CONSERVATION AND APPLIANCE TECHNOLOGY OPTIONS FOR COMMERCIAL BUILDINGS

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STUDY BACKGROUND

Pacific Gas and Electric Company (PG&E) uses an end-use model to forecast sales of electricity and gas in the commercial sector and to analyze the impact of state and utility conservation and load management programs. The model provides forecasts not only for the commercial sector as a whole but for various business types within the sector (e.g., offices, retail stores, etc.) and for different end-uses (e.g., space heating, space cooling).

To arrive at forecasts of energy sales for the different business types and the different end-uses, the model projects the market penetration of various technologies for providing the required end-use functions. The model bases these projections of market penetration on an analysis of data relating to each technology's cost, relative energy efficiency, and availability.

The accuracy of the end-use model in forecasting electricity and gas sales in the commercial sector and in showing the impacts of conservation and/or load management programs depends in large part on the adequacy of the data used to characterize the end-use technology options. Accurate data are also needed for market planning and market research. The purpose of this study therefore was to identify, collect and update information on major energy-using technologies in the commercial sector of PG&E's service area.

SCOPE OF THE STUDY

There were three main phases to the study. The first phase involved a preliminary updating of initial data included in the technology options data base. Data on relative energy efficiencies, capital costs, market shares and dates of availability for each technology option in the initial technology options data base were reviewed and evaluated for accuracy. The range and completeness of the list of technology options included in the initial data base were evaluated, and important technology options that are likely to come into significant use during the next ten years were identified and evaluated for inclusion in the data base. Based on this review and evaluation, a preliminary, updated version of the technology options data base was prepared and delivered to PG&E.

The second phase of the project involved an on-site survey of a statistically-representative sample of commercial premises in PG&E's service area. A plan for the on-site survey was first prepared that included recommendations on

how to identify the characteristics of currently available technology options, on what data to collect so that PG&E would be able to determine the relative efficiencies, capital costs and market shares of different technology options, and on what methods should be used to develop a final version of the technology options data base.

A survey instrument for collecting information on commercial sector technologies was developed. Survey instruments used in previous commercial sector surveys were reviewed and evaluated as part of this effort. A pilot study to evaluate the survey instrument was also conducted.

A sampling plan was prepared that addressed the design of the on-site survey and the selection of a statistically-representative sample of commercial premises. Alternative designs that took into consideration the mix of business types and energy-using technologies in PG&E's service area were prepared and compared as to effectiveness. In determining the number of premises to visit during the on-site survey, consideration was also given to sampling accuracy and to time and financial constraints.

The on-site data collection effort began in January, 1986, and spanned approximately 10 months. Data were collected at 855 commercial premises in PG&E's service area. The types and numbers of premises surveyed and their distributions by square footage, by year built, by type of heating fuel, and by type of cooling fuel are shown in Table 1. Also shown there are estimates by business type of the total numbers of premises served by PG&E and their aggregate square footage.

A data base was prepared that included the data collected during the on-site survey. The data collected for the 855 premises in the on-site survey were cleaned, verified, and validated for completeness and accuracy, and a data base was created that contains information pertaining to building structural characteristics, premise utilization, floorspace utilization, indoor and outdoor lighting, heating, cooling and ventilating fuels and equipment, water heating fuels and equipment, cooking fuels and equipment, refrigeration equipment and other equipment. Monthly billing data for the surveyed premises were obtained from PG&E records and merged with the survey data in the data base. Statistical weights were also developed that can be used to weight the survey data to represent the complete population of commercial premises in PG&E's service area.

The third phase of the study involved preparation of a final version of the technology options data base for the commercial sector end-use model and of a data base of hourly load profiles for the options.

A final technology options data base was developed that contains information on technology options for HVAC, lighting, water heating, cooking and refrigeration end-uses applicable for each of fourteen building types.

Two types of technology options were defined. Basic System options consisted of primary equipment installed in a building (e.g., boilers, lighting fixtures). Different Basic Systems were defined for buildings built before and after California's non-residential energy efficiency standards came into effect. ECM technology options consisted of energy conservation measures that can be installed as retrofits in existing buildings. The taxonomy of Basic System and ECM technology options that were considered is shown in Table 2.

The building types for which technology options information was developed include high rise offices, low rise offices, restaurants, retail stores, grocery stores, refrigerated warehouses, nonrefrigerated warehouses, schools, colleges, hospitals, hotels/motels, personal service premises, community service premises, and miscellaneous premises.

Information on relative energy efficiencies, capital costs, market shares and dates of availability was prepared for the various technology options. Table 3 provides an example of the information prepared. The data collected during the on-site survey were the primary source for developing the information included in the final technology options data base for all building types except colleges. (Data for colleges were taken from in-house sources.)

An adjunct data base of hourly load shape profiles was also developed for the various building types, end-uses, and technology options represented in the technology options data base. The profiles were developed through simulations with the ADM-2 Hourly Building Energy Analysis Model. For lighting-HVAC technology options, profiles of hourly energy consumption over a 24-hour period were developed for the different combinations of three types of season (cooling, heating and "shoulder") and three types of day (peak day, average standard day, and average non-standard day). For water heating, cooking and refrigeration technology options, load profiles were developed for two different types of days, average standard and average non-standard. This hourly load shape data base includes over 30,000 load shapes.

SUMMARY

This study provided data on the relative efficiencies, costs, dates of availablity, and market shares of appliance technologies used in commercial premises in the service area of Pacific Gas and Electric. An on-site survey was conducted to collect detailed data on building characteristics, end-use equipment and operational practices from a statistically-representative sample of 855 commercial premises served by PG&E. The data collected in the on-site survey were used to develop a technology options data base that contains efficiency, capital cost, and market share information on technology options used in fourteen types of commercial buildings. An adjunct data base of hourly load shape profiles was developed for the various building types, end-uses, and technology options represented in the technology options data base. The technology options and load profiles data bases developed in this study are used as input files for PG&E's end-use commercial sector electricity and gas forecasting model.

Table 1. Commercial Premises Surveyed in PG&E Service Area by Type of Business Activity and by Square Footage, Building Age, Heating Fuel and Cooling Fuel and Estimates of Population Numbers and Square Footage

	All Premises	Low Rise Offices	High Rise Offices	Retail Stores	Food Stores	Refrig Warehouses	Ware houses	Schools	Health	Restau rants	Hotels Motels	Miscell aneous
					Surveyed Premises							
Number Surveyed.......	855	118	55	133	88	14	22	54	90	85	34	162
By Square Footage:												
1-1,000..............	53	5	0	14	4	0	1	1	4	9	0	15
1,001-10,000........	382	66	0	62	64	5	7	6	12	76	7	77
10,001-100,000......	248	36	4	43	19	3	13	39	24	0	17	50
Over 100,000........	172	11	51	14	1	6	1	8	50	0	10	20
By Age of Building:												
Before 1940.........	99	13	7	17	8	0	0	5	13	9	7	20
1940-1949...........	66	5	2	9	8	0	1	10	10	5	3	13
1950-1959...........	116	8	8	13	16	1	3	16	12	13	2	24
1960-1969...........	198	24	9	30	21	7	6	9	29	14	7	42
1970-1979...........	218	38	17	35	20	1	8	11	17	27	6	38
1980-1987...........	101	26	12	14	4	5	2	2	9	9	7	11
Unknown.............	57	4	0	15	11	0	2	1	0	8	2	14
By Heating Fuel:												
None................	64	2	2	11	13	6	1	0	1	7	1	20
Electric............	148	23	5	35	21	2	3	4	6	10	13	26
Gas.................	604	90	39	85	49	6	18	48	82	65	17	105
Other/Unknown.......	39	3	9	2	5	0	0	2	1	3	3	11
By Cooling Fuel:												
None................	158	9	0	23	23	5	5	17	8	15	12	41
Electric............	667	107	51	104	65	9	17	37	70	69	21	117
Gas.................	17	1	2	5	0	0	0	0	9	0	0	0
Other/Unknown.......	13	1	2	1	0	0	0	0	3	1	1	4
					Population Estimates							
Number of Premises....	224,611	41,222	540	47,878	8,011	580	7,685	8,016	10,914	21,902	3,830	74,033
Million Square Feet...	2,203	214	101	316	40	32	61	324	228	60	119	708

Table 2. Basic System and Energy Conservation Measure Technology Options for PG&E Study by End Use Category

End Use	Basic System	ECM Technology
Lighting/HVAC	Base Equipment/Base Building/Electric Heat 1978 Equipment/Base Building/Electric Heat 1978 Title 24 Equipment/Base Building/Electric Heat 1987 Title 24 Equipment and Building/Electric Heat Base Equipment/Base Building/Gas Heat 1978 Equipment/Base Building/Gas Heat 1978 Title 24 Equipment and Building/Gas Heat 1987 Title 24 Equipment and Building/Gas Heat	Delamping Low Wattage Fluorescent Lamps Clock Thermostat Timeclock Electronic Ballast Ellipsoidal Reflecting Lamps Metal Halide Lamps Electronic Ignition Energy Management System Optical Reflectors Occupancy Sensors Heat Recovery System Fix Duct Leaks High Efficiency Fan Motors VAV Distribution System Photo Cells/Daylighting Roof Insulation Flue Gas Analyzer Double Bundle Chillers
Water Heating	Base Electric Equipment/Base Building Post 1978 Electric Equipment/Base Building 1978 Title 24 Electric Equipment and Building Base Gas Equipment/Base Building Post 1978 Gas Equipment/Base Building 1978 Title 24 Gas Equipment and Building	Tank Insulation Low-flow Showerhead Pipe Insulation Solar System
Cooking	Base Appliance New Appliance Base Equipment High Efficiency Equipment	Electronic Ignition
Refrigeration	Base Appliance 1979 Title 20 Appliance 1987 Title 20 Appliance 1992 Title 20 Appliance Base Equipment High Efficiency Equipment Base Rooftop System/Base Building 1978 Title 24 Rooftop System and Building	Delamping Low Wattage Fluorescent Lamps Strip Curtains Electronic Ballast Variable Frequency Drive Controls

Table 3. Example of Technology Options Data: High Rise Office Building, Lighting/HVAC End Use, Fresno Climate Zone

Technology Option		Date Available	Fuel	EUI	Cost	MktShr
BASE EQUIP / BASE BLDG	(G-HT)	1983-1983-1983	Gas	132.37	0.322	0.085
	(AC)		Elec	10.790		
	(V)		Elec	9.250		
	(LT)		Elec	12.310		
Very Short Payback ECMs	(G-HT)	1983-1983-1983	Gas	62.550	0.562	0.066
	(AC)		Elec	6.010		
	(V)		Elec	4.770		
	(LT)		Elec	5.000		
Short Payback ECMs	(G-HT)	1983-1983-1983	Gas	66.150	1.638	0.061
	(AC)		Elec	4.870		
	(V)		Elec	4.790		
	(LT)		Elec	3.840		
Moderate Payback ECMs	(G-HT)	1983-1983-1983	Gas	29.110	2.879	0.316
	(AC)		Elec	3.090		
	(V)		Elec	0.940		
	(LT)		Elec	2.550		
Long Payback ECMs	(G-HT)	1983-1983-1983	Gas	23.810	4.036	0.000
	(AC)		Elec	6.540		
	(V)		Elec	1.720		
	(LT)		Elec	2.550		
1978 EQUIP / BASE BLDG	(G-HT)	1983-1983-2007	Gas	60.370	0.322	0.158
	(AC)		Elec	6.430		
	(V)		Elec	2.590		
	(LT)		Elec	12.310		
Very Short Payback ECMs	(G-HT	1983-1983-2007	Gas	23.510	0.562	0.000
	(AC)		Elec	3.780		
	(V)		Elec	1.220		
	(LT)		Elec	5.000		
Short Payback ECMs	(G-HT)	1983-1983-2007	Gas	25.540	1.638	0.000
	(AC)		Elec	3.030		
	(V)		Elec	1.120		
	(LT)		Elec	3.840		
Moderate Payback ECMs	(G-HT)	1983-1983-2007	Gas	25.180	2.489	0.054
	(AC)		Elec	2.820		
	(V)		Elec	0.940		
	(LT)		Elec	2.550		
Long Payback ECMs	(G-HT)	1983-1983-2007	Gas	20.690	3.647	0.000
	(AC)		Elec	6.540		
	(V)		Elec	1.720		
	(LT)		Elec	2.550		

Technology Option		Date Available	Fuel	EUI	Cost	MktShr
1978 T24 EQUIP / BLDG	(G-HT)	1983-1987-2007	Gas	16.050	0.208	0.000
	(AC)		Elec	3.290		
	(V)		Elec	1.080		
	(LT)		Elec	4.850		
Very Short Payback ECMs	(G-HT)	1983-1987-2007	Gas	17.060	0.309	0.000
	(AC)		Elec	3.220		
	(V)		Elec	1.030		
	(LT)		Elec	4.290		
Short Payback ECMs	(G-HT)	1983-1987-2007	Gas	19.180	1.385	0.010
	(AC)		Elec	2.580		
	(V)		Elec	0.960		
	(LT)		Elec	3.260		
Moderate Payback ECMs	(G-HT)	1983-1987-2007	Gas	20.180	2.236	0.087
	(AC)		Elec	2.470		
	(V)		Elec	0.830		
	(LT)		Elec	2.180		
Long Payback ECMs	(G-HT)	1983-1987-2007	Gas	15.520	3.394	0.057
	(AC)		Elec	5.450		
	(V)		Elec	1.460		
	(LT)		Elec	2.180		
1987 T24 EQUIP / BLDG	(G-HT)	1988-2007-2007	Gas	16.600	0.253	0.000
	(AC)		Elec	2.850		
	(V)		Elec	1.060		
	(LT)		Elec	4.550		
Very Short Payback ECMs	(G-HT)	N/A	N/A	N/A	N/A	N/A
	(AC)					
	(V)					
	(LT)					
Short Payback ECMs	(G-HT)	1988-2007-2007	Gas	16.830	0.796	0.000
	(AC)		Elec	2.660		
	(V)		Elec	1.050		
	(LT)		Elec	4.450		
Moderate Payback ECMs	(G-HT)	1988-2007-2007	Gas	15.800	1.118	0.000
	(AC)		Elec	2.620		
	(V)		Elec	0.970		
	(LT)		Elec	4.120		
Long Payback ECMs	(G-HT)	1988-2007-2007	Gas	13.420	2.275	0.000
	(AC)		Elec	6.360		
	(V)		Elec	1.710		
	(LT)		Elec	4.120		

EUI: Energy Utilization Index (1,000 Btu/Sq. Ft.)
Cost: $/Sq. Ft. (1987 dollars)
MktShr: Market Share (fraction)

G-HT: Gas Heat
AC: Air Conditioning
V: Ventilation
LT: Lighting