the greatest amount of explanatory power in the regressions. Therefore, all the models were estimated by regressing energy consumption on this variable. Table 5-6 presents the estimation results.

Table 5-6

Urban Water Usage Energy Forecasting Models

Sample Period

	Estimated Coefficients	t-Statistics	R^2
PG&E			
Constant	-264.79	-2.16	0.82
Total Homes	0.0003	10.69	
SCE (sample period: 1977-2002)			
Constant	-1069.31	-1.46	0.60
Total Homes	0.0013	6.11	
SMUD			
Constant	-62.61	-6.89	0.88
Total Homes	0.0003	13.42	
LADWP			
Constant	-230.12	-2.59	0.42
Total Homes	0.0003	4.29	
SDG&E			
Constant	10.76	.81	0.78
Total Homes	0.00001	9.50	
BGP			
Constant	-27.06	-0.98	0.11
Total Homes	0.0002	1.75	
OTHER			
Constant	-73.65	-10.89	0.92
Total Homes	0.00005	16.99	

Table 5-7

Data and Data Sources

Variable	Source of Data
Energy usage	Quarterly Fuel and Energy Reports filed by LSEs with the California Energy Commission
Electricity prices	California Energy Commission
Diesel price	California Energy Commission
Rainfall (PG&E) Rainfall (SCE)	California Department of Water Resources Southern California Edison
Agricultural and dairy production	California Department of Food and Agriculture
Population, Income, CPI	California Department of Finance
Weather data	Various sources; compiled by California Energy Commission
Total homes	Compiled by California Energy Commission; see Chapter 2

---

[1] The conditional demand for an input is the result of a cost minimization problem by a producer. The demand is conditional on the amount of output produced. Note that output (i.e., crop) prices do not appear in the function. See Hal Varian, Microeconomic Analysis, 2nd ed.

[2] See Urban Water Use in California, Department of Water Resources, Bulletin 166-3.

[3] ibid

CHAPTER 6

ENERGY DEMANDS SUMMARY FORECAST MODEL

Introduction

The Summary Model combines the energy consumption forecasts for the residential; commercial (including transportation, communication, utilities and street lighting), industrial, and agriculture and water pumping sectors. Electricity and natural gas forecasts are transmitted from the individual sectoral models for final adjustments and tabular displays. The model combines these forecasts for purposes of writing total electricity and natural gas consumption reports for each utility planning area and transferring adjusted data to the Hourly Electric Load Model (HELM). Four adjustments are made to sector forecasts as the reports are prepared.

First, residential and commercial space conditioning estimates for the backcast and forecast period are adjusted for weather. Forecasts emanating 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 the long-term norm.

Second, certain demand side management (DSM) 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.

Third, the weather and DSM adjusted sector forecasts are calibrated to historical consumption levels. The intent is to assure that the projected values for the forecast base period 1980-2003 are close to actual values. This period, also referred to as the “backcast,” is that for which historical data is available for comparison; historical data for 2004 is not yet available.

Finally, certain consumption does not fall into the categories established in the energy modeling system. This "unclassified" consumption is generally believed to be nonresidential in nature and is therefore distributed proportionally to the nonresidential sectors. This minor adjustment is undertaken in the Summary Model.

In addition to the adjustments described above, the raw end use input data is processed to produce final end use data that is transmitted to the HELM model for use in preparing hourly electric load forecasts.

The data used in the historical analysis was derived from the Quarterly Fuel and Energy Report (QFER). The historical data for the period 1980-2000 is obtained from QFER Form 11 and Form 4. Data for the period 2001-2003 is obtained from

CEC-1304 and CEC-1306. The weather data analysis was derived from the National Oceanic and Atmospheric Administration (NOAA) - National Climatic Data Center.

The methods by which these adjustments are made to various sectors and end uses are the subject of this chapter.

Model Structure

Figure 6-1 is a flow diagram of the Summary Model. End use or subsector electricity consumption forecasts are basic ingredients for the model. Table 6-1 lists the end uses and subsectors of the various models. Residential and commercial sector end uses are grouped into space conditioning and non-space conditioning categories. The two space conditioning end use backcasts are separately adjusted for deviations in annual weather conditions from the long-term historical norm. End use and subsector forecasts are aggregated to derive total consumption for each sector by utility planning area. Energy savings from some demand side management programs are deducted. The resulting forecast is calibrated to recorded historical consumption.

Weather Adjustment Procedure

Backcasts (1980-2003) and forecasts (2004-2016) for space heating and cooling end uses in the residential and commercial sectors are subject to a weather adjustment procedure. Space conditioning forecasts are developed for each of the sixteen climate zones delineated for California. These weather zones are mapped regionally into the seven utility planning areas (see Table 6-2).

Space heating backcast end use consumption is multiplied by the ratio of annual heating degree days to the average number of degree days for the period 1974 - 2003:

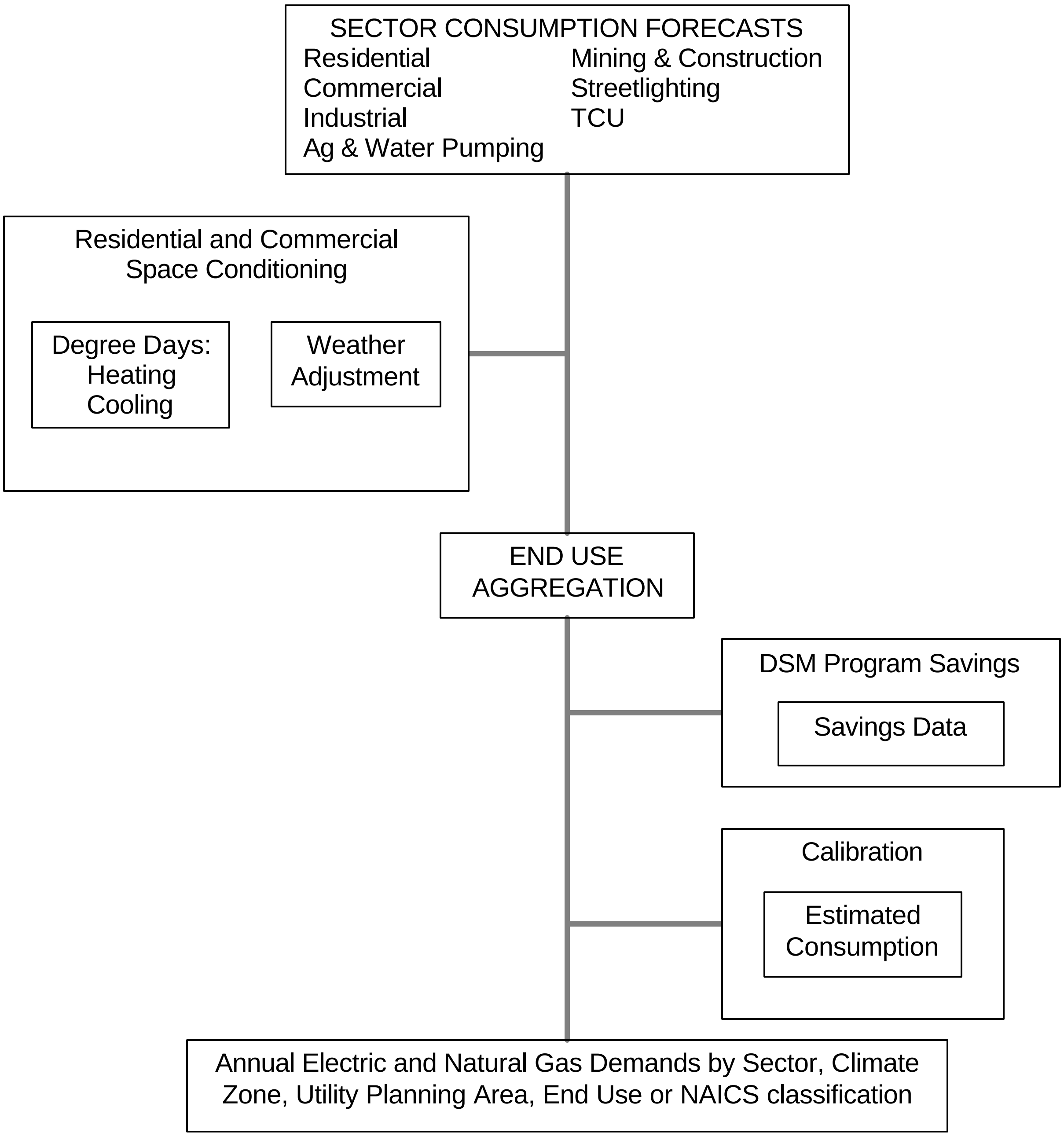
$$ADJDATA_{kl,l,t} = RAWDATA_{k,l,ti} * [ADJHT_{t,w} / NORMHT_{w}] \quad (1)$$

where:

ADJDATA = adjusted end use consumption
RAWDATA = end use consumption backcast

Figure 6-1

ENERGY DEMANDS SUMMARY FORECAST MODEL



Source: California Energy Commission staff, May 2005

Table 6-1

SUMMARY MODEL SECTOR END USES AND SUBSECTORS

1. RESIDENTIAL
   - <u>Space Conditioning</u>
     - Heating
     - Furnace Fan
     - Central Air Conditioning
     - Room Air Conditioning
     - Evaporative Air Conditioning
   - <u>Nonspace Conditioning</u>
     - Basic Water Heating
     - Dishwasher Water Heating
     - Clothes Washer Water Heating
     - Backup to Solar Water Heater
     - Solar Water Heater Pump
     - Dishwasher Motor
     - Clothes Washer Motor
     - Cooking
     - Clothes Dryer
     - Freezer
     - Color Television
     - Water Bed
     - Refrigerator
     - Miscellaneous
     - Solar Pool Backup
     - Pool Pump and Filter
     - Pool Heating
     - Hot Tub Pump and Filter
     - Hot Tub Heating
2. COMMERCIAL BUILDINGS
   - <u>Space Conditioning</u>
     - Heating
     - Cooling
     - Ventilation
   - <u>Nonspace Conditioning</u>
     - Water Heating
     - Cooking
     - Refrigeration
     - Lighting
     - Other
     - Outdoor lighting
     - Office equipment
3. INDUSTRIAL
   - Food and Beverage
   - Food Processing
   - Textile Mills
   - Textile Product Mills
   - Apparel and Leather Product Manufacturing
   - Logging and Wood Product Manufacturing
   - Paper Manufacturing (excl. Mills)
   - Pulp, Paper, and Paperboard Mills
   - Printing and Related Support Activities
   - Petroleum and Coal Products Manufacturing
   - Chemical Manufacturing
   - Plastics and Rubber Products Manufacturing
   - Nonmetallic Mineral Product Manufacturing (excl. Glass and Cement)
   - Glass Manufacturing
   - Cement
   - Primary Metal Manufacturing
   - Fabricated Metal Product Manufacturing
   - Machinery Manufacturing
   - Computer and Electronic Product Manufacturing (excl. Semiconductors)
   - Semiconductor and Other Electronic Component Manufacturing
   - Electrical Equipment, Appliance, and Component Manufacturing
   - Transportation Equipment Manufacturing
   - Furniture and Related Product Manufacturing
   - Miscellaneous Manufacturing
   - Publishing and Broadcasting Industries
4. TRANSPORTATION, COMMUNICATION, and UTILITIES
   - Rail Transportation
   - Land Passenger Transportation
   - Heavy Duty Vehicle Transportation
   - Postal Service
   - Water Transportation
   - Air Transportation
   - Pipeline Transportation
   - Rental and Leasing Services
   - Telecommunications
   - Radio and Television
   - Electric Services
   - Sanitary Services
   - National Security
5. MINING & CONSTRUCTION
   - Oil and Gas Extraction & Support Activities
   - Other Mining
   - Construction
6. AGRICULTURE AND WATER PUMPING
   - Crop Production
   - Livestock
   - Urban Water Pumping
   - Agriculture Water Deliveries
7. STREETLIGHTING

Table 6-2

ELECTRIC UTILITY PLANNING AREAS AND WEATHER STATIONS

Zone	Weather Station	Utility Planning Area
1	Ukiah (CDD) Eureka (HDD)	Pacific Gas & Electric
2	Sacramento	Pacific Gas & Electric
3	Fresno	Pacific Gas & Electric
4	San Jose	Pacific Gas & Electric
5	San Francisco Airport	Pacific Gas & Electric
6	Sacramento	Sacramento Municipal Utility District
7	Fresno	Southern California Edison
8	Long Beach (CDD) L.A. Airport (HDD)	Southern California Edison
9	Burbank	Southern California Edison
10	San Bernardino	Southern California Edison
11	Long Beach (CDD) L.A. Airport (HDD)	Los Angeles Department of Water & Power
12	Burbank	Los Angeles Department of Water & Power
13	San Diego	San Diego Gas & Electric
14	Yreka (CDD) Red Bluff (HDD)	Other
15	Blythe	Other
16	Burbank	Burbank, Glendale & Pasadena

Note: CDD = Cooling Degree Days
HDD = Heating Degree Days

ADJHT = annual heating degree days
NORMHT=average annual heating degree days (1974-2003)
i = sector index
k = utility index
w = climate zone index
t = year index

Space heating forecast end use consumption is multiplied by the ratio of the average number of degree days for the period 1992-2003 to the average number of degree days for the period 1974-2003. This adjustment is intended to capture more recent changes in weather conditions that can be expected to persist through the forecast period:

$$ADJDATA_{k,j,I} = RAWDATA_{k,j,i}*[NORM12HT_{w} / NORMHT_{w}] \qquad (2)$$

where:

NORM12HT = average annual heating degree days (1992-2003).

While both the residential and commercial sectors have the same heating adjustment, the adjustment for air-conditioning differs between the two sectors. The residential sector cooling adjustment uses the same logic as for heating, but the commercial sector adjustment attempts to account for internal heat load by reducing the effect of the weather adjustment. Residential air-conditioning backcast end use consumption is multiplied by the ratio of annual cooling degree days to the average number of degree days for the period 1974-2003:

$$ADJDATA_{k,j,I} = RAWDATA_{k,j,i} * [ADJCL_{j,w} / NORMCL_{w}] \qquad (3)$$

where:

ADJCL = annual cooling degree days;
NORMCL = average annual cooling degree days (1974-2003)

Residential air-conditioning forecast end use consumption is multiplied by the ratio of the average number of degree days for the period 1992-2003 to the average number of degree days for the period 1974-2003:

$$ADJDATA_{k,j,I} = RAWDATA_{k,j,i} * [NORM12CL_{w}/NORMCL_{w}] \qquad (4)$$

where:

NORM12CL = average annual cooling degree days (1992-2003).

In the commercial cooling adjustment the equations are the same except that the calculated ratios are reduced by a factor of 1/3. The backcast adjustment is:

$$ADJDATA_{k,j,l} = RAWDATA_{k,j,i} * [[[ADJCL_{jw}/NORMCL_{w}] * .67] + .33] \quad (5)$$

The forecast adjustment is:

$$ADJDATA_{k,j,l} = RAWDATA_{k,j,i} * [[[NORM12CL_{w}/NORMCL_{w}] * .67] + .33] \quad (6)$$

Demand Side Management Program Savings Adjustments

Many utility-sponsored DSM and voltage regulation programs 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. Table 6-3 lists the programs in these categories. Savings from these utility and public agency programs are quantified in the Summary Model.

Table 6-3

Demand Side Management Programs Quantified Externally

Residential

- New Construction (U)
- Master Meter (U)

Commercial

- New Construction (U)
- Miscellaneous Retrofit (P)
- Energy Extension Service (P)

Industrial and TCU

- Industrial Energy Management Services and Incentives (U)

Agriculture

- Energy Management Services and Incentives (U)

Note: U = Utility
P = Public Agency

Treatment of Unclassified Sales

Certain electricity use is reported in Quarterly Fuel and Energy Reports (QFER) as "unclassified."[1] Utilities have indicated this consumption is primarily nonresidential. Consequently, the Summary Model allocates unclassified use to four of the six nonresidential sectors (commercial, industrial, TCU and agricultural and water pumping) based on each one's share of total consumption across the four sectors (*e.g.*, if the industrial sector's share of total use by these sectors is 40%, this percentage of unclassified use is allocated to it).

Historical Electricity Consumption

Historical consumption is the sum of utility sales and estimates of self-generation.[2] QFER sales data are classified by NAICS codes into seven customer sectors used to define homogeneous groups.[3] Historical estimates of self-generation are provided by the electric generators.

Calibration

The energy forecasts may not exactly match recorded levels of historical consumption. End use energy forecasting methodology relies on representations of individual appliance energy use both now and in the future. The aggregate projected energy use of numerous appliances may not equal recorded historical energy use for a given sector. The Summary Model therefore calibrates each sector's energy demand backcast to actual consumption. This procedure adjusts the level of the forecast while maintaining the integrity of the projected annual growth rates from the sector forecasts.

The calibration method used for the CED 2006 electricity demand forecast was to calibrate the long-term forecast to the last year for which historical data is available (2003).

The Summary Model can calculate a calibration factor at the residential/nonresidential level, if desired, and also can exclude any sector or year from the regression calculating the trend values.

Calibrated consumption is the product of consumption from the sector projection model, appropriately adjusted for demand side management, voltage reduction, and deviations of weather conditions from the historical norm and the calibration factor:

$$CF_{i,t,k} = F_{i,t,k} * R_{i,k} \qquad (8)$$

where:

CF=calibrated consumption
F=sector consumption sales adjusted for weather and conservation
R= calibration factor

Endnotes

[1] The Quarterly Fuel and Energy Report (QFER) is a summary of California energy use supplied to the Energy Commission by energy retailers and generators operating within the state.
[2]Self-generation is generation of electricity by a non-utility party that is retained for use on site. Some third-party qualifying facilities retain a portion of plant output even if the majority is sold to a utility. Some facilities' output is used entirely on site.
[3] Historical data submitted that was based on Standard Industrial Classification (SIC) codes has been converted to NAICS.

CHAPTER 7

PEAK DEMAND AND HOURLY LOAD FORECAST MODEL

Introduction

The Energy Commission's Peak Demand and Hourly Load (PDHL) Model allocates annual electricity consumption to hourly loads for every hour of the forecast horizon, including the peak hour of each year. This model calculates hourly loads by end use and sums these to the utility level, providing a forecast of utility system loads for each hour and peak demand for each year of the forecast period. The forecasts of utility system peak are then adjusted to reflect known aspects of system behavior, such as the effect of transmission and distribution losses. HELM (the Hourly Electric Load Model), developed by EPRI (Electric Power Research Institute), and is used as a major component of the PDHL Model to produce staff's peak demand and hourly load forecast.

This chapter outlines the key features in each stage of the annual consumption to hourly and peak load allocation process. This chapter presents the theoretical basis for the PDHL Model and summarizes the important data sources required to operate the model and reports the significant modifications made for the current forecast. The data used in this analysis comes from Title 20 Load Metering Reports, NOAA, and Summary Model. These data sources are discussed in more detail below.

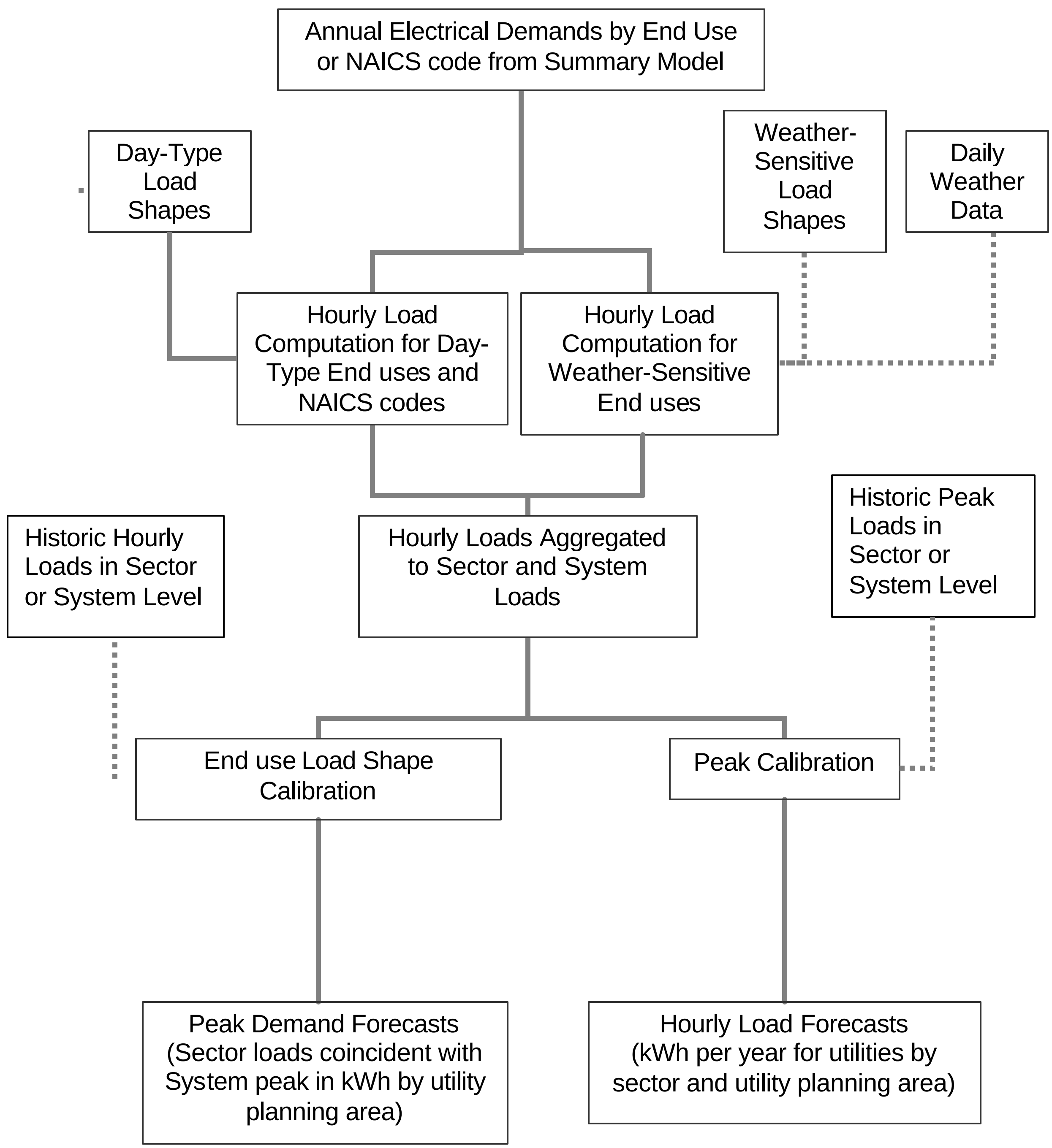
Model Structure

The purpose of the PDHL Model is to estimate hourly electricity loads from annual forecasts of electricity consumption. This explicit linkage of annual consumption and hourly load forecasts permits consistent treatment of factors affecting both annual and hourly electricity use.

A flow diagram of the PDHL Model is shown in Figure 7-1. As the first step of the peak forecast, annual end use consumption is allocated to hourly loads. With a few exceptions, sector end use categories in the PDHL model are consistent with those used in the sector models. Residential and commercial sector end uses are grouped into day-type and weather sensitive categories. All other sector end uses are categorized by day type. Different approaches are used to compute hourly loads for day-type and weather-sensitive end uses. Second, hourly end use loads are aggregated to hourly sector and system loads. The first and second steps are done with HELM, using macros created in the model's pre-processor. Third, coincident sector loads and system peak loads are extracted from hourly sector and system loads with the HELM post-processor. Finally, peak calibration is undertaken to compensate for discrepancies between model results and recorded peak data.

Figure 7-1

Peak Demand and Hourly Load Forecast Model



Source: California Energy Commission staff, May 2005

The first two steps of the hourly load forecast are the same as those of the peak forecast. After HELM generates the hourly loads at the sector or system level, the model's Auto-Calibration tool is used to calibrate the HELM hourly loads against historical hourly sector or system loads. Auto-Calibration creates a new set of end use load shapes. Finally, the first two steps are repeated to create calibrated hourly loads at the sector or system level.

Computing Hourly Loads on Weather-Sensitive End use

Weather-sensitive end uses, namely space cooling and heating, are assumed to be sensitive to daily weather conditions. At present, only hourly loads on cooling and heating in the residential and commercial sectors are allocated with weather sensitive load shapes and weather data. A weather sensitive load shape file contains a set of daily weather response functions used to derive daily consumption based on daily observations of various weather variables. It also includes a set of 24-hour load shapes defined for various combinations of seasons and day types. The HELM Model uses synthetic weather data in the forecast period and actual historic weather data in the backcast.

The allocation of hourly loads is divided into three steps. First, daily consumption as a percentage share of annual consumption is calculated for each day using weather response functions and weather data. Next, each daily percentage is multiplied by annual consumption to arrive at daily consumption. Finally, daily consumption is distributed to hourly loads based on a 24-hour load shape. In this section, the synthetic weather data used for the forecast period and weather response functions are described, and then the algorithms for hourly load allocation are represented.

Synthetic Weather Data

Staff uses a synthetic weather year developed from approximately 30 years of actual weather data for each climate region using a ranked-average methodology. The synthetic weather data is created by sorting and ranking the days of each year from highest to lowest according to daily high temperature. The first rank consists of all the days with the highest daily maximum temperature for each of thirty years, the second rank consists of all the days with the second highest daily maximum, and so on; 365 ranks (R_1, R_2,…R_{365}) are thus created, each with 30 observations.

The average high temperature for each of the ranks is then calculated. The average low temperature and humidity at the time of the high and the low is also calculated for each rank. This results in the average high, low and humidity for the hottest day, second hottest day, and so on.

Each rank is then assigned to a date. The rank assigned to each date of the year is based on the average high temperature for the date. R_1 (and its associated average high and low temperatures and humidity) is assigned to the date whose average high temperature over the past 30 years was greater than all other days of the year, R_2 to the date with the second highest average peak temperature, and so on. This provides a set of data which should represent typical extreme temperatures for each region. The typical extremes are instrumental in estimating weather sensitive demand for the hourly demand forecasts.

The result is a year's worth of daily highs, lows and humidity at the time of the high and the low temperature for each climate region derived from large samples of historic climatic events. This takes advantage of all the information contained in historic weather, rather than just utilizing one year of data as typical. To test the applicability of these weather series to peak demand forecasting, they were used in a regression model of system, daily peak weather-sensitive demand to find the weather-sensitive demand associated with "typical" (synthetic) weather. Each historic year's weather from 1960 through 1990 was also input to the model for a thorough comparison of the weather-sensitive demand produced by typical and selected years of actual weather. This resulted in 30 years of peak demands predicted by the actual weather of the last thirty years and our typical weather. The ranked estimates of peak demand produced from this procedure are close to the median of the actual recorded values.

Weather Response Function (WRF)

A weather response function is represented by a set of polynomial functions that have the same order. In the HELM Model, only linear and quadratic polynomial functions are used for weather response functions. The general form of the weather response function is given by:

$$F(x_1, x_2, \ldots, x_m) = c + (a_{11}x_1 + a_{12}x_2 + \ldots + a_{1m}x_m) + (a_{21}x_1^2 + a_{22}x_2^2 + \ldots + a_{2m}x_m^2) \qquad (1)$$

where

c = constant

a_{ij} = polynomial coefficient of weather parameter j to the i th power

x_j = daily observation of weather variable j

The relationship between weather and electricity demand was examined for many building type and climate zone combinations in the commercial sector and the residential sector. Analyses of load research data conducted by staff and research institutions provided the weather response functions used in the hourly load and peak demand forecast.

The weather response functions for different climate zones and types of buildings use different subsets of the weather variables listed in Table 7-1 to relate daily building cooling use to weather. The subsets of weather data used as independent variables in estimation of weather-load relations were chosen on the basis of statistical goodness-of-fit measures for each individual equation. Often, separate weather response functions were developed for different ranges of the weather variables. For example, commercial cooling energy use was estimated separately for days above and below 70 ^{o}F. Limits were also placed on the months to which annual commercial cooling energy could be allocated.

Table 7-1

Weather Variables Used in Weather Response Functions

Weather Variable	Description	Sector
AVGDRY	Average dry bulb temperature	Residential
AVGTHI	The daily average of the hourly THI	Commercial
TMX	Daily maximum of the hourly dry bulb temperature	Commercial
LTMN	Daily minimum of the hourly dry bulb temperature lagged one day	Commercial
AH	Average daily humidity	Commercial
PHOTOP	The hours of daylight in a day (a static function of longitude and latitude and date)	Commercial

The weather data used with the weather response functions for the backcast period are created from actual hourly weather data. The weather data used with the weather response functions for the forecast period is as described above. The following equations define the weather variables used in the HELM Model for the backcast period:

$$AVGDRY = \sum_{k=1}^{24} DB_k / 24 \quad (2)$$

$$TMX = \max(DB_1, DB_2, \ldots, DB_{24}) \quad (3)$$

$$TMN = \min(DB_1, DB_2, \ldots, DB_{24}) \quad (4)$$

$$LTMN = \text{lag}\ (TMN) \quad (5)$$

$$THI_k = 15 + 0.4 * (DB_k + WB_k) \quad (6)$$

$$AVGTHI = \sum_{k=1}^{24} THI_k / 24 \quad (7)$$

$$AH = \sum_{k=1}^{24} RHUM_k / 24 \quad (8)$$

where:

DB_k = dry bulb temperature (^{o}F) for hour *k*

WB_k = wet bulb temperature (^{o}F) for hour *k*

THI_k = temperature-humidity index at hour *k*

$RHUM_k$ = relative humidity for hour *k*

Since the synthetic weather analysis resulted in four daily weather variables (*TMX, TMN, HUMTMX, HUMTMN*), the weather variables used in the HELM Model for the forecast period are estimated as follows:

$AVGDRY = (TMX + TMN) / 2$ (9)

$AH = (HUMTMX + HUMTMN) / 2$ (10)

$AVGTHI = (MXTHI + MNTHI) / 2$ (11)

where:

$HUMTMX$ = humidity at the time of the high dry bulb temperature

$HUMTMN$ = humidity at the time of the low dry bulb temperature

Weather variables which are not described in equations (9) through (11) are calculated in the equations used for the backcast period.

Computation of Daily Consumption as Percentage of Annual Consumption

This step consists computing a normalization factor and applying it to relative daily loads, which are the values of the weather response functions based on daily weather conditions. The normalization factor is the sum of the relative daily loads. The following computation is made for this step:

$$WDCP_d = \frac{F_{st}(x_{d1}, x_{d2}, \ldots, x_{dn})}{DWNF} \quad (12)$$

$$DWNF = \sum_{d=1}^{ND} F_{st}(x_{d1}, x_{d2}, \ldots, x_{dn}) \quad (13)$$

where:

$WDCP_d$ **=** daily consumption for day *d* as percentage of annual energy usage

$DWNF$ = the normalization factor for daily weather-sensitive load shape computation

ND = the number of days in the year

x_{di} = daily observation of weather variable *i*

F_{st} = WRF applicable to season *s*, day-type *t*

n = number of weather variables used in WRF for season *s*, day type *t*

Allocation to Daily Consumption

The allocation of daily consumption proceeds as follows:

$$WDC_d = WDCP_d * AC \quad (14)$$

where:

WDC_d = consumption in day *d*

$WDCP_d$ **=** daily consumption for day *d* as percentage of annual energy usage

AC = annual consumption

Allocation to Hourly Loads

The allocation of daily consumption to hourly loads is similar to that of day-type end use. The following computation is made for this step:

$$WHL_{hd} = WDCP_d * WNHAF_{dh} \quad (15)$$

$$WNHAF_{dh} = \frac{WHAF_{dh}}{WHNF_d} \quad (16)$$

$$WHNF_d = \sum_{h=1}^{24} WHAF_{dh} \quad (17)$$

where:

WHL_{dh} = load in hour *h* of day *d*

$WDCP_d$ = daily consumption for day *d* as percentage of annual energy usage

$WNHAF_{dh}$ = the normalized hourly allocation factor for hour *h* of day *d*

$WHNF_d$ = the normalization factor for hourly allocation for day *d*

$WHAF_{dh}$ = the hourly allocation factor for hour *h* of day *d*

Computing Hourly Loads on Day-Type End use

The hourly loads of day-type end uses are assumed to respond, at most, to seasonal differences, which are not directly affected by weather conditions. Allocation of annual consumption to hourly loads is made using monthly, daily and hourly factors that are essentially fixed. Computing hourly loads is a three step process. First, the annual consumption is divided into a set of monthly consumption values. Second, monthly consumption is allocated to daily consumption. Finally, daily consumption is distributed to hourly loads.

Allocation to Monthly Consumption

Allocation of annual consumption to monthly consumption is accomplished by normalizing the monthly allocation factors and applying the normalized monthly allocation factors to annual consumption. The monthly allocation factors are a set of weights assigned to each month, which represent the relative energy usage from month to month. Allocation of annual to monthly consumption proceeds as follows:

$$DMC_m = DNMAF_m * AC \quad (18)$$

$$DNMAF_m = \frac{DMAF_m}{DMNF} \quad (19)$$

$$DMNF = \sum_{m=1}^{12} DMAF_m \quad (20)$$

where:

DMC_m = consumption in month *m*

$DNMAF_m$ = the normalized monthly allocation factor for month *m*

AC = annual consumption

$DMAF_m$ = the monthly allocation factor for month *m*

$DMNF$ = the normalization factor for monthly allocation

Allocation to Daily Consumption

Allocation of monthly consumption to daily consumption is accomplished by computing the normalized day-type allocation factors and applying the resulting factors to monthly consumption. Allocation of monthly consumption to daily consumption is accomplished as follows:

$$DDC_{mt} = DNDAF_{mt} * DMC_m \quad (21)$$

$$DNDAF_{mt} = \frac{DDAF_{mt}}{DDNF_m} \quad (22)$$

$$DDNF_m = \sum_{t=1}^{2} DWDAF_{mt} \quad (23)$$

$$DWDAF_{mt} = ND_{mt} * DDAF_{mt} \quad (24)$$

where:

DDC_{mt} = daily consumption for day-type *t* in month *m*

$DNDAF_{mt}$ = the normalized day-type allocation factor for day-type *t* in month *m*

DMC_m = consumption in month *m*

$DDAF_{mt}$ = the day-type allocation factor for day-type *t* in month *m*

$DDNF_m$ = the normalization factor for day-type allocation in month *m*

$DWDAF_{mt}$ = the weighted day-type allocation factor for day-type *t* in month *m*

ND_{mt} = the number of days assigned to day-type *t* in month *m*

Allocation to Hourly Loads

Allocation of daily consumption to hourly loads is accomplished by normalizing the hourly allocation factors which are also called as daily load shapes and applying the result to daily consumption. The following computation is made for this step:

$$DHL_{mth} = DNHAF_{mth} * DDC_{mt} \quad (25)$$

$$DNHAF_{mth} = \frac{DHAF_{mth}}{DHNF_{mt}} \quad (26)$$

$$DHNF_{mt} = \sum_{h=1}^{24} DHAF_{mht} \quad (27)$$

where:

DHL_{mht} = load in hour *h* of day-type *t* in month *m*

$DNHAF_{mth}$ = the normalized hourly allocation factor for hour *h* of day-type *t* in month *m*

$DHNF_{mt}$ = the normalization factor for hourly allocation for day-type *t* in month *m*

DDC_{mt} = daily consumption for day-type *t* in month *m*

$DHAF_{mth}$ = the hourly allocation factor for hour *h* of day-type *t* in month *m*

Calibration

Peak model calibration is an attempt to compensate for discrepancies between model results and recorded peak data. The sum of the results from HELM differs from the recorded peak for at least two reasons. First, despite staff's best efforts to model the primary relationships that drive peak demand, the model, like any model, cannot perfectly capture these relationships. Second, many of the secondary relationships associated with peak demand are not modeled. Thus, the raw results cannot be expected to exactly match recorded peak data.

In calibration, staff takes advantage of both data on the estimated coincident peak by sector and the historical data on total hourly demand on the utility system. The regressions of each sector backcast against the corresponding estimated coincident peak are pooled with the regression of all backcasts against the historical utility coincident peak demand. Weights are assigned to continue to give the bulk of the weight of calculation of calibration factors to the regression of backcasts against estimated sector coincident peaks. The bulk of the weight is still assigned to the separate regressions because multicollinearity may otherwise result in calibration factors that predict total load accurately, but not that of each sector. This approach allows the regression to extract information from the historical system demand for each coincident sector forecast. The loss factors used in calibration are listed in Table 7-2.

Table 7-2

Transmission and Distribution Loss Factors[1]

Utility	PG&E	SCE	SMUD	LADWP[2]	SDG&E	BGP
System Level	9.7%	7.6%	9.0%	11.2%	9.6%	5.1%

The hourly load calibration is done by the HELM Auto-Calibration tool, which calibrates the HELM-simulated hourly loads against estimated sector loads or historical system loads submitted by utilities. Specifically, it calculates the differences in load in each hour of the year, distributes that error over each of the end uses and creates a new set of end use load shapes.

Data Requirements and Sources

This section describes the data requirements and sources for operating the PDHL Model and identifies the key modifications made for the 2005 Energy Report. First, the weather data requirements and sources are described. Next, the sources of weather-sensitive end use data and day-type end use data are illustrated. Finally, the important improvements made for this most recent forecast are presented.

Weather Data

Weather data are used to model weather-sensitive end uses in the commercial and residential sectors. Daily weather variables used in the weather response functions are computed from hourly weather data purchased from the National Oceanic and Atmospheric Administration (NOAA). The PDHL Model uses climate zones defined in Table 7-3, which indicates the mapping between the airport weather stations used by the NOAA and the Energy Commission's climate zones.

Weather-Sensitive End use Data

The residential cooling and heating end use data including weather response functions and daily load shapes are composed of central air-conditioning and room air-conditioning for single family and multi-family as described in Chapter 2 for each climate zone. The data were updated in 2002 and recently calibrated with hourly residential sector loads estimated by utilities. The resource of hourly end use load data used for the updated load shapes was obtained from Primen, Inc., a consulting firm, which used metered data collected in the mid 1990s from three large end use metering studies.

Table 7-3

Climate Zones and Weather Stations

Utility	Zone No.	Climate Zone	Weather Station
PG&E	01	Blue Canyon	Arcata
	02	Sacramento	Sacramento
	03	Fresno	Fresno
	04	San Jose	San Jose
	05	San Francisco	San Francisco
SMUD	06	Sacramento	Sacramento
SCE	07	Fresno	Fresno
	08	Long Beach	Long Beach
	09	Burbank	Hollywood
	10	San Bernardino	March A. F. B.
LADWP	11	Long Beach	Long Beach
	12	Burbank	Hollywood
SDG&E	13	San Diego	San Diego
BGP	16	Burbank	Hollywood

The commercial cooling end use data were developed in the early 1990s.These consist of air conditioning data for 12 building types and 2 vintages as defined in Chapter 3 for each climate zone. The commercial heating end use data were updated in 2002 using data from Primen.

Day-Type End use Data

Monthly allocation factors are used in HELM to allocate annual day-type end use consumption to monthly energy use. These factors are periodically updated using the QFER monthly electricity consumption data. Day-type allocation factors are then applied to allocate monthly energy use to daily energy use. Hourly loads are derived from daily consumption with the use of load profiles. In general, these day-type allocation factors and load shapes are derived from end use load metering projects, class load studies, survey analyses and customer time-of-use data provided by the utilities.

The residential day-type end use data, like the cooling and heating end use data, were updated with data from Primen and calibrated to historical hourly sector load data. The commercial day-type end use data were developed through several projects in the 1980s and early 1990s. The monthly allocation factors for all end uses in the industrial, agriculture, transportation, communication and utilities, and street lighting sectors were updated using the QFER monthly energy consumption data from 1990 to 1999. The day-type allocation factors and load shapes of end uses for those sectors were developed in the 1980s.

Model Modification for the 2005 Energy Report

Enhancement of the Energy Commission's PDHL Model

The importance of hourly loads in the evaluation of energy trends and policy has been increasing since the restructuring of the electricity industry. The PDHL Model has been enhanced to produce more robust hourly load forecasts. The Auto-Calibration tool has been modified to calibrate a large number of end use load shapes against historical hourly loads at the system or sector level. Two other tools were developed to compare and select load shapes.

The Auto-Calibration tool is used to calibrate HELM-simulated hourly loads against historical loads at the system, sector, or end use level. The tool calculates the differences in load in every hour and distributes the error over the end use load shapes. The original Auto-Calibration code could process only 30 end use load shapes. In 2002, the code was enhanced to process up to 420 end uses, roughly the number associated with the service area of a large utility. With this enhanced tool, Staff is able to take full advantage of the hourly sector load data submitted by utilities, using it to calibrate end use load shapes and significantly improve hourly load forecasts.

Staff also developed two tools for the PDHL Model to streamline the end use load shape calibration process. First, the Energy and Peak Comparison tool extracts information on monthly energy and peak from hourly loads for multiple datasets at the system, sector or end use level and calculates the differences so that staff can decide which set of data most closely resembles to historical values. Second, the Weekday/Weekend Calculation tool converts HELM hourly loads into 24 hour peak day, weekday and weekend loads for every month of the year, which can then be easily imported into Excel for comparison to historical data.

Load Shape Data

The residential end use load data and the monthly allocation factors for all end uses in the industrial, agricultural, TCU and street lighting sectors were updated in 2002.

As a result of updated Title 20 data regulations (2002), large and medium sized electric utilities are required to submit hourly sector load estimates to the Energy Commission. Use of this data, in conjunction with the Auto-Calibration tool, has significantly improved HELM hourly load forecasts.

---

[1] Expressed as a percent of customer load during the forecast period.
[2] Total losses forecast for LADWP also include losses associated with the DC Intertie.

APPENDIX A
CALIFORNIA ECONOMIC PROJECTIONS

Introduction

The forecast of the California economic conditions is based on California and regional forecasts provided by Economy.com. The Energy Commission has chosen Economy.com as a source of economic forecasts for two reasons. First,Economy.com provides county level projections for key economic indicators. Second, recent forecasts by Economy.com have been highly regarded; *e.g.*, Barron's has awarded its highest ratings to Economy.com for its forecasts in each of the last two years. Economy.com's data is proprietary and not available on the web. All data used in the 2005 forecast is presented in the tables of this appendix.

Forecast Summary

The base year of this forecast (2003) is the most recent year for which a complete set of economic data exists. In 2003, California reached the bottom of the technology industry downturn and started a very slow recovery in 2004. In 2004, job growth was the strongest since early 2001, even though it remained weaker than the national average. Job growth in Southern California is 2004 was positive. Job growth in the San Francisco Bay Area was minimal in 2004, however, it was positive for the first time since the technology downturn began in 2001.

Table A-1 shows that, while the California economy, measured by employment and gross state product (GSP), grew more slowly than the U.S. as a whole during 1990-2003, it is projected to grow faster than the U.S. over 2003-2016. During 1990-2003, U.S. gross domestic product (GDP) grew at 2.95 percent per year (compared to 2.75 percent for California GSP). U.S. non-agricultural wage and salary jobs grew at 1.33 percent per year during the period (compared to 0.97 percent for California). Figure A-1 indicates that the slowdown in GSP is a result of the technology downturn in 2001**.** The latest job recovery is much slower than historic recoveries. However, California is expected to outpace the U.S. in both gross product and employment during the forecast period, which is consistent with pre-1990 historical data.

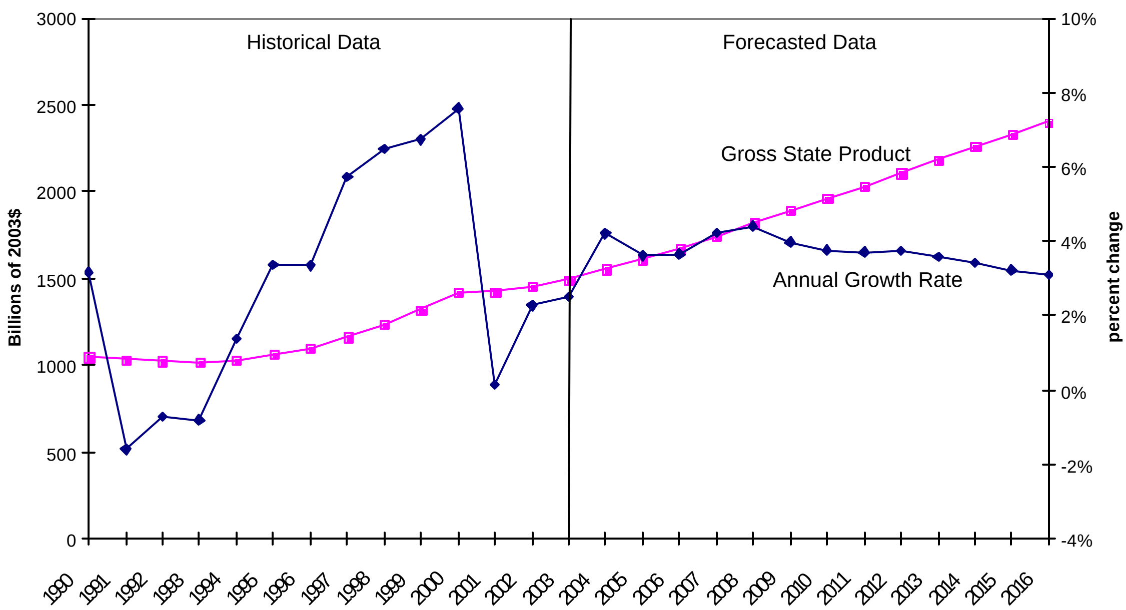
Table A-1

Comparison of U.S. and California Gross Product and Non-Agricultural Wage & Salary Jobs

	Gross Product (Billion 03$)		Non-Agricultural Wage & Salary Jobs (Thousands)	
	U.S. GDP	CA GSP	U.S.	CA
1990	7,539	1,048	109,489	12,547
2003	11,004	1,492	129,937	14,234
2016	16,167	2,403	153,610	17,366
	Average Annual Growth (%)			
1990-2003	2.95	2.75	1.33	0.97
2003-2016	3.00	3.73	1.30	1.54
Source: Economy.com				

Figure A-1

California Gross State Product



Source: Economy.com

Forecast Detail

The following sections discuss selected variables from staff's California economic forecast. Tables showing annual values for historic and forecast variables are presented at the end of this appendix.

Employment

In contrast to previous forecasts, where Standard Industrial Classification (SIC) codes were used, staff now reports data using North American Industrial Classification System (NAICS) codes. NAICS is a production-based concept of classification; that is, NAICS classifies each establishment into a detailed industry based on the production processes it uses. This reclassification markedly changes how many and which businesses are included in certain sectors, and results in tables with less detail and substantially different in appearance than those in years past.

Table A-2 shows California total non-agricultural wage and salary, manufacturing and service employment in California. Manufacturing jobs tend to be high wage jobs. Table A-2 indicates that the rise in jobs is in service employment while manufacturing employment continues to decline. This is common in the U.S., and a result of increased productivity and the movement of manufacturing out of the country, where labor costs are lower. This trend is not expected to change.

Table A-2

California Jobs (Thousands)

	Total			Average Annual Growth (%)		
	Non-Ag Wage & Salary	**Manufacturing**	**Services**	**Non-Ag Wage & Salary**	**Manufacturing**	**Services**
1990	12,547	2,000	4,173			
2003	14,234	1,551	5,429	.97	-1.93	2.05
2016	17,366	1,513	7,500	1.54	-0.19	2.52
Source: Economy.com						

Output

Table A-3 presents historical and forecasted growth rates for total output (gross state product) and for selected economic sectors. Gross state product is the total market value of all the goods and services produced within California during a specified period. While historic growth in manufacturing is close to total growth, the gap is greater during the forecast period. Over the entire forecast, manufacturing grows at a slower rate than any other sector shown. Manufacturing is no longer the primary driver of the California economy; the growth in services is apparent in the table.

Table A-3

Growth in GSP in California

Economic Sector	1990-2003	2003-2016
Manufacturing	2.70%	2.25%
Education & Health Services	0.91%	3.63%
Financial Activities	3.83%	3.70%
Leisure & Hospitality	2.72%	4.02%
Professional & Business Services	3.75%	4.74%
Retail Trade	4.16%	4.49%
Trade, Transportation, & Utilities	3.99%	4.13%
Government	0.89%	3.13%
Total	2.76%	3.74%
Source: Economy.com		

Table A-4 presents the output data used for the industrial demand forecasting model; output is the main economic driver in the model. During 1990-2003, beverage product and chemical manufacturing witnessed the most rapid growth (7.3 percent and 5.58 percent per year, respectively). During this period, California wine became more popular and the number of wineries and vineyard acreage under production increased. Chemical manufacturing growth centered around petroleum manufacturing, reflecting the increase in the price of gasoline.

From 2003-2010, the sectors in which GSP growth is forecasted to be highest are apparel manufacturing (5 percent per year) and mining (4.35 percent). Apparel manufacturing growth is high because of the growth of the apparel market in Los Angeles. While mining increases, it does so because of the expected increased value of mining products, not because of industry expansion and increases in the number of jobs. The greatest increase is expected in oil and gas exploration.

Table A-4

Historic and Forecasted GSP Growth

NAICS	Description	1990-2003	2003-2016
21	Mining	0.20%	4.35%
22	Utilities	-0.33%	3.46%
23	Construction	0.34%	3.10%
311	Food Manufacturing	-2.32%	1.30%
312	Beverage Product Manufacturing	7.30%	3.58%
313	Textile Mills	0.63%	3.61%
314	Textile Product Mills	-4.22%	-0.49%
315	Apparel Manufacturing	0.81%	5.00%
316	Leather & Allied Product Manufacturing	-5.27%	2.17%

321	Wood Product Manufacturing	-2.88%	-0.84%
322	Paper Manufacturing	-3.18%	-1.61%
323	Printing & Related Support Activities	-3.61%	-0.88%
324	Petroleum & Coal Products Manufacturing	-0.95%	0.52%
325	Chemical Manufacturing	5.58%	2.95%
326	Plastics & Rubber Products Manufacturing	3.32%	1.71%
327	Nonmetallic Mineral Product Manufacturing	0.15%	2.41%
331	Primary Metal Manufacturing	2.20%	2.67%
332	Fabricated Metal Product Manufacturing	5.70%	1.91%
333	Machinery Manufacturing	7.90%	2.70%
334	Computer & Electronic Product Manufacturing	6.65%	2.21%
335	Electrical Equipment, Appliance, & Component Manufacturing	1.73%	2.26%
336	Transportation Equipment Manufacturing	-4.72%	2.95%
337	Furniture and Related Product Manufacturing	0.70%	1.80%
339	Miscellaneous Manufacturing	-0.28%	2.33%
	Total	2.76%	3.74%
Source: Economy.com			

Population

Table A-5 shows historic and projected total and household population, the latter being an important variable for analyzing the residential sector. The difference between total and household population represents persons living in group quarters (military, prisons, school dormitories).

Table A-5

California Population

	Total Population	**Household Population**
1990	29,828,685	29,072,779
2003	35,878,192	35,034,768
2016	42,009,751	41,108,682
	Average Annual Growth (%)	
1990-2003	1.43	1.45
2003-2016	1.22	1.24
Source: Department of Finance, Economy.com		
Population is as of July 1st		

Table A-6 shows historic and forecast households and persons per household. The latter is calculated using household population estimates rather than total population estimates; while the difference is small, it has a significant impact on the results from the residential energy demand model.

Table A-6

California Households

	Households	Persons Per Household
1990	10,433,724	2.79
2003	11,940,384	2.93
2016	13,743,854	2.99
	Average Annual Growth (%)	
1990-2003	1.04	0.40
2003-2016	1.09	0.15
Source: Department of Finance, Economy.com		
Population is as of July 1st		

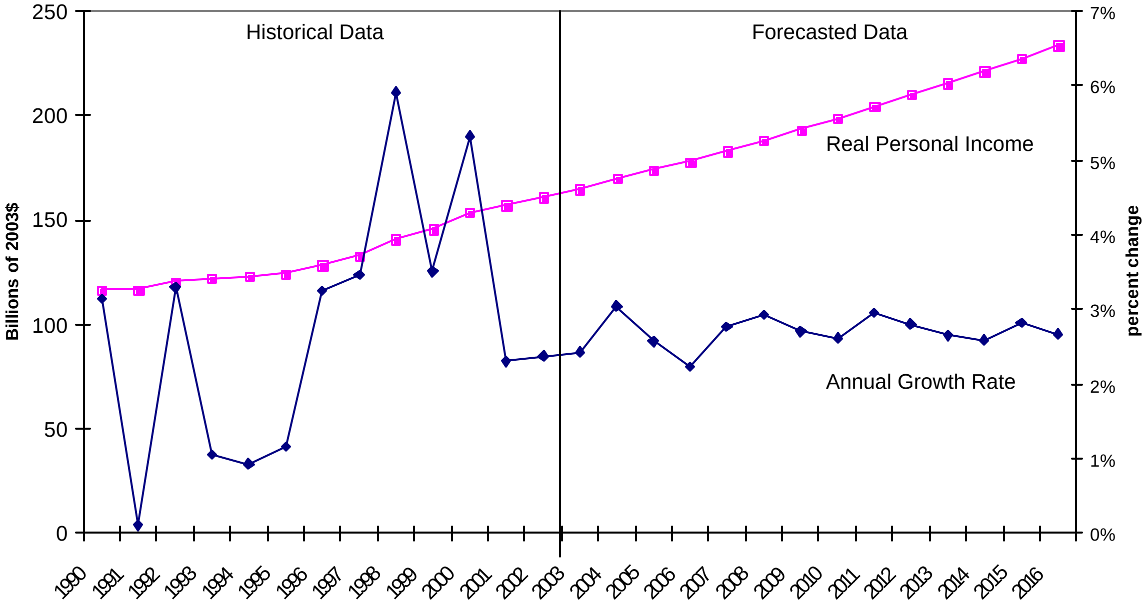
The number of California households grew at a rate of 1.04 percent per year from 1990-2003 and persons per household grew by 0.40 percent per year. California occupied households are projected to grow at 0.15 percent per year from 2003 to 2016. The number of households grows more slowly than household population because persons per household are projected to increase over the forecast period.

Personal Income

Figures A-2 and A-3 graphically illustrate the data from Table A-7, which indicates California total and per capita personal income. Personal Income is defined as total income received from all sources, including wages, salaries, or rents, etc.

Figure A-2

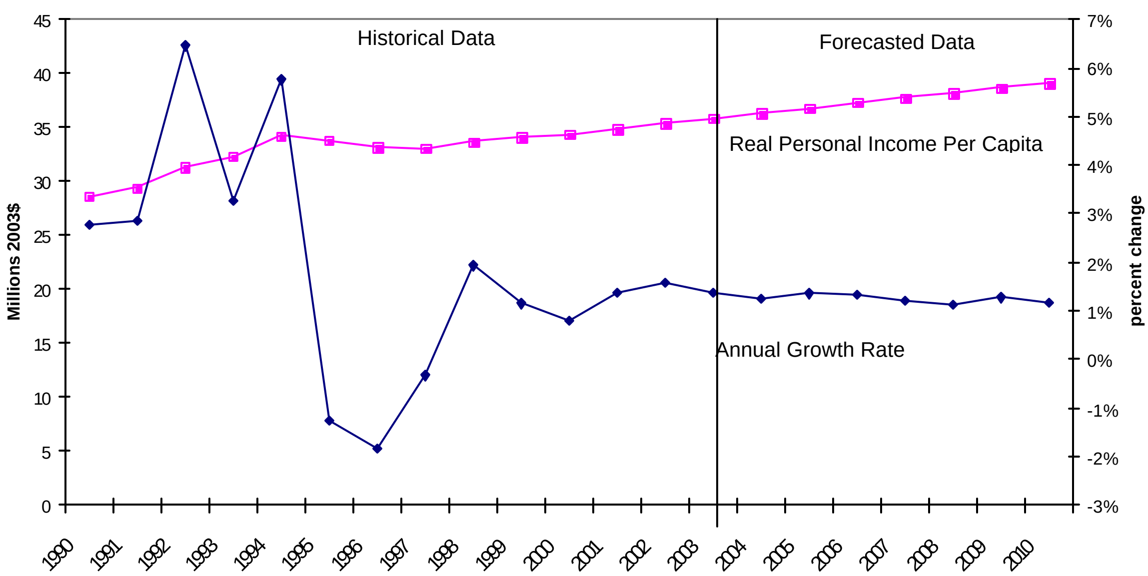
California Personal Income



Source: Economy.com

Figure A-3

California Personal Income Per Capita



Source: Economy.com

Table A-7

California Personal Income

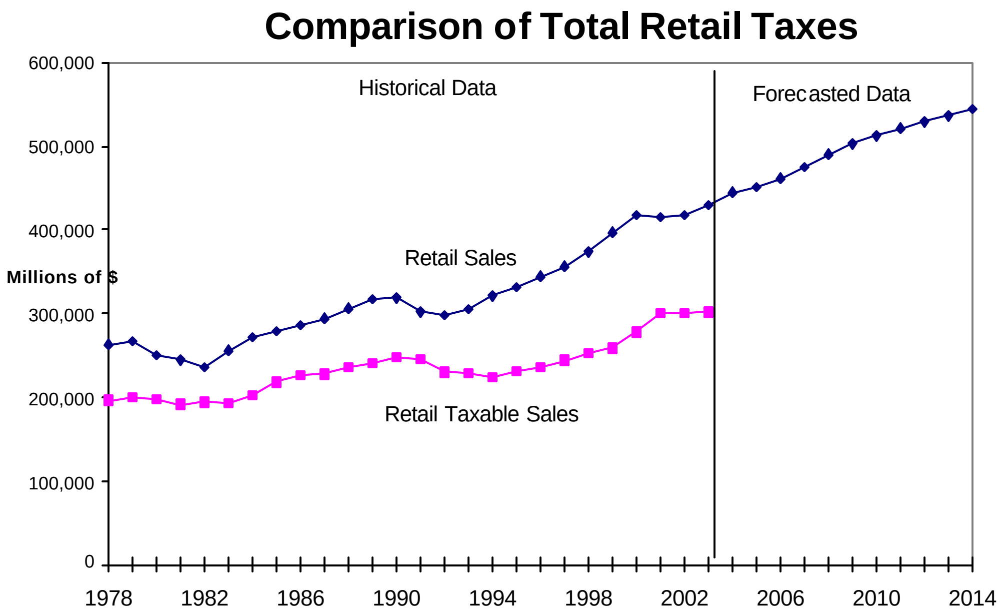
	Personal Income (Billion 2003$)	Per Capita Income (Thousand 2003$)
1990	850.0	28.5
2003	1185.8	33.0
2016	1694.3	39.1
	Average Annual Growth (%)	
1990-2003	2.59	1.15
2003-2016	2.54	1.30
Source: Economy.com		

California real personal income grew at a rate of 2.59 percent per year from 1990-2003; per capita income increased annually an average of 1.15 percent over this period. California personal income is projected to grow at 2.54 percent per year during 2003-2016. This reflects faster population growth than income growth, a trend which is expected to persist during 2003-2016.

Retail Sales

In previous forecasts, taxable retail sales were one of the variables used to estimate floor space in the commercial model. As of the 2005 forecast, total retail sales (including non-taxable sales) data, previously unavailable, is used. While total and taxable retail sales move together (see Figure A-4), the former results in an improved forecast of commercial floor space and, thus, energy demand.

Figure A-4



Source: Economy.com; Board of Equalization

Comparison to Energy Report 2003 Economic Projections

Table A-8 compares the economic projections used for the 2005 forecast with those used in 2003.

For 2013 (the outermost year for which projections were made in 2003), staff's current economic projections, compared to those in 2003, are lower for all key variables except persons per household. This reflects revised expectations regarding economic performance over the period in light of observed and anticipated weaknesses in the current economic recovery. Two years ago economists were anticipating a "traditional" recovery, in which jobs and wages rapidly accelerated. However, the current recovery has been characterized by slower-than-expected job growth, especially for higher-wage jobs and those traditionally occupied by the middle class. As little improvement in this regard is expected, future growth is assumed to be slower.

Staff projects that total population will increase by 1.31 percent per year during 2001-2013 compared to 1.46 percent growth forecast in 2003, resulting in a value lower by 653,000 persons. The lower growth in the 2005 projections is due to the assumption of lower immigration, itself a response to slower forecasted economic growth.

Staff projects that the number of households will increase by 1.13 percent per year during 2001-2013 compared to 1.24 percent per year growth forecast in 2003, resulting in a value lower by 168,000 households.

Persons per household are expected to increase to 2.98 by 2013, up from the 2.92 persons forecasted in 2003. This occurs because total population is expected to grow faster than household formation.

Staff now projects that wage and salary job growth will be 1.09 percent per year during 2001-2013 compared to 2.02 percent forecast in 2003, resulting in staff's estimate of total wage and salary jobs being 2,008,000 lower in 2013.

Staff projects personal income to grow at 2.25 percent per year during 2001-2013 compared to a forecast of 3.12 percent in 2003, resulting in staff's 2005 estimate of 2013 income being $136 billion, or 8.42 percent lower in 2013. Per capita income projections show similar changes; the projected annual growth rate for 2001-2013 has declined from 1.64 percent in 2003 to 0.93 percent in 2005, a reduction in 2013 of $2,721 per capita (6.94 percent).

Staff's retail sales forecast is being compared to retail taxable sales, because retail sales is replacing taxable sales as a forecasting variable. Growth in retail sales is projected to be lower as a result of slower population, job, and income growth.

Table A-8

Demographic Indicators

Total Population (Thousands)				
	Forecast			Percent
	2003	2005	Difference	Difference
2001	34,711	34,740	29	0.08%
2013	41,281	40,628	-653	-1.58%
2001-2013 Percent Growth	1.46	1.31		
Households (Thousands)				
	Forecast			Percent
	2003	2005	Difference	Difference
2001	11,662	11,662	0	0.84%
2013	13,513	13,345	-168	-1.24%
2001-2013 Growth Percent	1.24	1.13		
Persons Per Household				
	Forecast			Percent
	2003	2005	Difference	Difference
2001	2.88		0.03	1.04%
2013	2.92	2.98	0.06	2.05%
2001-2013 Growth Percent	0.12	0.20		
Wage and Salary Jobs (Thousands)				
	Forecast			Percent
	2003	2005	Difference	Difference
2001	14,698	14,439	-259	-1.77%
2013	18,681	16,674	-2,007	-10.75%
2001-2013 Growth Percent	2.02	1.09		
Source: Department of Finance, Economy.com				

Table A-8 (cont.)

Personal Income (Millions of 2001$)				
	Forecast			Percent Difference
	2003	2005	Difference	
2001	1,119	1,134	15	1.35%
2013	1,617	1,481	-136	-8.42%
2001-2013 Percent Growth	3.12	2.25		

Per Capita Income (2001$)				
	Forecast			Percent Difference
	2003	2005	Difference	
2001	32,223	32,631	408	1.26
2013	39,178	36,457	-2,721	-6.94
2001-2013 Percent Growth	1.64	0.93		

Retail Sales (2001$)				
	Forecast			Percent Difference
	2003	2005	Difference	
2001	286.1	396.4	110.2	
2013	374.1	511.9	137.7	
2001-2013 Percent Growth	2.26	2.15		
Taxable sales presented for CED 2003, total sales for CED 2006				
Source: Department of Finance, Economy.com				

REGIONAL ECONOMIC PROJECTIONS

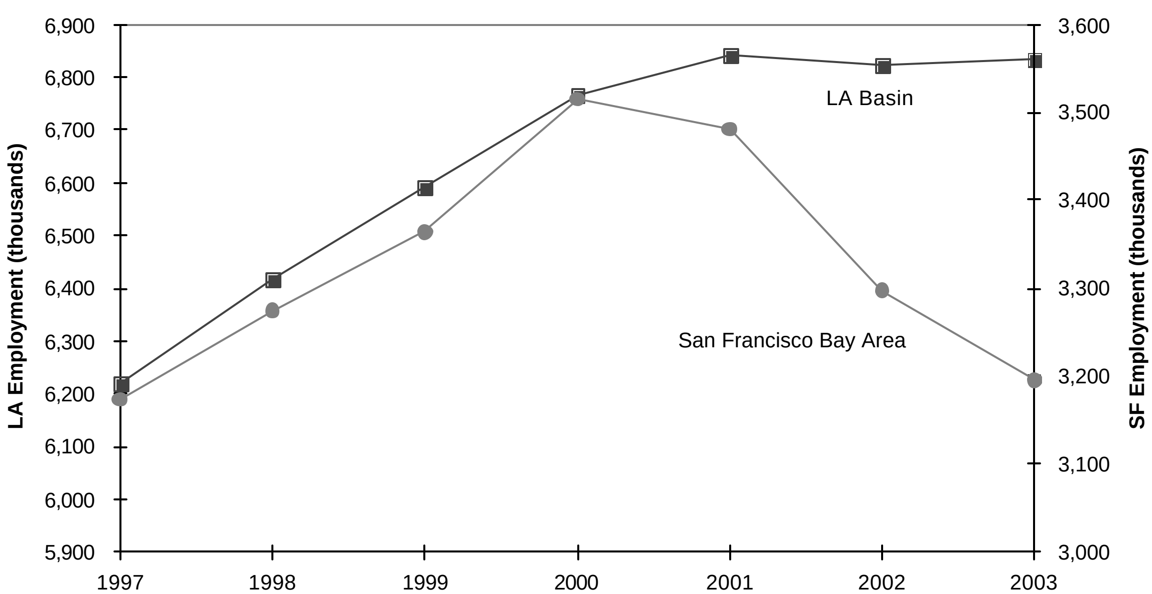
Introduction

The forecasts of the five regional economies (Los Angeles Basin, San Francisco Bay Area, San Diego, Sacramento and Rest of State) drive the statewide California forecasts discussed above. In this section, these regional forecasts are discussed, highlighting the regions of the state in which substantial growth is expected to occur.

California's economy has markedly changed in the last fifteen years. Prior to 1990 Los Angeles was the primary driver of the state economy, responsible for almost 50 percent of the state's economic activity. Subsequently, federal government base closures and reduced defense spending took a toll on the Southern California economy, especially the Los Angeles area. At the same time, Northern California experienced an economic boom, largely due to the growth of the technology sector, which was centered in San Francisco and San Jose. As housing prices and commercial rents soared, buyers sought nearby, but cheaper alternatives, extending the benefits of economic expansion to Sacramento and the Central Valley. It is not surprising, therefore, that the collapse of the technology sector and accompanying recession was most severely felt in San Francisco and San Jose. Figure A-5 shows that during 2001-2003, Los Angeles Basin employment did not show the strong growth of years past, but that there has been virtually no decline. San Francisco Bay Area employment, however, dropped sharply, and was a drag on the state economy.

Figure A-5

LA Basin vs. San Francisco Bay Area Employment 1997-2003



Source: Economy.com

Looking more closely at the San Francisco Bay Area, many counties showed a decline in employment. San Francisco, San Mateo and Santa Clara counties (which includes the city of San Jose) showed the steepest fall in employment starting in 2001. Table A-9 shows that from 2001 to 2003, employment in San Francisco, San Mateo and Santa Clara fell an average of 4.27 percent to 6.04 percent per year. However, the rest of the bay area shows a slight decline or leveling of employment through 2003 (from an average of -1.33 percent to 2.39 percent per year).

Table A-9

San Francisco Bay Area Employment

								% growth
County	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2001-03**
Alameda	642	661	683	711	715	696	683	-1.33%
Contra Costa	306	315	325	333	340	344	342	0.81%
Marin	106	108	111	112	113	112	109	-1.08%
Napa	50	52	55	57	58	59	59	1.28%
San Francisco	545	568	583	602	576	538	521	-4.67%
San Mateo	333	336	346	368	365	337	323	-4.27%
Santa Clara	927	956	971	1,030	1,004	903	854	-6.04%
Solano	100	105	110	115	120	122	124	2.39%
Sonoma	165	173	179	186	190	186	181	-0.99%
Source: Economy.com								

A California recovery is dependent on San Francisco and San Jose. Since their 2003 employment levels are now slightly below 1997 levels, the fall in employment in the technology sector may be over. In the first quarter of 2005 there has been a slight increase in San Francisco's and San Jose's employment numbers. Careful examination shows an increase in NAICS 518 (search portals and data processing), which is only occurring in San Francisco and San Jose. It will be a while before we know if this increase is the beginning of a job recovery in the technology sector in the Bay Area, or a small blip in a continuing downward trend.

The remainder of this section discusses regional economic growth, both historical and forecast. It is not surprising that the Los Angeles Basin, San Francisco Bay Area and San Diego show slowing growth because of scarce land and escalating costs. The areas expected to grow most quickly are those where land is available and the costs of doing business and living are expected to be lower.

Los Angeles Basin Forecast

The Los Angeles Basin Region consists of Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura counties. In 2003, the Basin accounted for approximately 48 percent of California's nonfarm wage and salary jobs, personal income and population.

The data for the Los Angeles Basin (see Table A-10) shows lower growth compared to the rest of the state for 1990 - 2003. While forecasted values reflect expected growth during 2003-2016, this growth is remains slower than that of California as a whole. Overall, the Los Angeles Basin's share of California economic variables is slowly declining.

While it is not forecasted to grow at a rapid pace the economy of the Los Angeles Basin should not be discounted in importance. Employment is rising, its ports are crowded with international trade and the tourism sector is recovering. Riverside, San Bernardino and Orange county have experienced growth in industrial jobs and production that is among the strongest in the nation. While Riverside and San Bernardino counties were a source of growth throughout the recession, Los Angeles county is now leading the basin's growth. While the Los Angeles Basin is experiencing stronger growth than in recent years, however, it will ultimately be constrained by there being limited land on which to build and high land and business costs.

San Francisco Bay Area Forecast

The San Francisco Bay Area Region consists of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma counties. In 2003 the San Francisco Region accounted for approximately 19 percent of California's population, 26 percent of California's personal income and 22 percent of California's nonfarm wage and salary jobs. The income and jobs shares were higher in 2003 than in 1990 due to the technology boom, but, as a result of the downturn, much lower than in 2000. Given the high costs of living and doing business in the San Francisco Bay Area, recovery is expected to be slow.

Table A-10 shows that the San Francisco Bay area is forecasted to grow at slower rates during the next ten years and at rates closer to the statewide average. The region cannot experience the growth rates of the 1990s until and unless the technology sector recovers, or a new sector emerges and takes its place.

San Diego Forecast

The San Diego Region consists of San Diego County. In 2003, the region accounted for approximately 9 percent of California's nonfarm wage and salary jobs, total population, occupied households, and personal income.

San Diego's economy is continuing to expand with employment consistently growing at a rate above the national average. Much of this growth has been from recent increases in defense spending, but San Diego is also a desirable location in which to live. The forecast, however, indicates slower growth during the next ten years. While San Diego is a desirable location, it is still an expensive place to live and do business.

Sacramento Forecast

The Sacramento Region consists of El Dorado, Placer, Sacramento and Yolo Counties. In 2003, the Sacramento Region accounted for approximately 5 to 6 percent of California's population, nonfarm wage and salary jobs, and personal income.

The Sacramento area has experienced substantial growth in recent years due to the relocation of both population and businesses from the San Francisco Bay Area, attracted by lower land and living costs. Of all five regions, Sacramento is forecasted to grow most rapidly, with all measures of economic growth expected to increase more rapidly than those for the entire state. Recently, however, housing prices have escalated and land available for commercial and residential development has decreased. This fact, along with possible public sector woes, may portend slower economic growth at some point in the future.

Rest of State Forecast

The Rest of State region consists of all the California counties not included in the four regions previously defined. This is primarily Central and Northern California. In 2003, the region accounted for approximately 14 percent of California nonfarm wage and salary jobs and 17 percent of California population and households.

The Central Valley has seen substantial growth in the last few years, and is expected to continue to do so. Workers from the San Francisco Bay Area increasingly commute from the Central Valley because of the availability and (low) cost of housing. Growth in the region is expected to continue, especially if housing and land costs in more desirable coastal areas, already high, continue to escalate.

Table A-10

Regional Economic Indicators

	Nonfarm Wage & Salary Jobs (Thousands)			Growth Rate (%)	
Region	1990	2003	2016	1990-2003	2003-2016
Los Angeles Basin	6,299	6,835	8,298	0.63	1.50
San Francisco Bay Area	2,919	3,195	3,788	0.70	1.32
San Diego Area	967	1,242	1,630	1.95	2.12
Sacramento Area	619	844	1,103	2.42	2.09
Rest of State	1,745	2,118	2,546	1.50	1.43
California	12,547	14,234	17,366	0.97	1.54
	Region as Percent of California				
Los Angeles Basin	50.2%	48.0%	47.8%		
San Francisco Bay Area	23.3%	22.5%	21.8%		
San Diego Area	7.7%	8.7%	9.4%		
Sacramento Area	4.9%	5.9%	6.3%		
Rest of State	13.9%	14.9%	14.7%		
	Population (Thousands)				
				Growth Rate (%)	
	1990	**2003**	**2016**	**1990-2003**	**2003-2016**
Los Angeles Basin	14,672	17,595	20,032	1.41	1.00
San Francisco Bay Area	6,022	6,9854	8,045	1.15	1.09
San Diego Area	2,505	2,997	3,484	1.39	1.17
Sacramento Area	1,491	1,961	2,663	2.13	2.38
Rest of State	5,139	6,341	7,785	1.63	1.59
California	29,829	35,878	42,010	1.43	1.22
	Region as Percent of California				
Los Angeles Basin	49.2%	49.0%	47.7%		
San Francisco Bay Area	20.2%	19.5%	19.2%		
San Diego Area	8.4%	8.3%	8.3%		
Sacramento Area	5.0%	5.5%	6.3%		
Rest of State	17.2%	17.7%	18.5%		
	Households (Thousands)				
				Growth Rate (%)	
	1990	**2003**	**2016**	**1990-2003**	**2003-2016**
Los Angeles Basin	4,958	5,550	6,167	0.87	0.81
San Francisco Bay Area	2,254	2,541	2,887	0.93	0.99
San Diego Area	892	1,036	1,195	1.16	1.10
Sacramento Area	562	725	976	1.97	2.32
Rest of State	1,768	2,089	2,519	1.29	1.45
California	10,434	11,940	13,744	1.04	1.09
	Region as Percent of California				
Los Angeles Basin	47.5%	46.5%	44.9%		
San Francisco Bay Area	21.6%	21.3%	21.0%		
San Diego Area	8.5%	8.7%	8.7%		
Sacramento Area	5.4%	6.1%	7.1%		
Rest of State	17.0%	17.5%	18.3%		

Source: Economy.com; Department of Finance

Table A-10 (Continued)

Region	Personal Income (Millions 2003$) 1990	2003	2016	Growth Rate (%) 1990-2003	2003-2016
Los Angeles Basin	417,828	543,372	724,445	2.04	2.24
San Francisco Bay Area	206,886	310,933	434,741	3.18	2.61
San Diego Area	68,691	104,684	140,175	3.29	2.27
Sacramento Area	39,991	62,121	110,179	3.45	4.51
Rest of State	116,625	164,648	233,413	2.69	2.72
California	850,021	1,185,758	1,642,953	2.59	2.54
	Region as Percent of California				
Los Angeles Basin	49.2%	45.8%	44.1%		
San Francisco Bay Area	24.3%	26.2%	26.5%		
San Diego Area	8.1%	8.8%	8.5%		
Sacramento Area	4.7%	5.2%	6.7%		
Rest of State	13.7%	13.9%	14.2%		

	Per Capita Income (2003$) 1990	2003	2016	Growth Rate (%) 1990-2003	2003-2016
Los Angeles Basin	28,478	30,883	36,164	0.63	1.22
San Francisco Bay Area	34,355	44,515	54,039	2.01	1.50
San Diego Area	27,423	34,934	40,237	1.88	1.09
Sacramento Area	26,824	31,667	41,369	1.29	2.07
Rest of State	22,694	25,996	29,981	1.04	1.11
California	28,497	33,050	39,109	1.15	1.30

	Retail Sales (millions 2003$) 1990	2003	2016	Growth Rate (%) 1990-2003	2003-2016
Los Angeles Basin	159,739	209,122	269,628	2.09	1.97
San Francisco Bay Area	72,903	100,293	126,998	2.48	1.83
San Diego Area	29,448	41,160	53,871	2.61	2.09
Sacramento Area	16,424	22,728	33,839	2.53	3.11
Rest of State	48,636	67,339	88,698	2.53	2.14
California	327,151	440,642	573,034	2.32	2.04
	Region as Percent of California				
Los Angeles Basin	48.8%	47.5%	47.1%		
San Francisco Bay Area	22.3%	22.8%	22.2%		
San Diego Area	9.0%	9.3%	9.4%		
Sacramento Area	5.0%	5.2%	5.9%		
Rest of State	14.9%	15.3%	15.5%		

SERVICE AREA ECONOMIC PROJECTIONS

Introduction

As the demand for electricity and natural gas is estimated for investor-owned and municipal utilities, economic and demographic data needs to be projected by electric service area. This section discusses the mapping of economic and demographic variables from the county and city levels to these service areas.

Major California Electric Utilities

There are three major electric utilities in California: PG&E, SCE and SDG&E. Their planning areas correspond to the five regions: Los Angeles Basin, San Francisco, San Diego, Sacramento and Rest of State. Table A-11 shows the utility and the planning area.

Table A-11

Major Utility Planning Areas

Utility	Acronym	Planning Area
Pacific Gas & Electric	PG&E	San Francisco, Sacramento, Rest of State
Southern California Edison	SCE	Los Angeles Basin
San Diego Gas & Electric	SDG&E	San Diego

The following sections discuss the state's municipal utilities; the major-utility planning area in which each is located and how data is apportioned to arrive at economic projections for each of them.

Northern California Municipal Electric Utilities

Table A-12 lists the municipal utilities in Northern California (PG&E planning area), identifying them by utility, county, and the city used to estimate the population for the utility. To estimate shares, historic Department of Finance data ("Total Population by City and County"; Tables E1, E4 and E5) were used.

Table A-12

Northern California Municipal Utilities

Municipal Utility	County	City
Alameda Power & Telecom	Alameda	Alameda
Biggs Electric	Butte	Biggs
Gridley Municipal Utilities	Butte	Gridley
Healdsburg Municipal Electric Dept.	Sonoma	Healdsburg
Lompoc Utility Electrical Services	Santa Barbara	Lompoc
Modesto Irrigation District (MID)	San Joaquin	Lodi
Modesto Irrigation District (MID)	Stanislaus	Modesto, Waterford
Redding Electric Utility	Shasta	Redding
Roseville Electric Dept.	Placer	Roseville
Sacramento Municipal Utility District	Sacramento	entire county
Silicon Valley Power	Santa Clara	Palo Alto & Santa Clara
Turlock Irrigation District (TID)	Stanislaus, Merced	Varies – special analysis
Ukiah Municipal Light Dept.	Mendocino	Ukiah

Population estimates for the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) are more difficult to construct as both utilities not only provide service in two counties, but many of the municipalities in their planning areas are very small and often unincorporated. Staff at TID stated that roughly 30 percent and 70 percent of their service area is in Merced and Stanislaus Counties, respectively. Staff at MID said that more than 99 percent of the MID service area is in Stanislaus County, and that the county is a good proxy for MID as a whole. Actual population estimates from TID and MID were used with growth rates from the Merced and Stanislaus counties.

While the Sacramento Municipal Utility District (SMUD) includes parts of other counties only, very small portions of their populations are in the SMUD service area. Therefore, SMUD was assumed to be contiguous with Sacramento County.

Southern California Municipal Electric Utilities

The population forecast for the Southern California municipal utilities (see Table A-13) was performed in a manner similar to that for Northern California municipal utilities. Municipals were chosen based on previous analysis and available population data from the Department of Finance. Some municipals have been added since prior forecasts as, once very small, they have grown in the last decade and data for them is now available. The City of Vernon was dropped because of the very low total population numbers in the Department of Finance’s E-1 Report. Other municipals were considered, but because they were very small or comprised of unincorporated areas for which little, if any, data is available, they were not included in the analysis.

Table A-13

Southern California Municipal Utilities

Municipal Utility	**County**	**City**
City of Anaheim	Orange	Anaheim
City of Azusa	Los Angeles	Azusa
City of Banning	Riverside	Banning
City of Burbank	Burbank	Burbank
City of Colton	San Bernardino	Colton
City of Escondido	San Diego	Escondido
City of Glendale	Los Angeles	Glendale
Imperial Irrigation District	Riverside	Coachella, Indio, LaQuinta
Imperial Irrigation District	Imperial	Entire county
LADWP	Los Angeles	Los Angeles
City of Needles	San Bernardino	Needles
City of Pasadena	Los Angeles	Pasadena
City or Riverside	Riverside	Riverside

For each municipal utility in the state, the utility's share of county population was estimated. If a municipal provides service to more than one county, the shares for each county are calculated separately. The shares are then applied to the remaining economic and demographic variables used in the analysis; population shares serve as proxies for shares of all variables since no other data is available at the city level.

HISTORICAL AND FORECASTED ECONOMIC AND DEMOGRAPHIC VARIABLES

Table A-14

California Historical & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CPI Chained 2003$	70.86	73.85	76.45	78.43	79.56	80.87	82.49	84.26	85.94	88.49
Rate of Change (%)	5.42%	4.22%	3.52%	2.59%	1.44%	1.65%	2.00%	2.15%	1.99%	2.96%
Real Personal Income (billions 2003$)	850	839	857	851	860	883	914	955	1,029	1,081
Rate of Change (%)	3.06%	-1.35%	2.18%	-0.68%	1.07%	2.63%	3.60%	4.42%	7.80%	5.01%
Real Per Capita Personal Income (2003$)	28,497	27,532	27,651	27,176	27,284	27,835	28,610	29,424	31,324	32,346
Rate of Change (%)	0.70%	-3.39%	0.43%	-1.72%	0.40%	2.02%	2.78%	2.84%	6.46%	3.26%
Total Population (thousands)	29,829	30,458	30,987	31,314	31,523	31,711	31,962	32,452	32,862	33,417
Rate of Change (%)	2.34%	2.11%	1.74%	1.05%	0.67%	0.60%	0.79%	1.53%	1.26%	1.69%
Household Population (thousands)	29,073	29,688	30,216	30,539	30,743	30,926	31,165	31,647	32,049	32,598
Rate of Change (%)	2.31%	2.12%	1.78%	1.07%	0.67%	0.60%	0.77%	1.55%	1.27%	1.71%
Households (thousands)	10,434	10,608	10,732	10,836	10,931	11,024	11,114	11,208	11,314	11,435
Rate of Change (%)	1.93%	1.67%	1.17%	0.96%	0.88%	0.85%	0.81%	0.85%	0.94%	1.07%
Persons per Household	2.79	2.80	2.82	2.82	2.81	2.81	2.80	2.82	2.83	2.85
Rate of Change (%)	0.37%	0.44%	0.60%	0.10%	-0.21%	-0.25%	-0.04%	0.69%	0.33%	0.64%
Non-Ag Wage & Salary Jobs (thousands)	12,547	12,360	12,136	12,030	12,065	12,308	12,618	12,982	13,429	13,823
Rate of Change (%)	2.07%	-1.50%	-1.81%	-0.87%	0.29%	2.02%	2.52%	2.89%	3.44%	2.94%
Retail Sales (millions 2003$)	318,538	301,830	297,815	304,529	320,826	331,647	344,194	356,131	373,679	396,782
Rate of Change (%)	2.14%	-5.24%	-1.33%	2.25%	5.35%	3.37%	3.78%	3.47%	4.93%	6.18%

Source: Economy.com; Department of Finance

Table A-14 (Continued)

California Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CPI Chained 2003$	91.74	95.44	97.70	100.00	102.70	105.53	108.22	110.97	113.61	116.28
Rate of Change (%)	3.68%	4.03%	2.37%	2.35%	2.70%	2.75%	2.55%	2.55%	2.38%	2.35%
Real Personal Income (billions 2003$)	1,165	1,173	1,171	1,186	1,225	1,255	1,282	1,316	1,354	1,390
Rate of Change (%)	7.79%	0.71%	-0.16%	1.22%	3.30%	2.49%	2.10%	2.68%	2.89%	2.65%
Real Per Capita Personal Income (2003$)	34,208	33,776	33,157	33,050	33,689	34,078	34,347	34,819	35,373	35,860
Rate of Change (%)	5.76%	-1.26%	-1.83%	-0.32%	1.93%	1.16%	0.79%	1.37%	1.59%	1.38%
Total Population (thousands)	34,059	34,740	35,330	35,878	36,359	36,841	37,322	37,803	38,284	38,766
Rate of Change (%)	1.92%	2.00%	1.70%	1.55%	1.34%	1.32%	1.31%	1.29%	1.27%	1.26%
Household Population (thousands)	33,236	33,911	34,493	35,035	35,511	35,988	36,466	36,943	37,420	37,897
Rate of Change (%)	1.96%	2.03%	1.72%	1.57%	1.36%	1.34%	1.33%	1.31%	1.29%	1.27%
Households (thousands)	11,547	11,662	11,797	11,940	12,085	12,229	12,372	12,515	12,658	12,800
Rate of Change (%)	0.98%	0.99%	1.16%	1.21%	1.21%	1.19%	1.17%	1.16%	1.14%	1.12%
Persons per Household	2.88	2.91	2.92	2.93	2.94	2.94	2.95	2.95	2.96	2.96
Rate of Change (%)	0.96%	1.03%	0.55%	0.35%	0.15%	0.15%	0.15%	0.15%	0.15%	0.15%
Non-Ag Wage & Salary Jobs (thousands)	14,284	14,439	14,282	14,234	14,321	14,603	14,870	15,105	15,379	15,657
Rate of Change (%)	3.33%	1.08%	-1.08%	-0.34%	0.61%	1.97%	1.83%	1.59%	1.81%	1.81%
Retail Sales (millions 2003$)	417,587	415,290	417,113	429,041	444,919	450,796	461,440	475,143	490,055	502,827
Rate of Change (%)	5.24%	-0.55%	0.44%	2.86%	3.70%	1.32%	2.36%	2.97%	3.14%	2.61%

Table A-14 (Continued)

California Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
CPI Chained 2003$	119.19	122.29	125.60	129.09	132.66	136.58	140.47
Rate of Change (%)	2.51%	2.60%	2.71%	2.78%	2.77%	2.96%	2.84%
Real Personal Income (billions 2003$)	1,425	1,461	1,498	1,533	1,568	1,606	1,643
Rate of Change (%)	2.50%	2.55%	2.51%	2.36%	2.29%	2.42%	2.29%
Real Per Capita Personal Income (2003$)	36,306	36,801	37,291	37,737	38,167	38,655	39,109
Rate of Change (%)	1.24%	1.36%	1.33%	1.20%	1.14%	1.28%	1.17%
Total Population (thousands)	39,247	39,707	40,168	40,628	41,089	41,549	42,010
Rate of Change (%)	1.24%	1.17%	1.16%	1.15%	1.13%	1.12%	1.11%
Household Population (thousands)	38,374	38,830	39,286	39,742	40,197	40,653	41,109
Rate of Change (%)	1.26%	1.19%	1.17%	1.16%	1.15%	1.13%	1.12%
Households (thousands)	12,942	13,076	13,211	13,345	13,478	13,611	13,744
Rate of Change (%)	1.11%	1.04%	1.03%	1.01%	1.00%	0.99%	0.97%
Persons per Household	2.97	2.97	2.97	2.98	2.98	2.99	2.99
Rate of Change (%)	0.15%	0.15%	0.15%	0.15%	0.15%	0.15%	0.15%
Non-Ag Wage & Salary Jobs (thousands)	15,906	16,158	16,414	16,673	16,925	17,148	17,366
Rate of Change (%)	1.59%	1.58%	1.59%	1.58%	1.51%	1.32%	1.27%
Retail Sales (millions 2003$)	512,331	520,956	529,199	536,295	544,286	550,704	557,946
Rate of Change (%)	1.89%	1.68%	1.58%	1.34%	1.49%	1.18%	1.32%

Table A-15

California GSP by NAICS code (billions of 2003$)

NAICS	Description:	1990	1991	1992	1993	1994	1995	1996	1997	1998
	Total	1,048	1,031	1,023	1,015	1,029	1,064	1,099	1,162	1,238
21	Mining	5.6	4.9	4.2	4.0	4.4	5.6	5.4	6.0	7.0
22	Utilities	17.7	15.2	15.0	15.0	14.7	14.3	14.3	14.0	14.3
23	Construction	66.5	55.2	49.5	45.6	46.6	47.0	47.5	49.4	54.8
311	Food Mfg	14.9	14.9	14.1	13.5	12.9	14.7	13.2	13.0	12.2
312	Beverage Mfg	2.4	2.4	2.4	2.4	2.2	2.6	2.5	2.5	2.4
313	Textile Mills	0.5	0.5	0.6	0.6	0.7	0.6	0.6	0.7	0.7
314	Textile Product Mills	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.7	0.7
315	Apparel Mfg	3.8	4.2	4.0	3.8	4.2	4.3	4.6	4.5	4.7
316	Leather and Allied Product Mfg	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.2
321	Wood Product Mfg	3.6	3.2	2.8	2.3	2.5	2.3	2.2	2.6	2.4
322	Paper Mfg	2.8	3.2	3.2	3.5	3.1	2.4	2.7	3.0	2.9
323	Printing and Related Support Activities	6.7	6.5	6.1	5.5	5.5	5.2	5.5	5.8	5.9
324	Petroleum and Coal Products Mfg	3.7	3.6	4.0	3.8	3.6	4.4	5.5	4.6	6.6
325	Chemical Mfg	6.9	7.0	7.9	8.6	9.3	8.8	9.0	9.6	9.3
326	Plastics and Rubber Products Mfg	2.7	2.8	2.8	3.1	3.3	3.4	3.6	4.1	4.5
327	Nonmetallic Mineral Product Mfg	3.5	2.8	2.8	2.5	2.8	2.7	2.7	3.2	3.3
331	Primary Metal Mfg	1.9	1.9	1.6	1.8	1.8	1.9	2.0	2.4	2.6
332	Fabricated Metal Product Mfg	9.3	8.7	8.5	8.3	9.5	11.1	12.0	13.0	13.9
333	Machinery Mfg	6.7	6.2	6.8	6.2	7.4	9.6	10.1	11.5	14.4
334	Computer and Electronic Product Mfg	28.4	29.4	27.7	26.9	28.2	36.1	41.3	48.6	52.9
335	Electrical Equip., Appliance, & Component Mfg	2.6	2.8	2.5	2.5	2.8	3.8	4.3	5.4	6.3
336	Transportation Equipment Mfg	19.2	17.5	13.4	15.2	13.0	11.1	11.6	12.7	14.5
337	Furniture and Related Product Mfg	3.4	3.0	3.1	3.0	2.8	2.8	3.0	3.4	3.6
339	Miscellaneous Mfg	6.3	6.0	5.8	5.8	6.0	6.2	6.9	7.5	8.0

Source: Economy.com; Department of Finance

Table A-15 (Continued)

California GSP by NAICS code (billions of 2003$)

NAICS	Description:	1999	2000	2001	2002	2003	2004	2005	2006	2007
	Total	1,321	1,421	1,423	1,455	1,492	1,554	1,610	1,669	1,740
21	Mining	7.4	6.8	6.2	5.4	5.8	6.2	6.3	6.7	7.0
22	Utilities	15.4	16.2	15.2	16.5	17.0	17.3	17.9	18.6	19.3
23	Construction	59.5	63.8	67.0	70.2	69.5	68.0	69.6	71.1	74.2
311	Food Mfg	12.8	12.9	11.3	11.1	11.0	11.0	11.1	11.2	11.3
312	Beverage Mfg	2.6	2.7	5.3	5.3	6.0	6.5	6.7	7.0	7.3
313	Textile Mills	0.8	0.8	0.6	0.5	0.5	0.5	0.6	0.6	0.6
314	Textile Product Mills	0.7	0.8	0.4	0.4	0.3	0.3	0.3	0.3	0.3
315	Apparel Mfg	4.5	4.7	4.7	4.1	4.2	4.5	4.7	4.9	5.2
316	Leather and Allied Product Mfg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
321	Wood Product Mfg	2.6	2.7	2.5	2.5	2.4	2.4	2.3	2.3	2.3
322	Paper Mfg	3.0	2.6	2.1	1.9	1.9	1.8	1.8	1.7	1.7
323	Printing and Related Support Activities	5.9	6.0	5.1	4.4	4.1	4.1	4.0	4.0	4.0
324	Petroleum and Coal Products Mfg	6.6	4.7	3.5	3.4	3.3	3.3	3.3	3.3	3.3
325	Chemical Mfg	12.7	14.3	13.5	13.4	14.0	14.7	15.3	15.8	16.3
326	Plastics and Rubber Products Mfg	4.7	4.8	4.5	4.1	4.2	4.4	4.4	4.5	4.6
327	Nonmetallic Mineral Product Mfg	3.4	3.7	3.6	3.6	3.6	3.6	3.7	3.8	3.9
331	Primary Metal Mfg	2.8	3.0	2.6	2.5	2.6	2.8	2.9	2.9	3.0
332	Fabricated Metal Product Mfg	16.7	19.2	19.9	19.0	19.1	20.2	20.9	21.2	21.5
333	Machinery Mfg	20.3	26.0	18.1	18.2	18.0	18.8	19.7	20.3	20.8
334	Computer and Electronic Product Mfg	65.8	83.2	85.0	65.5	65.6	68.3	70.6	71.9	73.2
335	Electrical Equipment, Appliance, & Component Mfg	8.3	10.9	4.1	3.5	3.2	3.1	3.2	3.3	3.4
336	Transportation Equipment Mfg	14.2	14.3	10.3	10.4	10.2	10.5	10.9	11.2	11.7
337	Furniture and Related Product Mfg	3.9	4.0	4.1	3.9	3.8	3.9	3.9	4.0	4.1
339	Miscellaneous Mfg	8.7	9.2	7.0	6.3	6.1	6.3	6.5	6.6	6.8

Table A-15 (Continued)

California GSP by NAICS code (billions of 2003$)

NAICS	Description:	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	Total	1,817	1,889	1,960	2,032	2,108	2,183	2,258	2,331	2,403
21	Mining	7.3	7.7	8.0	8.3	8.7	9.0	9.4	9.7	10.1
22	Utilities	20.1	20.8	21.5	22.3	23.1	23.9	24.7	25.6	26.4
23	Construction	77.6	81.0	84.6	88.2	91.9	95.8	99.5	101.2	103.3
311	Food Mfg	11.5	11.7	11.9	12.1	12.3	12.5	12.7	12.8	13.0
312	Beverage Mfg	7.5	7.8	8.1	8.3	8.6	8.8	9.1	9.4	9.5
313	Textile Mills	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8
314	Textile Product Mills	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
315	Apparel Mfg	5.5	5.8	6.1	6.4	6.7	7.0	7.4	7.6	7.9
316	Leather and Allied Product Mfg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
321	Wood Product Mfg	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
322	Paper Mfg	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.5	1.5
323	Printing and Related Support Activities	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.7	3.7
324	Petroleum and Coal Products Mfg	3.4	3.4	3.4	3.4	3.5	3.5	3.5	3.5	3.5
325	Chemical Mfg	16.8	17.3	17.8	18.2	18.7	19.2	19.6	20.0	20.4
326	Plastics and Rubber Products Mfg	4.6	4.7	4.8	4.9	4.9	5.0	5.1	5.2	5.2
327	Nonmetallic Mineral Product Mfg	4.0	4.1	4.2	4.3	4.4	4.6	4.7	4.8	4.9
331	Primary Metal Mfg	3.1	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6
332	Fabricated Metal Product Mfg	21.9	22.2	22.6	22.9	23.2	23.5	23.9	24.2	24.4
333	Machinery Mfg	21.4	21.9	22.4	22.9	23.5	24.0	24.5	25.0	25.5
334	Computer and Electronic Product Mfg	74.8	76.2	77.8	79.2	80.8	82.5	84.1	85.6	87.1
335	Electrical Equipment, Appliance, & Component Mfg	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3
336	Transportation Equipment Mfg	12.2	12.7	13.1	13.4	13.8	14.1	14.4	14.7	15.0
337	Furniture and Related Product Mfg	4.1	4.2	4.3	4.4	4.5	4.5	4.6	4.7	4.8
339	Miscellaneous Mfg	6.9	7.1	7.3	7.4	7.6	7.8	7.9	8.1	8.2

Table A-16

Los Angeles Basin Historic & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real Personal Income (billions 2003$)	418	408	414	406	409	416	427	443	477	493
Rate of Change (%)	3.50%	-2.35%	1.37%	-1.74%	0.54%	1.79%	2.72%	3.71%	7.65%	3.28%
Real Per Capita Personal Income (2003$)	28,478	27,279	27,187	26,489	26,471	26,822	27,370	28,030	29,811	30,263
Rate of Change (%)	1.29%	-4.21%	-0.33%	-2.57%	-0.07%	1.33%	2.04%	2.41%	6.36%	1.52%
Total Population (thousands)	14,672	14,957	15,214	15,343	15,436	15,506	15,609	15,808	16,000	16,278
Rate of Change (%)	2.18%	1.95%	1.71%	0.85%	0.61%	0.45%	0.66%	1.28%	1.22%	1.74%
Household Population (thousands)	14,383	14,666	14,921	15,043	15,129	15,196	15,296	15,493	15,682	15,958
Rate of Change (%)	2.16%	1.97%	1.74%	0.81%	0.57%	0.44%	0.66%	1.29%	1.22%	1.76%
Households (thousands)	4,958	5,035	5,087	5,128	5,165	5,201	5,236	5,274	5,315	5,360
Rate of Change (%)	1.95%	1.56%	1.03%	0.81%	0.73%	0.70%	0.67%	0.72%	0.78%	0.85%
Persons per Household	2.90	2.91	2.93	2.93	2.93	2.92	2.92	2.94	2.95	2.98
Rate of Change (%)	0.21%	0.40%	0.71%	0.00%	-0.15%	-0.25%	-0.02%	0.56%	0.44%	0.91%
Non-Ag Wage & Salary Jobs (thousands)	6,299	6,106	5,927	5,821	5,849	5,951	6,050	6,219	6,415	6,591
Rate of Change (%)	1.20%	-3.05%	-2.94%	-1.79%	0.48%	1.73%	1.66%	2.80%	3.16%	2.74%
Retail Sales (millions 2003$)	155,533	145,515	143,207	145,408	152,710	159,361	164,474	168,787	178,560	189,149
Rate of Change (%)	-0.44%	-6.44%	-1.59%	1.54%	5.02%	4.36%	3.21%	2.62%	5.79%	5.93%

Source: Economy.com; Department of Finance

Table A-16 (Continued)

Los Angeles Basin Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Real Personal Income (billions 2003$)	515	528	535	543	561	573	583	597	613	628
Rate of Change (%)	4.50%	2.62%	1.29%	1.55%	3.30%	2.16%	1.74%	2.38%	2.62%	2.40%
Real Per Capita Personal Income (2003$)	30,995	31,148	30,954	30,883	31,527	31,833	32,015	32,406	32,883	33,298
Rate of Change (%)	2.42%	0.50%	-0.62%	-0.23%	2.09%	0.97%	0.57%	1.22%	1.47%	1.26%
Total Population (thousands)	16,609	16,961	17,287	17,595	17,804	18,013	18,222	18,431	18,640	18,849
Rate of Change (%)	2.03%	2.12%	1.92%	1.78%	1.19%	1.17%	1.16%	1.15%	1.13%	1.12%
Household Population (thousands)	16,284	16,634	16,961	17,266	17,474	17,682	17,890	18,097	18,305	18,513
Rate of Change (%)	2.04%	2.15%	1.97%	1.80%	1.20%	1.19%	1.17%	1.16%	1.15%	1.13%
Households (thousands)	5,402	5,444	5,495	5,550	5,606	5,661	5,716	5,771	5,826	5,881
Rate of Change (%)	0.77%	0.79%	0.93%	1.00%	1.01%	0.99%	0.98%	0.96%	0.95%	0.93%
Persons per Household	3.01	3.06	3.09	3.11	3.12	3.12	3.13	3.14	3.14	3.15
Rate of Change (%)	1.26%	1.35%	1.02%	0.79%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
Non-Ag Wage & Salary Jobs (thousands)	6,767	6,843	6,822	6,835	6,893	7,032	7,161	7,272	7,399	7,527
Rate of Change (%)	2.66%	1.12%	-0.30%	0.18%	0.84%	2.02%	1.83%	1.55%	1.74%	1.74%
Retail Sales (millions 2003$)	195,086	194,511	197,674	203,616	211,123	213,700	218,469	224,778	231,719	237,632
Rate of Change (%)	3.14%	-0.30%	1.63%	3.01%	3.69%	1.22%	2.23%	2.89%	3.09%	2.55%

Table A-16 (Continued)

Los Angeles Basin Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
Real Personal Income (billions 2003$)	642	655	669	682	695	710	724
Rate of Change (%)	2.25%	2.13%	2.10%	1.96%	1.90%	2.13%	2.02%
Real Per Capita Personal Income (2003$)	33,674	34,101	34,526	34,910	35,279	35,737	36,164
Rate of Change (%)	1.13%	1.27%	1.25%	1.11%	1.06%	1.30%	1.19%
Total Population (thousands)	19,059	19,221	19,383	19,546	19,708	19,870	20,032
Rate of Change (%)	1.11%	0.85%	0.84%	0.84%	0.83%	0.82%	0.82%
Household Population (thousands)	18,720	18,881	19,042	19,203	19,364	19,524	19,685
Rate of Change (%)	1.12%	0.86%	0.85%	0.84%	0.84%	0.83%	0.82%
Households (thousands)	5,935	5,974	6,013	6,052	6,090	6,128	6,167
Rate of Change (%)	0.92%	0.66%	0.65%	0.64%	0.64%	0.63%	0.62%
Persons per Household	3.15	3.16	3.17	3.17	3.18	3.19	3.19
Rate of Change (%)	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
Non-Ag Wage & Salary Jobs (thousands)	7,641	7,755	7,871	7,988	8,102	8,201	8,298
Rate of Change (%)	1.51%	1.49%	1.50%	1.49%	1.42%	1.23%	1.18%
Retail Sales (millions 2003$)	241,972	245,926	249,732	252,986	255,883	259,004	262,529
Rate of Change (%)	1.83%	1.63%	1.55%	1.30%	1.15%	1.22%	1.36%

Table A-17

San Francisco Bay Area Historic & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real Personal Income (billions 2003$)	207	205	212	212	216	227	239	253	275	298
Rate of Change (%)	2.32%	-0.79%	3.20%	0.25%	1.74%	4.99%	5.38%	5.83%	8.65%	8.27%
Real Per Capita Personal Income (2003$)	34,355	33,617	34,192	33,825	34,212	35,750	37,310	38,804	41,555	44,391
Rate of Change (%)	1.03%	-2.15%	1.71%	-1.07%	1.15%	4.50%	4.36%	4.00%	7.09%	6.83%
Total Population (thousands)	6,022	6,105	6,195	6,278	6,315	6,345	6,407	6,519	6,614	6,703
Rate of Change (%)	1.28%	1.38%	1.47%	1.34%	0.59%	0.47%	0.97%	1.75%	1.46%	1.35%
Household Population (thousands)	5,871	5,954	6,042	6,125	6,163	6,195	6,260	6,375	6,470	6,560
Rate of Change (%)	1.31%	1.41%	1.48%	1.38%	0.62%	0.51%	1.05%	1.84%	1.50%	1.38%
Households (thousands)	2,254	2,280	2,301	2,320	2,339	2,357	2,374	2,395	2,421	2,450
Rate of Change (%)	1.28%	1.17%	0.91%	0.85%	0.78%	0.77%	0.74%	0.89%	1.10%	1.18%
Persons per Household	2.60	2.61	2.63	2.64	2.64	2.63	2.64	2.66	2.67	2.68
Rate of Change (%)	0.03%	0.23%	0.56%	0.53%	-0.16%	-0.26%	0.31%	0.94%	0.39%	0.19%
Non-Ag Wage & Salary Jobs (thousands)	2,919	2,907	2,860	2,863	2,869	2,938	3,046	3,173	3,274	3,364
Rate of Change (%)	2.03%	-0.39%	-1.62%	0.11%	0.19%	2.40%	3.70%	4.17%	3.18%	2.73%
Retail Sales (Billions 2003$)	70,984	68,039	67,221	68,726	72,662	75,513	78,695	83,377	87,484	94,049
Rate of Change (%)	0.53%	-4.15%	-1.20%	2.24%	5.73%	3.92%	4.21%	5.95%	4.93%	7.50%

Source: Economy.com; Department of Finance

Table A-17 (Continued)

San Francisco Bay Area Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Real Personal Income (billions 2003$)	342	328	312	311	320	329	337	346	357	367
Rate of Change (%)	14.87%	-3.94%	-4.93%	-0.39%	2.93%	2.79%	2.37%	2.85%	3.01%	2.75%
Real Per Capita Personal Income (2003$)	50,164	47,561	44,930	44,515	45,304	46,050	46,622	47,428	48,329	49,129
Rate of Change (%)	13.00%	-5.19%	-5.53%	-0.92%	1.77%	1.65%	1.24%	1.73%	1.90%	1.66%
Total Population (thousands)	6,813	6,903	6,947	6,985	7,064	7,144	7,223	7,303	7,382	7,462
Rate of Change (%)	1.65%	1.32%	0.64%	0.54%	1.14%	1.12%	1.11%	1.10%	1.09%	1.08%
Household Population (thousands)	6,670	6,759	6,803	6,841	6,920	6,998	7,077	7,156	7,235	7,314
Rate of Change (%)	1.68%	1.33%	0.65%	0.56%	1.15%	1.14%	1.13%	1.11%	1.10%	1.09%
Households (thousands)	2,476	2,498	2,520	2,541	2,567	2,594	2,620	2,646	2,672	2,698
Rate of Change (%)	1.05%	0.91%	0.88%	0.82%	1.04%	1.03%	1.01%	1.00%	0.99%	0.98%
Persons per Household	2.69	2.71	2.70	2.69	2.70	2.70	2.70	2.70	2.71	2.71
Rate of Change (%)	0.62%	0.42%	-0.22%	-0.26%	0.11%	0.11%	0.11%	0.11%	0.11%	0.11%
Non-Ag Wage & Salary Jobs (thousands)	3,515	3,481	3,297	3,195	3,181	3,242	3,296	3,341	3,396	3,452
Rate of Change (%)	4.49%	-0.97%	-5.27%	-3.09%	-0.44%	1.90%	1.67%	1.36%	1.64%	1.66%
Retail Sales (Billions 2003$)	103,174	98,884	94,784	97,652	101,179	102,410	104,692	107,573	110,677	113,272
Rate of Change (%)	9.70%	-4.16%	-4.15%	3.03%	3.61%	1.22%	2.23%	2.75%	2.89%	2.34%

Table A-17 (Continued)

San Francisco Bay Area Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
Real Personal Income (billions 2003$)	376	386	396	406	416	425	435
Rate of Change (%)	2.57%	2.65%	2.63%	2.47%	2.37%	2.34%	2.23%
Real Per Capita Personal Income (2003$)	49,860	50,616	51,380	52,082	52,750	53,418	54,039
Rate of Change (%)	1.49%	1.52%	1.51%	1.37%	1.28%	1.27%	1.16%
Total Population (thousands)	7,541	7,625	7,709	7,793	7,877	7,961	8,045
Rate of Change (%)	1.07%	1.11%	1.10%	1.09%	1.08%	1.07%	1.05%
Household Population (thousands)	7,392	7,476	7,559	7,642	7,725	7,808	7,891
Rate of Change (%)	1.08%	1.13%	1.11%	1.10%	1.09%	1.08%	1.06%
Households (thousands)	2,724	2,752	2,779	2,806	2,833	2,860	2,887
Rate of Change (%)	0.96%	1.00%	0.99%	0.98%	0.97%	0.95%	0.94%
Persons per Household	2.71	2.72	2.72	2.72	2.73	2.73	2.73
Rate of Change (%)	0.11%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%
Non-Ag Wage & Salary Jobs (thousands)	3,502	3,552	3,603	3,654	3,704	3,746	3,788
Rate of Change (%)	1.45%	1.42%	1.43%	1.43%	1.36%	1.15%	1.12%
Retail Sales (Billions 2003$)	115,122	116,735	118,231	119,457	121,221	122,355	123,654
Rate of Change (%)	1.63%	1.40%	1.28%	1.04%	1.48%	0.94%	1.06%

Table A-18

San Diego Region Historic & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real Personal Income (billions 2003$)	69	68	70	69	70	71	74	78	86	91
Rate of Change (%)	1.34%	-0.44%	1.81%	-0.54%	0.86%	1.90%	4.45%	5.29%	9.56%	6.41%
Real Per Capita Personal Income (2003$)	27,423	26,770	26,880	26,655	26,748	27,213	28,296	29,204	31,458	32,865
Rate of Change (%)	-1.58%	-2.38%	0.41%	-0.84%	0.35%	1.74%	3.98%	3.21%	7.72%	4.47%
Total Population (thousands)	2,505	2,555	2,590	2,598	2,611	2,615	2,627	2,680	2,726	2,776
Rate of Change (%)	2.96%	1.98%	1.39%	0.30%	0.50%	0.16%	0.45%	2.02%	1.71%	1.86%
Household Population (thousands)	2,395	2,444	2,486	2,497	2,510	2,515	2,524	2,578	2,626	2,678
Rate of Change (%)	2.92%	2.03%	1.72%	0.45%	0.52%	0.19%	0.36%	2.11%	1.88%	1.98%
Households (thousands)	892	908	920	929	937	946	954	963	974	987
Rate of Change (%)	2.04%	1.79%	1.29%	1.00%	0.92%	0.89%	0.88%	0.96%	1.16%	1.34%
Persons per Household	2.69	2.69	2.70	2.69	2.68	2.66	2.65	2.68	2.70	2.71
Rate of Change (%)	0.87%	0.24%	0.42%	-0.54%	-0.39%	-0.69%	-0.52%	1.14%	0.71%	0.63%
Non-Ag Wage & Salary Jobs (thousands)	967	963	948	947	955	978	1,006	1,054	1,105	1,153
Rate of Change (%)	2.72%	-0.42%	-1.56%	-0.06%	0.87%	2.43%	2.84%	4.77%	4.86%	4.29%
Retail Sales (millions 2003$)	28,673	26,832	26,553	27,580	28,495	28,800	31,079	31,522	32,644	34,648
Rate of Change (%)	-1.85%	-6.42%	-1.04%	3.87%	3.32%	1.07%	7.91%	1.43%	3.56%	6.14%

Source: Economy.com; Department of Finance

Table A-18 (Continued)

San Diego Region Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Real Personal Income (billions 2003$)	98	100	103	105	109	111	113	115	118	120
Rate of Change (%)	7.18%	2.61%	2.40%	1.87%	3.92%	2.00%	1.56%	2.19%	2.35%	2.14%
Real Per Capita Personal Income (2003$)	34,530	34,645	34,834	34,934	35,855	36,124	36,245	36,598	37,015	37,368
Rate of Change (%)	5.07%	0.33%	0.54%	0.29%	2.64%	0.75%	0.33%	0.97%	1.14%	0.95%
Total Population (thousands)	2,832	2,896	2,950	2,997	3,034	3,072	3,109	3,147	3,184	3,221
Rate of Change (%)	2.01%	2.27%	1.85%	1.58%	1.25%	1.23%	1.22%	1.21%	1.19%	1.18%
Household Population (thousands)	2,737	2,799	2,846	2,893	2,931	2,968	3,006	3,043	3,081	3,118
Rate of Change (%)	2.21%	2.26%	1.69%	1.65%	1.30%	1.28%	1.26%	1.25%	1.23%	1.22%
Households (thousands)	999	1,009	1,022	1,036	1,049	1,061	1,073	1,085	1,098	1,110
Rate of Change (%)	1.15%	1.07%	1.28%	1.35%	1.19%	1.18%	1.16%	1.14%	1.13%	1.11%
Persons per Household	2.74	2.77	2.78	2.79	2.80	2.80	2.80	2.80	2.81	2.81
Rate of Change (%)	1.05%	1.18%	0.41%	0.29%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
Non-Ag Wage & Salary Jobs (thousands)	1,194	1,218	1,231	1,242	1,260	1,294	1,325	1,353	1,386	1,419
Rate of Change (%)	3.55%	2.07%	1.00%	0.92%	1.49%	2.70%	2.34%	2.16%	2.40%	2.38%
Retail Sales (millions 2003$)	37,501	37,757	38,478	40,077	41,531	41,966	42,856	44,101	45,450	46,604
Rate of Change (%)	8.24%	0.68%	1.91%	4.15%	3.63%	1.05%	2.12%	2.90%	3.06%	2.54%

Table A-18 (Continued)

San Diego Region Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
Real Personal Income (billions 2003$)	123	126	128	131	134	137	140
Rate of Change (%)	2.08%	2.25%	2.18%	2.05%	2.01%	2.47%	2.35%
Real Per Capita Personal Income (2003$)	37,708	38,117	38,510	38,862	39,209	39,740	40,237
Rate of Change (%)	0.91%	1.09%	1.03%	0.91%	0.89%	1.36%	1.25%
Total Population (thousands)	3,259	3,296	3,334	3,371	3,409	3,446	3,484
Rate of Change (%)	1.16%	1.15%	1.14%	1.12%	1.11%	1.10%	1.09%
Household Population (thousands)	3,156	3,193	3,231	3,268	3,306	3,343	3,380
Rate of Change (%)	1.20%	1.19%	1.17%	1.16%	1.15%	1.13%	1.12%
Households (thousands)	1,122	1,134	1,146	1,159	1,171	1,183	1,195
Rate of Change (%)	1.10%	1.08%	1.07%	1.06%	1.04%	1.03%	1.02%
Persons per Household	2.81	2.82	2.82	2.82	2.82	2.83	2.83
Rate of Change (%)	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
Non-Ag Wage & Salary Jobs (thousands)	1,449	1,480	1,512	1,544	1,576	1,603	1,630
Rate of Change (%)	2.15%	2.13%	2.14%	2.15%	2.04%	1.76%	1.68%
Retail Sales (millions 2003$)	47,472	48,266	49,032	49,695	51,101	51,734	52,453
Rate of Change (%)	1.86%	1.67%	1.59%	1.35%	2.83%	1.24%	1.39%

Table A-19

Sacramento Region Historic & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real Personal Income (billions 2003$)	40	40	41	41	43	44	45	48	51	54
Rate of Change (%)	5.13%	0.47%	2.43%	-0.11%	3.60%	4.16%	2.31%	4.93%	7.12%	5.39%
Real Per Capita Personal Income (2003$)	26,824	26,045	26,171	25,716	26,401	27,188	27,393	28,269	29,787	30,417
Rate of Change (%)	1.07%	-2.90%	0.48%	-1.74%	2.67%	2.98%	0.75%	3.20%	5.37%	2.11%
Total Population (thousands)	1,491	1,543	1,573	1,599	1,613	1,632	1,657	1,685	1,713	1,768
Rate of Change (%)	4.03%	3.47%	1.94%	1.66%	0.91%	1.15%	1.54%	1.68%	1.66%	3.21%
Household Population (thousands)	1,458	1,508	1,539	1,565	1,579	1,597	1,621	1,649	1,676	1,731
Rate of Change (%)	4.13%	3.48%	2.00%	1.68%	0.92%	1.14%	1.54%	1.68%	1.66%	3.27%
Households (thousands)	562	580	591	601	610	620	629	636	644	657
Rate of Change (%)	3.57%	3.13%	2.01%	1.63%	1.56%	1.56%	1.46%	1.09%	1.29%	2.07%
Persons per Household	2.59	2.60	2.60	2.60	2.59	2.58	2.58	2.59	2.60	2.63
Rate of Change (%)	0.54%	0.35%	-0.01%	0.05%	-0.63%	-0.41%	0.07%	0.57%	0.37%	1.17%
Non-Ag Wage & Salary Jobs (thousands)	619	631	623	626	644	663	681	702	731	770
Rate of Change (%)	5.06%	2.02%	-1.23%	0.44%	2.84%	2.95%	2.81%	2.99%	4.19%	5.36%
Retail Sales (millions 2003$)	15,992	15,242	15,002	15,233	16,197	16,626	17,003	17,651	18,265	20,032
Rate of Change (%)	5.25%	-4.69%	-1.57%	1.54%	6.33%	2.65%	2.27%	3.81%	3.48%	9.68%

Source: Economy.com; Department of Finance

Table A-19 (Continued)

Sacramento Region Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Real Personal Income (billions 2003$)	57	59	61	62	65	68	71	75	78	82
Rate of Change (%)	6.47%	3.76%	2.19%	2.35%	4.82%	4.59%	4.43%	4.90%	5.14%	4.80%
Real Per Capita Personal Income (2003$)	31,596	31,794	31,639	31,677	32,367	33,021	33,658	34,479	35,422	36,294
Rate of Change (%)	3.88%	0.63%	-0.49%	0.12%	2.18%	2.02%	1.93%	2.44%	2.73%	2.46%
Total Population (thousands)	1,812	1,868	1,918	1,961	2,012	2,062	2,113	2,164	2,214	2,265
Rate of Change (%)	2.49%	3.11%	2.69%	2.22%	2.58%	2.52%	2.46%	2.40%	2.34%	2.29%
Household Population (thousands)	1,775	1,831	1,881	1,923	1,974	2,024	2,075	2,125	2,176	2,226
Rate of Change (%)	2.53%	3.16%	2.74%	2.26%	2.63%	2.56%	2.49%	2.43%	2.38%	2.32%
Households (thousands)	670	685	704	725	743	761	780	798	816	834
Rate of Change (%)	1.98%	2.17%	2.85%	2.88%	2.53%	2.46%	2.40%	2.34%	2.28%	2.22%
Persons per Household	2.65	2.67	2.67	2.65	2.66	2.66	2.66	2.66	2.67	2.67
Rate of Change (%)	0.54%	0.97%	-0.11%	-0.60%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%
Non-Ag Wage & Salary Jobs (thousands)	797	819	832	844	849	863	884	905	929	953
Rate of Change (%)	3.45%	2.74%	1.62%	1.37%	0.60%	1.65%	2.46%	2.43%	2.61%	2.59%
Retail Sales (millions 2003$)	21,001	21,514	21,849	22,129	23,089	23,799	24,742	25,812	26,989	28,048
Rate of Change (%)	4.84%	2.44%	1.56%	1.28%	4.34%	3.07%	3.96%	4.33%	4.56%	3.92%

Table A-19 (Continued)

Sacramento Region Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
Real Personal Income (billions 2003$)	86	90	94	98	103	106	110
Rate of Change (%)	4.45%	4.82%	4.71%	4.47%	4.31%	3.66%	3.50%
Real Per Capita Personal Income (2003$)	37,080	37,918	38,757	39,546	40,311	40,858	41,369
Rate of Change (%)	2.17%	2.26%	2.21%	2.04%	1.94%	1.36%	1.25%
Total Population (thousands)	2,316	2,374	2,432	2,490	2,547	2,605	2,663
Rate of Change (%)	2.24%	2.50%	2.44%	2.38%	2.33%	2.27%	2.22%
Household Population (thousands)	2,277	2,334	2,392	2,450	2,508	2,565	2,623
Rate of Change (%)	2.27%	2.54%	2.47%	2.41%	2.36%	2.30%	2.25%
Households (thousands)	852	873	894	914	935	956	976
Rate of Change (%)	2.17%	2.44%	2.38%	2.32%	2.26%	2.21%	2.16%
Persons per Household	2.67	2.67	2.68	2.68	2.68	2.68	2.69
Rate of Change (%)	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%
Non-Ag Wage & Salary Jobs (thousands)	975	997	1,019	1,042	1,065	1,084	1,103
Rate of Change (%)	2.30%	2.25%	2.25%	2.26%	2.12%	1.85%	1.75%
Retail Sales (millions 2003$)	28,897	29,701	30,495	31,221	31,934	32,418	32,948
Rate of Change (%)	3.03%	2.78%	2.68%	2.38%	2.28%	1.51%	1.64%

Table A-20

Rest of State Historic & Forecasted Economic & Demographic Variables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real Personal Income (billions 2003$)	117	117	121	122	123	124	128	133	141	146
Rate of Change (%)	3.15%	0.11%	3.29%	1.05%	0.93%	1.17%	3.25%	3.46%	5.91%	3.50%
Real Per Capita Personal Income (2003$)	22,694	22,036	22,270	22,171	22,168	22,167	22,688	23,076	24,233	24,732
Rate of Change (%)	-0.14%	-2.90%	1.06%	-0.44%	-0.01%	-0.01%	2.35%	1.71%	5.01%	2.06%
Total Population (thousands)	5,139	5,298	5,415	5,496	5,548	5,613	5,663	5,760	5,809	5,892
Rate of Change (%)	3.29%	3.10%	2.21%	1.50%	0.94%	1.17%	0.88%	1.72%	0.86%	1.42%
Household Population (thousands)	4,965	5,116	5,229	5,309	5,361	5,423	5,463	5,552	5,594	5,671
Rate of Change (%)	3.10%	3.04%	2.20%	1.54%	0.99%	1.15%	0.74%	1.63%	0.76%	1.38%
Households (thousands)	1,768	1,805	1,834	1,857	1,880	1,901	1,920	1,940	1,959	1,980
Rate of Change (%)	2.16%	2.09%	1.58%	1.30%	1.20%	1.12%	1.04%	1.00%	0.98%	1.08%
Persons per Household	2.81	2.83	2.85	2.86	2.85	2.85	2.84	2.86	2.86	2.86
Rate of Change (%)	0.92%	0.93%	0.61%	0.23%	-0.21%	0.03%	-0.30%	0.62%	-0.22%	0.30%
Non-Ag Wage & Salary Jobs (thousands)	1,745	1,752	1,777	1,772	1,748	1,779	1,834	1,834	1,902	1,945
Rate of Change (%)	3.94%	0.43%	1.44%	-0.28%	-1.40%	1.78%	3.14%	-0.02%	3.71%	2.23%
Retail Sales (millions 2003$)	47,356	46,203	45,832	47,583	50,762	51,348	52,943	54,793	56,726	58,904
Rate of Change (%)	2.17%	-2.43%	-0.80%	3.82%	6.68%	1.15%	3.11%	3.49%	3.53%	3.84%

Source: Economy.com; Department of Finance

Table A-20 (Continued)

Rest of State Historic & Forecasted Economic & Demographic Variables

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Real Personal Income (billions 2003$)	153	157	161	165	170	174	178	183	188	193
Rate of Change (%)	5.32%	2.30%	2.38%	2.43%	3.04%	2.57%	2.24%	2.78%	2.93%	2.70%
Real Per Capita Personal Income (2003$)	25,611	25,692	25,811	25,966	26,323	26,568	26,737	27,054	27,422	27,741
Rate of Change (%)	3.56%	0.32%	0.46%	0.60%	1.37%	0.93%	0.63%	1.19%	1.36%	1.16%
Total Population (thousands)	5,992	6,111	6,227	6,341	6,445	6,550	6,654	6,759	6,863	6,968
Rate of Change (%)	1.71%	1.98%	1.91%	1.82%	1.65%	1.62%	1.60%	1.57%	1.55%	1.52%
Household Population (thousands)	5,770	5,889	6,002	6,111	6,213	6,315	6,418	6,521	6,623	6,726
Rate of Change (%)	1.74%	2.06%	1.92%	1.82%	1.66%	1.65%	1.63%	1.60%	1.57%	1.55%
Households (thousands)	2,001	2,025	2,055	2,089	2,120	2,152	2,183	2,215	2,246	2,277
Rate of Change (%)	1.05%	1.23%	1.49%	1.63%	1.50%	1.49%	1.46%	1.44%	1.41%	1.39%
Persons per Household	2.88	2.91	2.92	2.93	2.93	2.93	2.94	2.94	2.95	2.95
Rate of Change (%)	0.68%	0.82%	0.43%	0.18%	0.16%	0.16%	0.16%	0.16%	0.16%	0.16%
Non-Ag Wage & Salary Jobs (thousands)	2,011	2,078	2,100	2,118	2,138	2,172	2,204	2,234	2,270	2,306
Rate of Change (%)	3.43%	3.31%	1.04%	0.88%	0.93%	1.61%	1.48%	1.36%	1.59%	1.60%
Retail Sales (millions 2003$)	60,824	62,624	64,328	65,566	67,998	68,921	70,681	72,879	75,219	77,270
Rate of Change (%)	3.26%	2.96%	2.72%	1.92%	3.71%	1.36%	2.56%	3.11%	3.21%	2.73%

Table A-20 (Continued)

Rest of State Historic & Forecasted Economic & Demographic Variables

	2010	2011	2012	2013	2014	2015	2016
Real Personal Income (billions 2003$)	198	204	210	215	221	227	233
Rate of Change (%)	2.62%	2.95%	2.80%	2.65%	2.59%	2.83%	2.67%
Real Per Capita Personal Income (2003$)	28,047	28,397	28,719	29,008	29,292	29,654	29,981
Rate of Change (%)	1.10%	1.25%	1.13%	1.01%	0.98%	1.23%	1.10%
Total Population (thousands)	7,072	7,191	7,310	7,429	7,548	7,666	7,785
Rate of Change (%)	1.50%	1.68%	1.65%	1.63%	1.60%	1.57%	1.55%
Household Population (thousands)	6,828	6,945	7,062	7,179	7,295	7,412	7,529
Rate of Change (%)	1.52%	1.71%	1.68%	1.65%	1.63%	1.60%	1.57%
Households (thousands)	2,308	2,343	2,379	2,414	2,449	2,484	2,519
Rate of Change (%)	1.36%	1.54%	1.51%	1.48%	1.45%	1.43%	1.40%
Persons per Household	2.96	2.96	2.97	2.97	2.98	2.98	2.99
Rate of Change (%)	0.16%	0.17%	0.17%	0.17%	0.17%	0.17%	0.17%
Non-Ag Wage & Salary Jobs (thousands)	2,339	2,374	2,409	2,444	2,479	2,513	2,546
Rate of Change (%)	1.43%	1.49%	1.48%	1.46%	1.43%	1.37%	1.32%
Retail Sales (millions 2003$)	78,869	80,329	81,708	82,935	84,147	85,193	86,363
Rate of Change (%)	2.07%	1.85%	1.72%	1.50%	1.46%	1.24%	1.37%

APPENDIX B

DEMAND SIDE MANAGEMENT QUANTIFICATION IN THE ENERGY DEMAND FORECAST MODELS

The Energy Commission is statutorily required to incorporate conservation and energy efficiency that is "reasonably expected to occur" (RETO) in its energy demand forecasts. The term RETO is interpreted to include electricity demand reductions due to customer response to rising electricity prices and additional savings induced by the broad range of conservation programs in California. The Energy Commission's forecasting models have been expressly developed to quantify energy savings from mandatory building and appliance standards. A major effort of Energy Commission forecasting is to account for these influences in an internally consistent manner.

The original Warren-Alquist Act specified that demand forecasts include savings from RETO conservation and load management. Since 1985 the Energy Commission has distinguished between savings impacts that are reasonably expected to occur (committed RETO) and savings that are likely to occur if current trends in funding and policy continue to contribute additional savings from future year programs (uncommitted RETO). Only committed programs, which are programs that are implemented or for which funding has been approved, are included in the forecast. Uncommitted savings are considered on the supply side. The principal sources of program savings data are the Annual Earnings Assessment Reports of the investor owned utilities, the annual reports of municipal utilities, other published reports on efficiency programs, and the Energy Information Agency. Building and appliance standards savings are taken from the impact assessment reports developed for the standards rulemakings.

For the investor-owned utilities (IOUs), committed conservation programs are the 2006-2008 program plans that will be approved by the CPUC in fall 2005 in the Energy Efficiency Rulemaking Proceeding (R.01-08-028). Uncommitted programs are those expected or scheduled to begin post-2008. For publicly owned utilities, committed means the governing board for a municipal utility has authorized expenditure of funds for at least a preliminary program plan from which savings can be quantified.

Accounting for savings from the demand response/load management programs depends on whether or not the program is dispatchable. Dispatchable programs, such as direct control, interruptible tariffs, or demand bidding programs, are under the control of the utility or grid operator and are triggered by specific system operating conditions. Energy or peak load saved from dispatchable programs is treated as a resource and, therefore, is not counted in the demand forecast.

Nondispatchable programs have no triggering threshold condition, but allow a customer to make the individual choice to modify usage in response to ongoing price signals. Only impacts from committed nondispatchable programs are included in the demand forecast. Dispatchable demand response programs are considered on the supply side.

Attribution of Savings Among Programs

The large number of current and prospective conservation and load management programs meeting “committed program” criteria require substantial effort to quantify individually. Estimated savings by program are obtained directly from utilities and public agencies. All building and appliance standards are modeled within the sector forecast models. The models account for building decay, equipment replacement, and estimates of market induced impacts. Staff is in the process of updating the standards modeling and conducting an updated conservation quantification analysis.

Attribution of savings is guided by the principle that program savings are determined in the reverse order of introduction. This chronological sequencing approach requires that a series of model runs be made. As an example, let A, B, and C denote three runs of a sector model characterizing the combined influence of two programs, a single program introduced first, and no programs, respectively. The difference between runs A and B quantifies the savings from the last program introduced. This convention makes the estimate for the second program conditional upon the first. The difference between runs B and C quantifies the savings from the first program introduced. This example is complicated several fold in actual practice due to the large number of programs.

A significant complication of implementing this convention is the attribution of savings to market forces, including direct consumer price response. Extending the previous example further, let run D denote a case with fuel prices constant at the level of some reference year. Runs A, B and C used fuel price assumptions from the baseline forecast. Market savings are quantified as the difference between runs C and D. This is a straightforward extension of the previous example. Unfortunately, savings quantified using runs A, B, and C are conditional upon the market savings, which depend upon the fuel price assumptions of the baseline forecast. Changes in such fuel price assumptions, all other effects held constant, change the savings quantified for each program. High fuel prices lead to lower program savings and lower fuel prices lead to higher program savings.

Savings Analysis Using Models

The impacts from many DSM programs sponsored by utilities, state government, municipal utilities and third parties are estimated directly within the market sector end use models. Use of the basic forecasting models to quantify standards and program savings depends on determining a certain set of characteristics for each program that describes how it will function. This includes items such as the year of program introduction, customer type affected, program measures end use classifications, and compliance levels if the program is nominally mandatory, etc. All such characteristics must be converted into input parameters used in the sector forecasting models. Most programs affect only a single sector, but others cut across several sectors. Judgment may be necessary in assigning participation to the specified customer groupings.

Savings Analysis External to the Models

Energy impacts from some programs are quantified outside the sector models using a five step process. First, estimated energy impacts (energy savings in KWh, peak impacts in KW, and therm savings) by program are obtained directly from utilities and public agencies. Second, the programs are grouped and assigned a code that is consistent with the model based upon the year, plan area, sector, program type, and program category (i.e. energy efficiency incentives, energy management services, new construction, etc.) Third, first year energy impacts from a given program are assigned a useful measure life depending on the program type. Fourth, a degradation factor is applied to each year of the useful life and is used as a proxy to describe poor maintenance or equipment failure. Fifth, adjustments are made to distinguish between program induced and nonprogrammatic, or market, effects. The final results are aggregated by sector and plan area, and provided to the summary model where they are used to evaluate the appropriate sector forecasts. At the aggregate, the utility and program estimates are used to gauge the impacts included within the end use models.

The majority of the energy savings and peak impacts from conservation and efficiency programs come from the statewide IOU programs. Table B-1 is a listing of all the statewide IOU programs for 2002-2003. Programs such as information, education, and training programs are not counted towards energy impact estimates at this time because of the difficulty of attributing energy savings to these types of programs.

Table B-1

IOU Statewide Energy Efficiency Programs 2004-2005

Standard Performance Contract	Residential Retrofit Home Energy Survey*	Express Efficiency
Multi-Family Energy Efficiency Rebates	Nonresidential Energy Audit*	Residential Appliance Recycling
Building Operator Certification and Training*	Upstream Residential HVAC and Motors	Savings by Design
Codes & Standards Advocacy*	Emerging Technologies*	Education and Training*
Single Family Energy Efficiency Rebates	CA Energy Star New Homes	

* Information, education or training program that does not contribute energy or peak savings