

LA-Plan: Virtual Co-Laboratory for Policy Analysis in the Greater L.A. Region

Building Energy Usage – Data Review

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1.0 Introduction

Energy usage in buildings consists primarily of electricity and natural gas. Combustion of fuel, such as natural gas, is a source of criteria pollutant and greenhouse gas (GHG) emissions. The combustion of fuel on-site produces pollutant and GHG emissions directly. The use of electricity on-site is an indirect source of pollutant and GHG emissions since the electricity is produced off-site, in part by the combustion of fuel. In California, roughly 53% of the electricity produced in-state (71% of the total electricity consumption) is from natural gas. In this research, building energy usage data were compiled for selected building types to produce energy use factors, which can support estimation of criteria pollutant and GHG emission production from these sources.

2.0 Building Types

Energy use factors were developed for RELU-Tran building types. In the RELU-Tran model, building types include residential housing or business. Residential housing is divided into single family and multi-family. Business buildings are divided into industrial and commercial as shown in Table 2.1.

Table 2.1 Building types

Residential housing	Single family
	Multi-family
Business	Industrial
	Commercial

Industry types defined in RELU-Tran are listed in Table 2.2.

Table 2.2 Industry types

Agriculture
Manufacturing
Business
Retail
Construction

In this research, energy usage data were obtained in relation to the square footage of the building or the building units.

3.0 Data Sources

Energy use factors for these building types were compiled from a number of data sources. This section discusses these data sources as well as other sources which were reviewed.

3.1 The U.S. Department of Energy (DOE)

3.1.1 Building Energy Data Book

The Building Energy Data Book is compiled by the U.S. DOE and contains national statistics on residential and commercial energy consumption. The statistical information is derived from sources such as the Annual Energy Outlook (AEO) and the Residential Energy Consumption Survey (RECS) which are discussed in later sections. Figure 3-1 shows energy intensities in thousand BTUs per square foot by year for commercial buildings from the 2011 Building Energy Data Book. Similar data are available for the residential sector. Comparable data for both commercial and residential sectors are also available in terms of building carbon dioxide (CO₂) emissions as shown in Figure 3-2.

	Floorspace (million SF)	Percent Post-2000 Floorspace (1)	Delivered Energy Consumption		Primary Energy Consumption	
			Total (10 ¹⁵ Btu)	Consumption per SF (thousand Btu/SF)	Total (10 ¹⁵ Btu)	Consumption per SF (thousand Btu/SF)
1980	50.9	N.A.	5.99	117.7	10.57	207.7
1990	64.3	N.A.	6.74	104.8	13.30	207.0
2000 (2)	68.5	N.A.	8.20	119.7	17.15	250.3
2010	81.1	26%	8.74	107.7	18.22	224.6
2015	84.1	34%	8.88	105.5	18.19	216.2
2020	89.1	43%	9.02	101.2	19.15	214.9
2025	93.9	52%	9.56	101.8	20.06	213.6
2030	98.2	60%	9.96	101.5	20.92	213.1
2035	103.0	68%	10.38	100.8	21.78	211.4

Note(s): 1) Percent built after Dec. 31, 2000. 2) Data for 2000 and after excludes parking garages and commercial buildings on multi-building manufacturing facilities.

Figure 3-1 Commercial energy consumption intensities by year [from U.S. DOE's 2011 Building Energy Data Book]

	Residential		
	Site	Fossil	Electricity
1990	340	624	963
1991	347	633	980
1992	357	624	981
1993	372	667	1040
1994	364	668	1032
1995	361	678	1039
1996	389	710	1099
1997	371	719	1090
1998	339	759	1097
1999	360	762	1122
2000	380	805	1185
2001	367	805	1172
2002	368	835	1204
2003	383	847	1230
2004	371	856	1228
2005	364	897	1261
2006	323	869	1192
2007	345	897	1242
2008	351	878	1229
2009	343	820	1162
2010	353	879	1231
2011	350	861	1211
2012	356	818	1174
2013	343	791	1134

Figure 3-2 CO₂ emissions for U.S. residential buildings by year in million metric tons [from U.S. DOE's 2011 Building Energy Data Book]

3.2 Energy Information Administration (EIA)

The EIA is the statistical and analytical agency within the U.S. DOE which collects, analyzes, and disseminates independent and impartial energy information for the country. Products produced by the EIA are by law not required to obtain DOE review or approval. The EIA publishes several sets of data that were reviewed in this research which are described in this section.

3.2.1 EIA - Residential Energy Consumption Survey (RECS)

The EIA publishes the Residential Energy Consumption Survey (RECS). The RECS survey is conducted every four years and provides data gathered from a representative sample of housing units and their energy suppliers. The latest RECS survey was conducted in 2009. The survey sample size for the state of California in 2009 is 1,606 households. RECS survey data are released in summary format. The EIA also releases individual data records in the form of Public Use Microdata Files (PUMF). A preliminary PUMF file for 2009 is available that contains survey respondent data only. Data such as square footage, weather data, energy consumption, and expenditure data are not available as of September 2012. These data will be released at a later date. However, a complete PUMF data set is available for 2005. Data from the RECS survey were used to determine trends between residential energy consumption and square footage. The data analysis and results are presented in the following section.

RECS 2005 Data Analysis

RECS 2005 microdata were processed to determine trends relating square footage with energy usage. The selected variables from the microdata file which were used in the analysis are given in Table 3.1.

Table 3.1 Selected variables available in RECS PUMF file.

DOEID	'4-digit identification number'
NWEIGHT	'The Final Weight'
REGIONC	'Census Region'
DIVISION	'Census Division'
LRGSTATE	'Four Largest States' (2 = California)
SQFTEST	'Square Footage or residence'
BTUEL	'Electric Annual Use In Thousands Of BTU'
BTUNG	'Natural Gas Annual Use In Thousands Of BTU'
BTUFO	'Fuel Oil Annual Use In Thousands Of BTU'
BTULP	'LPG Annual Use In Thousands Of BTU'

The variable NWEIGHT is a weighting factor which defines the observation as being representative of a certain number of households. The sum of all the NWEIGHT factors for the California samples is the total number of households in California. Total energy consumption for a household was calculated as the sum of the electric, natural gas, fuel oil, and liquid propane gas. Total energy consumption for the state was calculated as the sum of the quantity of all total household energy consumptions multiplied by the corresponding population weighting factors. Energy consumption by square footage was calculated as total household energy consumption divided by household square footage. Figure 3-3 and Figure 3-4 show the relationships between California household energy consumption and floor space for natural gas and electricity, respectively. Figure 3-5 show the relationship between California household energy consumption and floor space for all energy sources including electric, natural gas, fuel oil, and liquid propane gas.

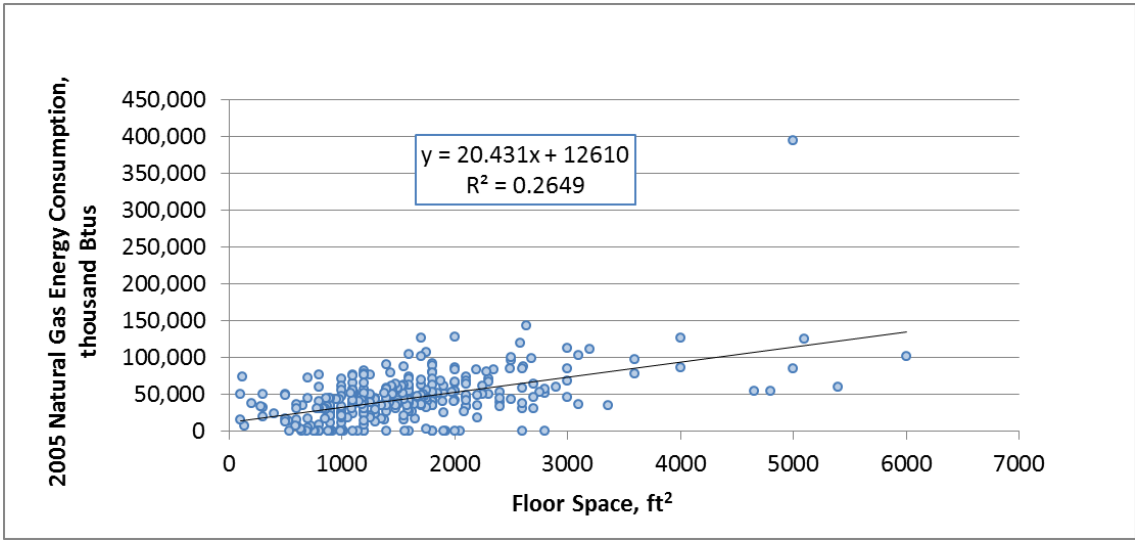


Figure 3-3 CA household natural gas energy consumption in 2005 [based on RECS 2005 PUMF microdata]

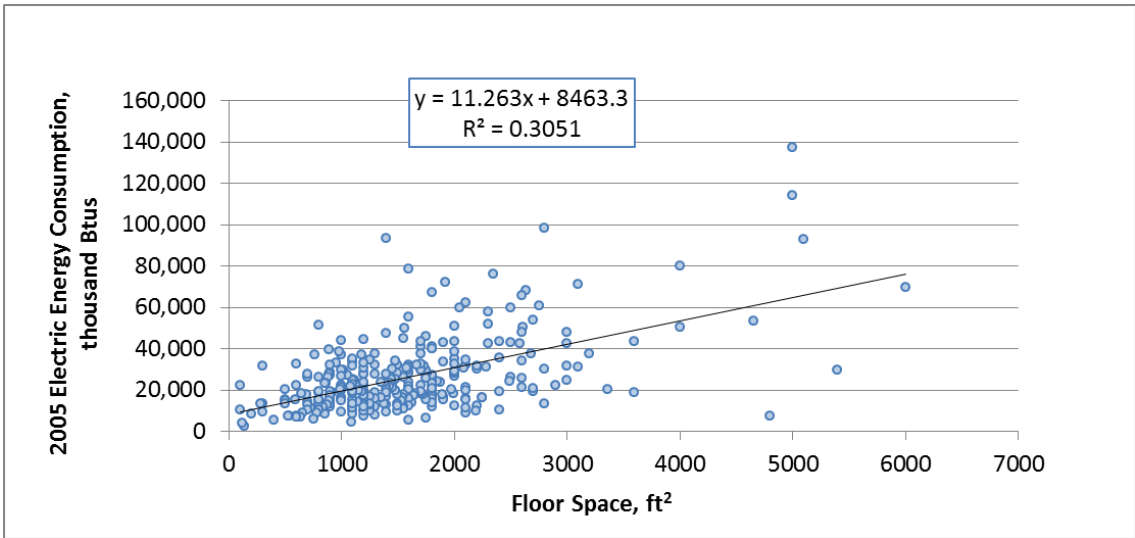


Figure 3-4 CA household electrical energy consumption in 2005 [based on RECS 2005 PUMF microdata]

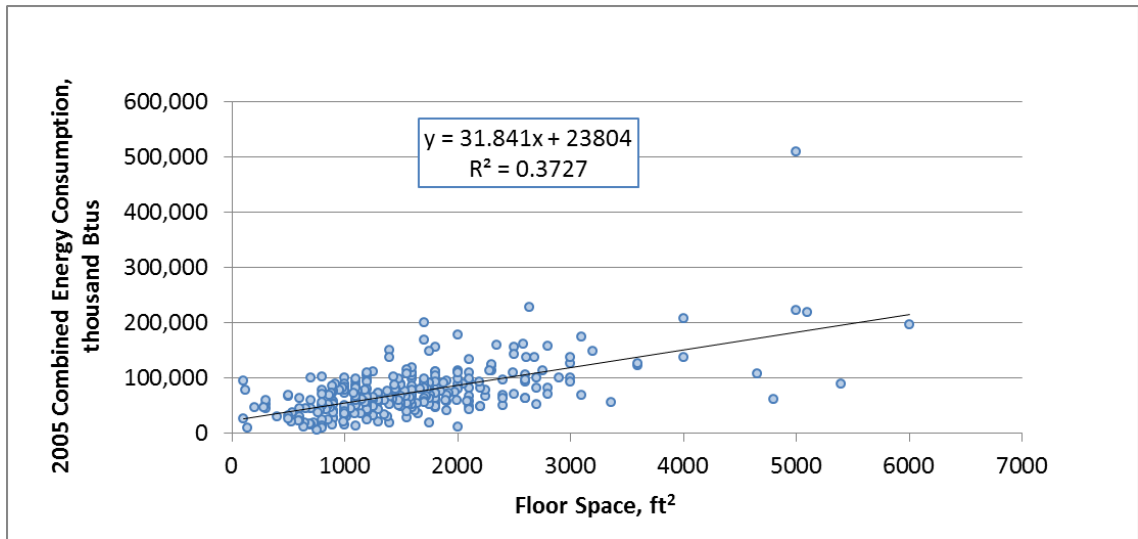


Figure 3-5 CA household combined energy consumption in 2005, including electric, natural gas, fuel oil, and liquid propane gas [based on RECS 2005 PUMF microdata]

RECS Data in Urban Energy Footprint Model

Larson et al. (2012) present a household energy consumption model as part of their Urban Energy Footprint Model (UEFM). The model is calibrated with microdata from the EIA’s 2005 RECS. The model estimates household energy consumption based on specific housing characteristics. These characteristics include area of interior space, income, average price per BTU, structure type characteristics, and control characteristics such as heating and cooling days. The model equation is presented below.

$$\ln E_i = \alpha + \beta \ln A_i + \phi \ln I_i + \delta \ln p_i + S_i' \gamma + X_i' \varphi + \varepsilon_i$$

where E is energy consumption of household I ; A is the area of interior space in the dwelling; I is income; p is the average price paid per thousand BTUs; S is a vector of variables describing the structure type; and X is a vector of other controls such as heating and cooling degree days.

3.2.2 EIA – Annual Energy Outlook (AEO)

The EIA’s Annual Energy Outlook report provides projections and analysis of U.S. energy supply, demand, consumption, and pricing for current and future years. The

report discusses legislation, regulation, special issues, market trends, and comparisons of AEO projections with other projections. Data provided in the AEO report are annual summary data at the national level (see Figure 3-6). Data for individual states are not provided.

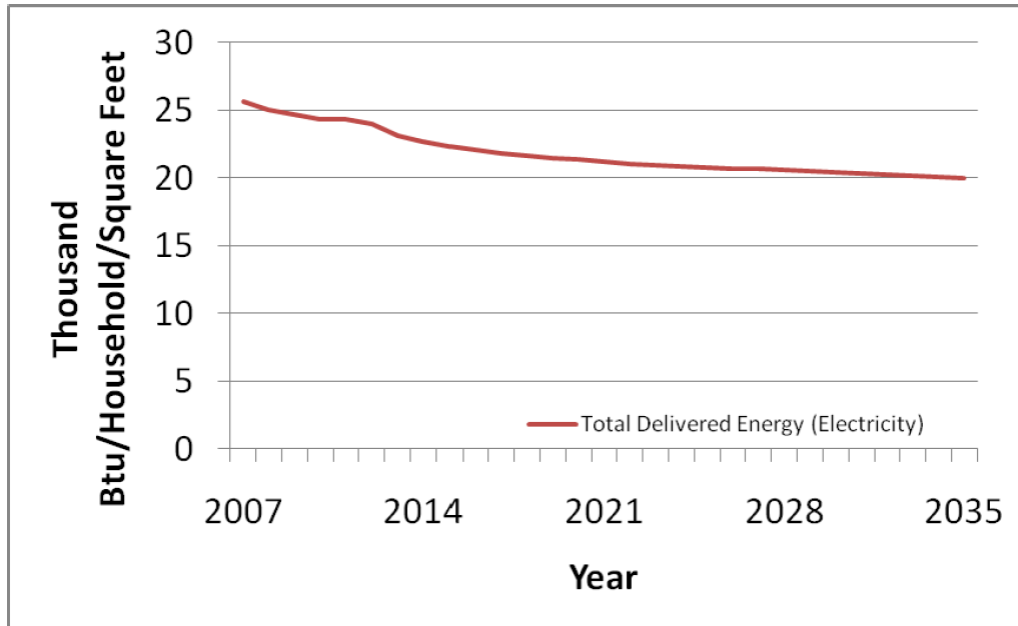


Figure 3-6 Residential sector energy in the form of electricity outlook normalized by the number of residential sector dwellings and the average square feet of the dwellings [based on Annual Energy Outlook 2010]

3.2.3 EIA – Monthly Energy Review (MER)

The EIA releases monthly and annual energy summary data for the country. The dataset contains monthly breakdown of energy use in the U.S. for various sectors and energy sources. Figure 3-7 and Figure 3-8 were created from the August 2012 MER dataset.

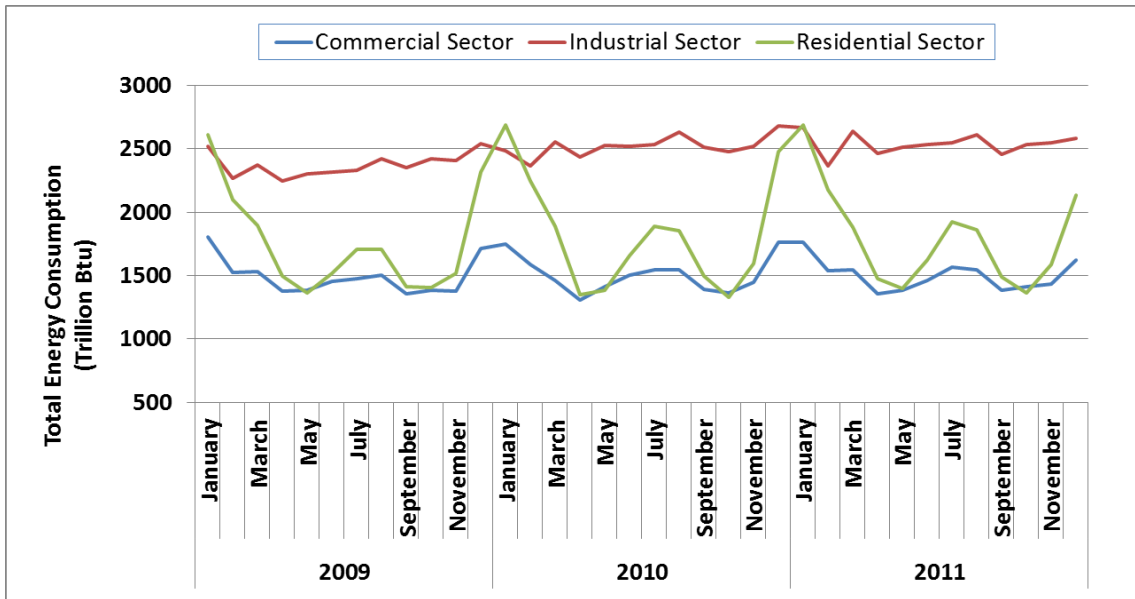


Figure 3-7 Monthly energy consumption in the U.S. for commercial, industrial, and residential sectors in 2009, 2010, and 2011 [data from MER August 2012]

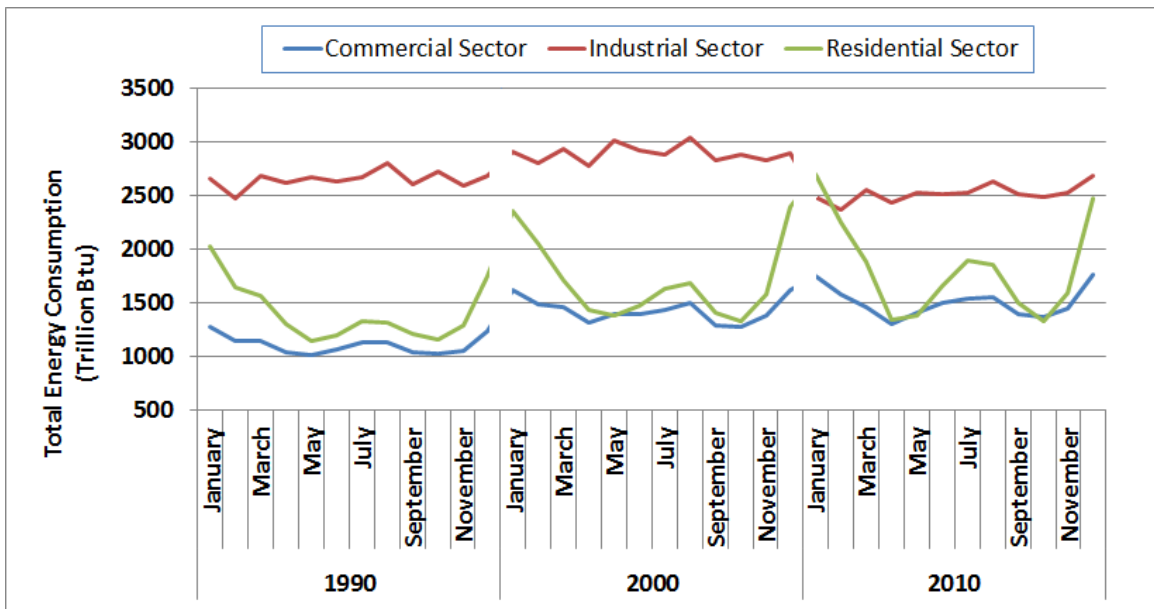


Figure 3-8 Monthly energy consumption in the U.S. for commercial, industrial, and residential sectors in 1990, 2000, and 2010 [data from MER August 2012]

3.2.4 EIA – State Energy Data System (SEDS)

The State Energy Data System is the EIA’s source for state energy statistics. The database contains energy data and estimates from 1960 to the present (see Figure 3-9). However, the dataset does not contain building information such as floor space which is needed for calculating energy usage factors.

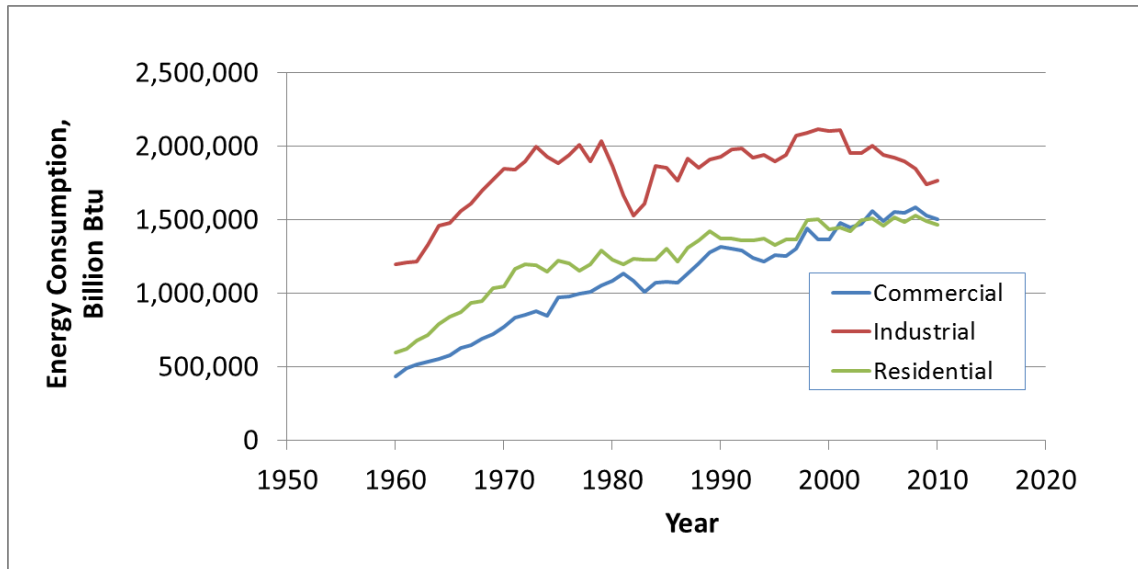


Figure 3-9 California energy consumption by sector and year [data from SEDS]

3.2.5 EIA – Commercial Building Energy Consumption Survey (CBECS)

Similar to the EIA’s RECS dataset for residential buildings, the EIA also conducts energy consumption surveys on commercial buildings. The latest CBECS dataset available is for 2003. Although the CBECS survey was conducted in 2007, most of the detailed data records were not released aside from data pertaining to large hospitals. The CBEC dataset contains summary data for the U.S. Census Regions and Divisions shown in Figure 3-10. California is part of the Pacific region along with Washington, Oregon, Alaska, and Hawaii. Data from the 2003 CBEC dataset are presented in Table 3.2 and Table 3.3.

U. S. Census Regions and Divisions:

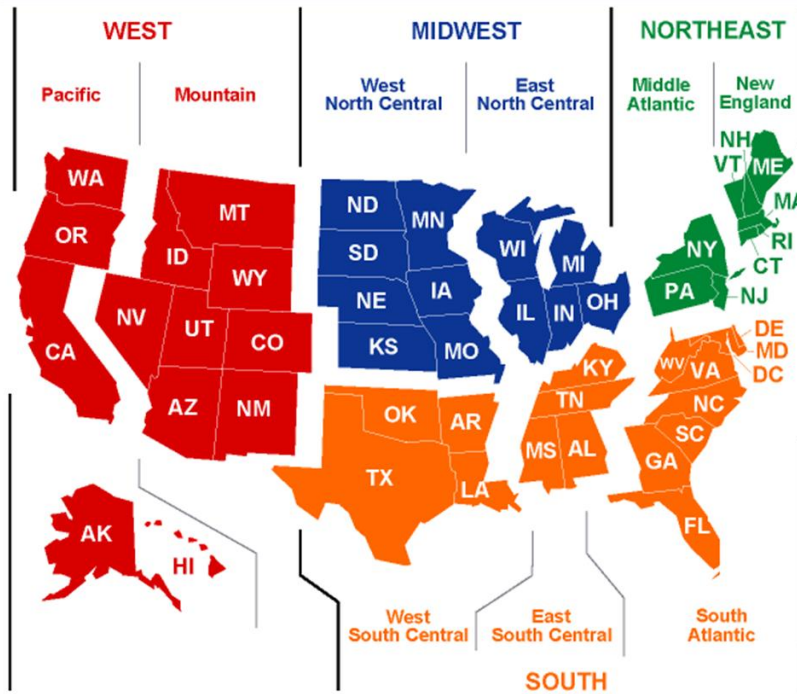


Figure 3-10 U.S. Census Regions and Divisions

Table 3.2 Commercial building energy consumption by floor space for Pacific region in 2003 [data from CBEC 2003]

Building Floor Space (million ft ²)	Annual Energy Consumption (Trillion Btu)	Energy Consumption per square foot (thousand Btu)
8,613	617	71.60
1,001 to 5,000	64	73.00
5,001 to 10,000	84	95.10
10,001 to 25,000	89	62.40
25,001 to 50,000	71	57.50
50,001 to 100,000	78	71.20
100,001 to 200,000	79	78.00
200,001 to 500,000	68	69.60
Over 500,000	n/a	n/a

Table 3.3 Commercial building energy consumption by building type for Pacific region in 2003 [data from CBEC 2003]

Building Type	Building Floor Space (million ft²)	Annual Energy Consumption (Trillion Btu)	Energy Consumption per square foot (thousand Btu)
Education	1,027	76	74.30
Food Sales	n/a	n/a	n/a
Food Service	232	n/a	n/a
Health Care - All	323	57	177.70
Health Care - Inpatient	176	n/a	n/a
Health Care - Outpatient	147	n/a	n/a
Lodging	649	47	71.80
Mercantile - All	1,732	127	73.40
Mercantile - Retail (Other Than Mall)	753	40	52.80
Mercantile - Enclosed and Strip Malls	979	n/a	n/a
Office	1,796	117	65.10
Public Assembly	468	n/a	n/a
Public Order and Safety	n/a	n/a	n/a
Religious Worship	341	n/a	n/a
Service	319	n/a	n/a
Warehouse and Storage	1,066	25	23.30

3.2.6 EIA - Manufacturing Energy Consumption Survey (MECS)

The EIA also conducts the Manufacturing Energy Consumption Survey (MECS). The 2006 MECS sample size of approximately 15,500 establishments was drawn from a nationally representative sample frame representing 97-98% of the manufacturing payroll. This sample allows EIA to report separate estimates of energy use for 21 3-digit industry subsectors, and 50 industry groups and industries according to the North American Industry Classification System (NAICS). Energy use data from this survey will be investigated in the next phase of research.

3.3 California Energy Commission (CEC)

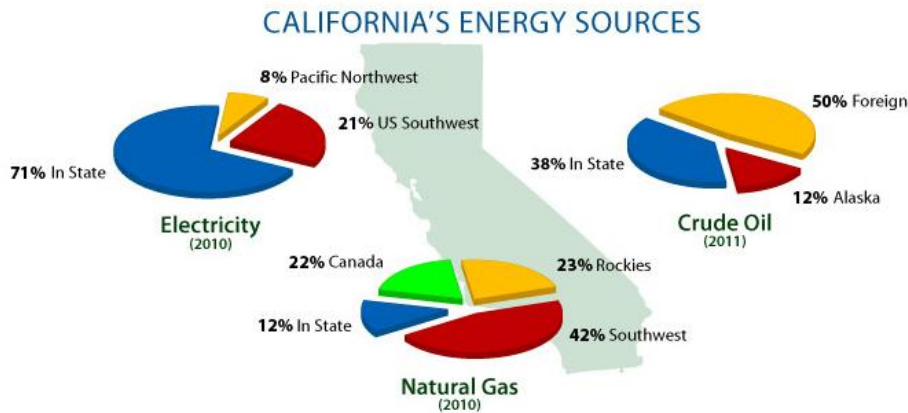
The CEC is California’s primary energy policy and planning agency. The agency is responsible for forecasting future energy needs, promoting energy efficiency and conservation, supporting public interest energy research, developing renewable and alternative energy resources, licensing of large scale power plans, and energy response planning and direction.

3.3.1 CEC – The California Energy Almanac

The Energy Almanac prepared by the CEC provides energy summary data for California’s energy industry. The Almanac provides the overall distribution of energy sources by energy type for the state (see

California's Major Sources of Energy

Page last updated: 4/7/2011



Electricity (2010) In-State Generation	
Source	
Natural Gas	53.4%
Nuclear	15.7%
Large Hydro	14.6%
Coal	1.7%
Renewable	14.6%

Natural Gas (2010)	
Source	
In State	12%
Canada	22%
Rockies	23%
Southwest	42%

Crude Oil (2011)	
Source	
In State	38.22%
Alaska	11.84%
Foreign	49.94%

Figure 3-11).

California's Major Sources of Energy

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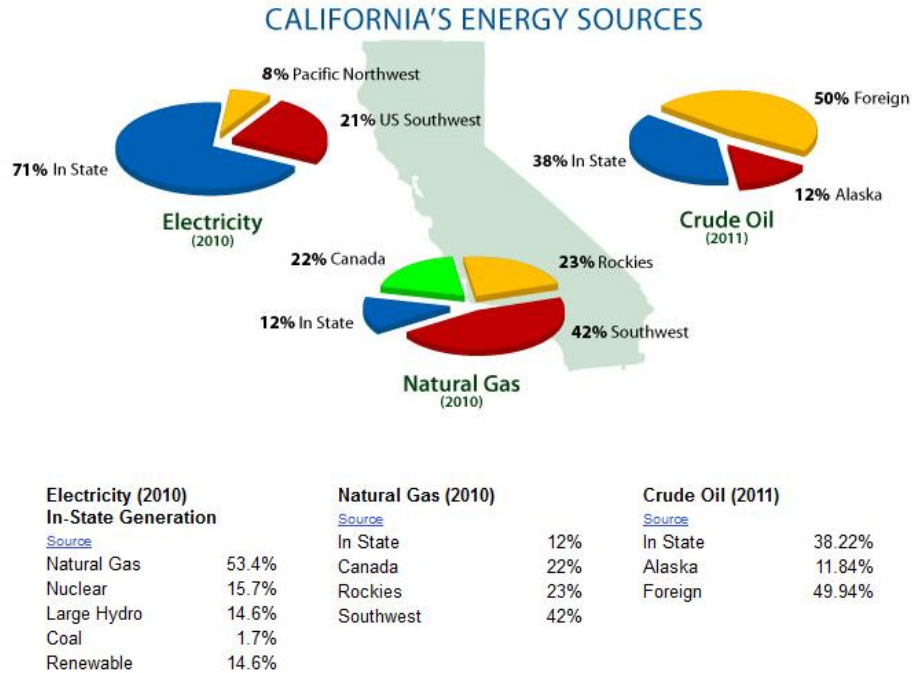


Figure 3-11 Distribution of energy sources by energy type for California

3.3.2 CEC – California Energy Demand (CED)

The CEC publishes energy use forecasts by sector for the state in the California Energy Demand Forecast. The dataset provides data for residential, commercial, and industrial sectors where the industrial sector is a combination of manufacturing, resource extraction, and construction. The forecasts are used in a variety of applications such as in the California Public Utilities Commission (CPUC) long-term procurement process. In this research, the CED 2000-2010 Staff Report was reviewed and selected data are presented in Table 3.4 and Table 3.5. The dataset also includes information on floor space and energy intensity. Examples are provided in Figure 3-12 through Figure 3-18.

Table 3.4 California electricity consumption by sector in billion BTU [data converted from GWh in CED 2000-2010 Staff Report]

California Electricity Consumption by Sector Billion Btu					
Year	Residential	Commercial	Industrial	Agricultural	Total Consumption
1980	177,725	169,795	144,139	45,385	569,756
1990	230,896	254,416	174,685	71,140	778,098
1998	257,235	297,174	177,418	50,025	833,958
2004	283,133	342,886	205,206	64,674	953,915
2010	316,394	375,083	229,467	68,639	1,057,314

Table 3.5 California natural gas consumption by sector in billion BTU [data converted from million Therms in CED 2000-2010 Staff Report]

California Natural Gas Consumption by Sector Billion Btu					
Year	Residential	Commercial	Industrial	Natural Gas Vehicles	Total Consumption
1980	584,000	164,600	576,300	0	1,362,700
1990	521,200	189,500	422,800	1,174,800	0
1998	552,100	210,300	634,100	0	1,434,400
2004	525,400	225,200	659,700	15,000	1,463,500
2010	551,100	244,900	722,500	22,200	1,580,200

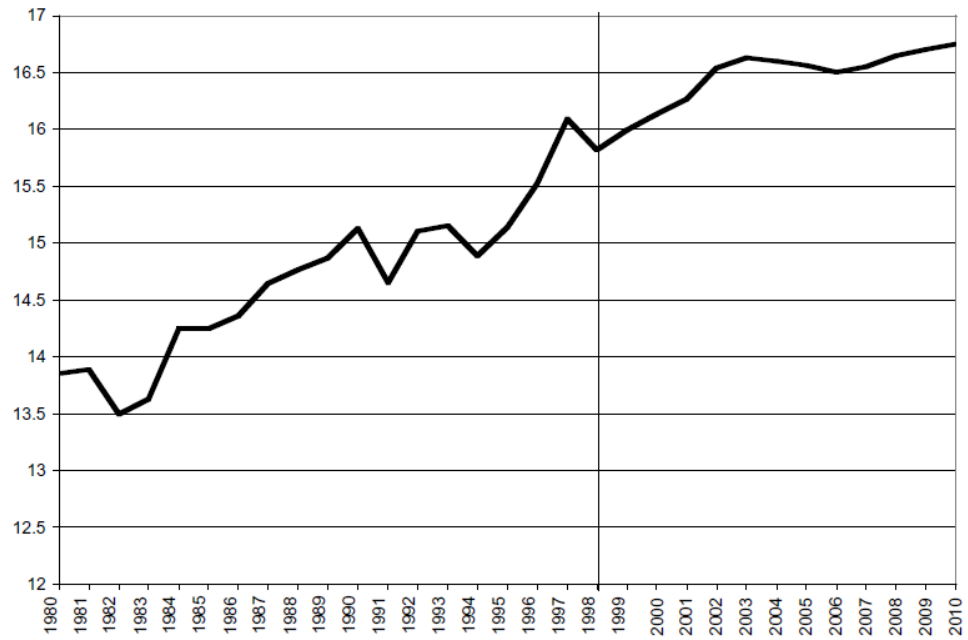


Figure 3-12 Commercial electricity consumption (kWh per square foot) [Source: California Energy Demand 2000-2010]

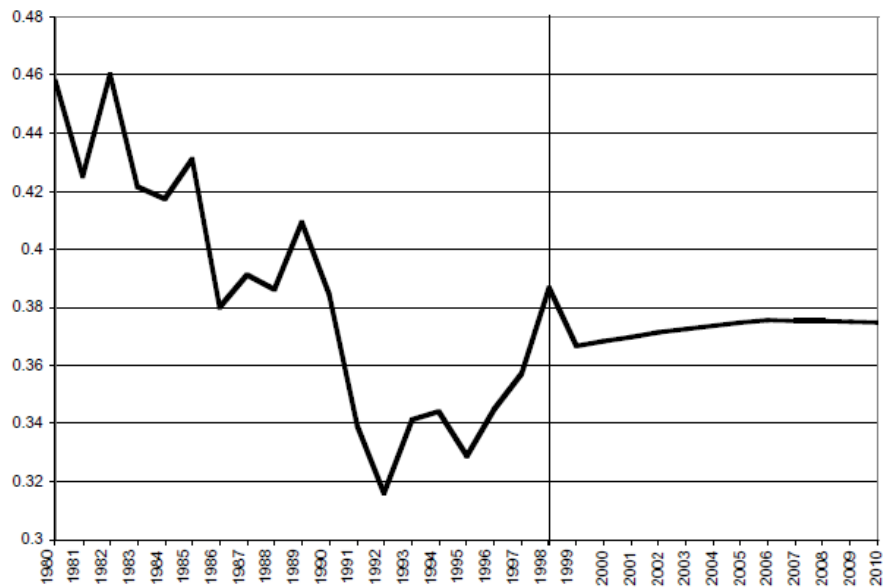


Figure 3-13 Commercial natural gas consumption (Therms per square foot) [Source: California Energy Demand 2000-2010]

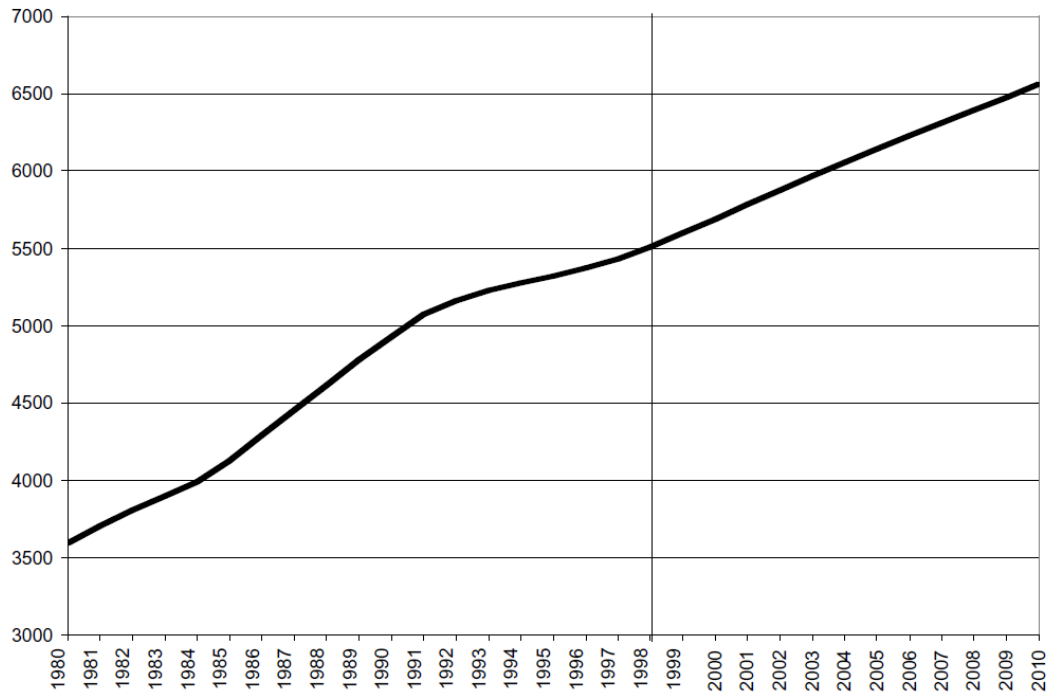


Figure 3-14 Commercial floor space (millions of square feet) [Source: California Energy Demand 2000-2010]

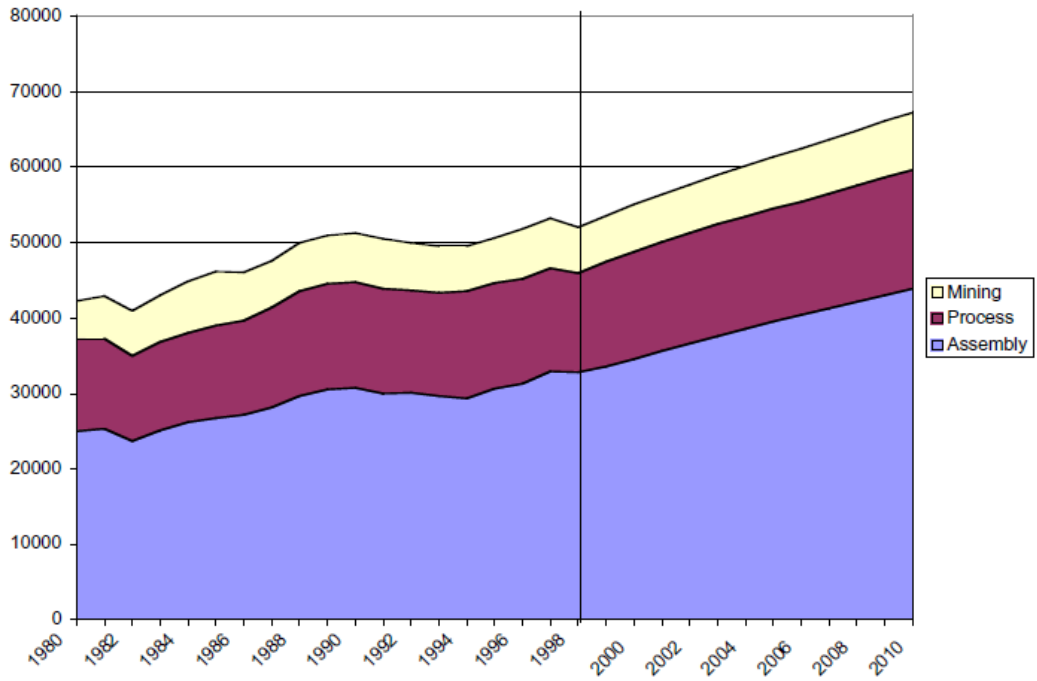


Figure 3-15 Industrial electricity use (GWh) [Source: California Energy Demand 2000-2010]

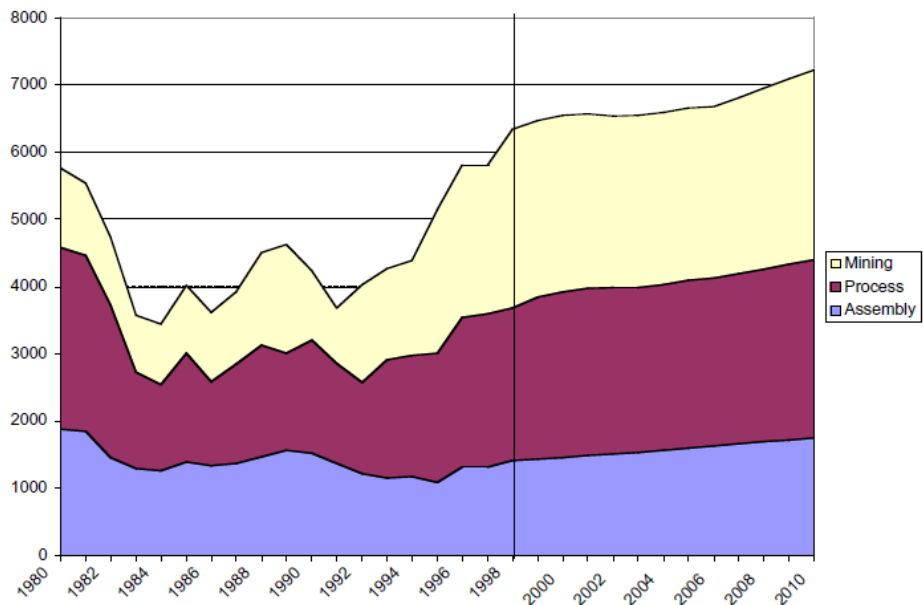


Figure 3-16 Industrial natural gas use (Million Therms) [Source: California Energy Demand 2000-2010]

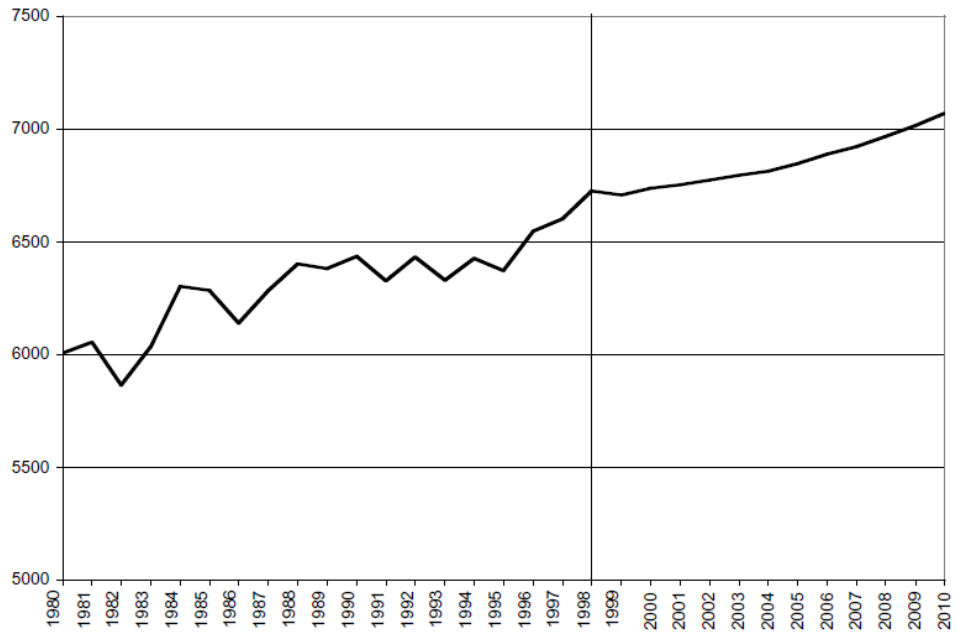


Figure 3-17 Residential electricity use per household (kWh per household) [Source: California Energy Demand 2000-2010]

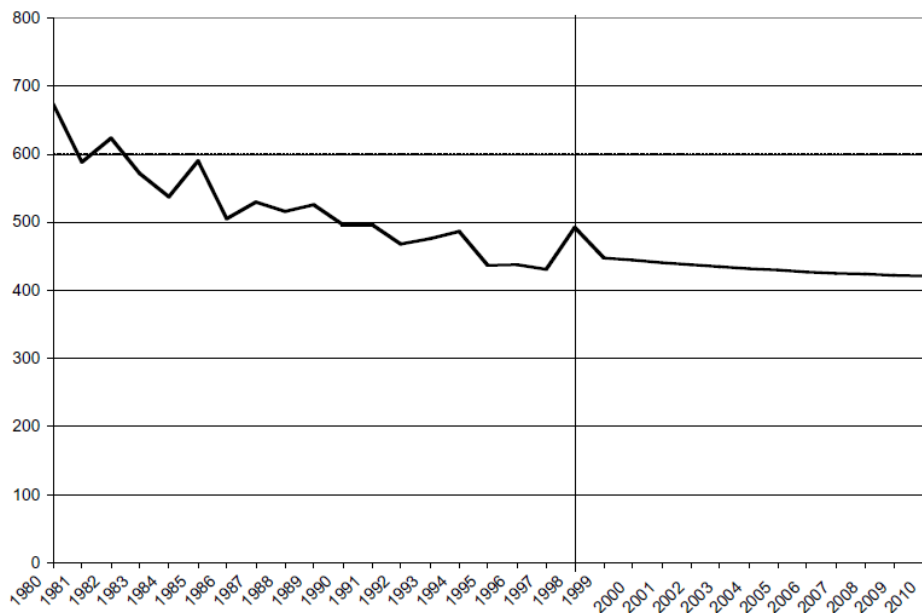


Figure 3-18 Residential natural gas consumption per household (Therms per household) [Source: California Energy Demand 2000-2010]

3.3.3 CEC – Residential Appliance Saturation Study (RASS)

The CEC conducted a Residential Appliance Saturation Study (RASS) in 2009 which collected survey data from California households regarding appliances and their energy usage patterns. Participating utilities included Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas & Electric Company (SDG&E), Southern California Gas Company (SoCal Gas), and Los Angeles Department of Water and Power (LADWP). Data from this survey include annual kWh consumption, dwelling type, square footage, primary heating fuel, air conditioning type, domestic hot water heating fuel, and their statistics.

The RASS database can be accessed interactively through the website <http://websafe.kemainc.com/RASSWEB/DesktopDefault.aspx>. Note that this website is not sponsored by the CEC.

3.3.4 CEC – California Commercial End-Use Survey (CEUS)

CEUS is a comprehensive study of commercial sector energy use, designed primarily to support energy demand forecasting activities. The survey database contains statistics for a random sample of 2,790 commercial facilities collected from Pacific Gas and Electric, San Diego Gas and Electric, Southern California Edison, Southern California Gas Company, and the Sacramento Municipal Utility District.

CEUS is used for the California Air Resources Board (CARB)'s CalEEMod model for commercial energy usage. The data can be accessed interactively using the DrCEUS System located on <http://capabilities.itron.com/CeusWeb/Chart.aspx>.

3.3.5 Energy Consumption Data Management System (ECDMS)

The Energy Consumption Data Management System is an online application that provides on-line searching capability over numerous data sources for electricity and natural gas consumption. Selected data retrieved from the ECDMS system are presented in Figure 3-19 through Figure 3-21.

2010		Converted to Billion Btu	
County	Sector	Electricity Consumption (Millions of kWh)	Electricity Consumption (Billion Btu)
Imperial	Residential	499.11	1,703.05
Los Angeles	Residential	19,591.17	66,847.83
Orange	Residential	6,856.89	23,396.68
Riverside	Residential	6,271.39	21,398.88
San Bernardino	Residential	4,589.89	15,661.37
Ventura	Residential	1,769.50	6,037.78
Imperial	Non-Residential	911.39	3,109.79
Los Angeles	Non-Residential	47,731.96	162,868.20
Orange	Non-Residential	13,840.91	47,227.15
Riverside	Non-Residential	7,493.92	25,570.33
San Bernardino	Non-Residential	8,623.52	29,424.67
Ventura	Non-Residential	3,617.70	12,344.11

Figure 3-19 Electrical energy consumption for selected CA counties [Source: ECDMS]

2010		Converted to Billion Btu	
County	Sector	Natural Gas Consumption (Millions of Therms)	Natural Gas Consumption (Billion Btu)
Imperial	Residential	7.77	776.58
Los Angeles	Residential	1,358.92	135,891.93
Orange	Residential	404.66	40,466.48
Riverside	Residential	267.22	26,721.54
San Bernardino	Residential	268.95	26,895.25
Ventura	Residential	122.78	12,278.48
Imperial	Non-Residential	23.03	2,302.91
Los Angeles	Non-Residential	1,766.87	176,687.22
Orange	Non-Residential	236.42	23,642.23
Riverside	Non-Residential	135.08	13,507.72
San Bernardino	Non-Residential	224.21	22,420.90
Ventura	Non-Residential	77.98	7,798.30

Figure 3-20 Natural gas energy consumption for selected CA counties [Source: ECDMS]

2010		Calculated
County	Sector	Total Consumption (Billion Btu)
Imperial	Residential	2,479.63
Los Angeles	Residential	202,739.76
Orange	Residential	63,863.16
Riverside	Residential	48,120.41
San Bernard	Residential	42,556.62
Ventura	Residential	18,316.26
Imperial	Non-Residential	5,412.71
Los Angeles	Non-Residential	339,555.41
Orange	Non-Residential	70,869.38
Riverside	Non-Residential	39,078.04
San Bernard	Non-Residential	51,845.56
Ventura	Non-Residential	20,142.41

Figure 3-21 Natural gas and electrical energy consumption for selected CA counties
[Source: ECDMS)

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