

CURRENT AND FUTURE ENERGY END-USE CONSUMPTION IN THE RESIDENTIAL SECTOR

by

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The views presented in this paper are those of the author and do not necessarily represent those of PGandE or its management.

By the year 2000, rising energy costs, appliance standards, and consumer awareness will cause a shift from the use of relatively inefficient appliances to the use of appliances with increased energy efficiency. These trends will affect many sectors of the economy, including households and utilities. Future appliance owners are likely to substitute capital for energy as they purchase more efficient appliances for the benefits of energy savings. Utilities will experience a decrease in demand relating to some end-uses as this shift to more efficient appliances occurs. However, the increasing saturation of some appliances will offset the gains in efficiency to some degree. Whether or not average household energy consumption will increase, decrease, or remain the same in the next twenty years is of concern to many planners in both the public and private sector.

This paper will discuss current and future end-use energy consumption of the residential customers of the Pacific Gas and Electric Company. The trends which are implicit in the end-use consumption projections, including gains in efficiency and trends in the saturations of various gas and electric appliances, will be highlighted. Although some of the projections are specific to residences in Northern California, many of the trends will be experienced in other regions.

## Introduction

By the year 2000, rising energy costs, appliance standards, and consumer awareness will cause a shift from the use of relatively inefficient appliances to the use of appliances with increased energy efficiency. These trends will affect many sectors of the economy, including households and utilities. Future appliance owners are likely to substitute capital for energy as they purchase more efficient appliances for the benefits of energy savings. Utilities will experience a decrease in demand relating to some end-uses as this shift to more efficient appliances occurs. However, the increasing saturation of some appliances will offset the gains in efficiency to some degree. Whether or not average household energy consumption will increase, decrease, or remain the same in the next twenty years is of concern to many planners in both the public and private sector.

This paper will discuss current and future end-use energy consumption of the residential customers of the Pacific Gas and Electric Company. The trends which are implicit in the end-use consumption projections, including gains in efficiency and trends in the saturations of various gas and electric appliances, will be highlighted. The underlying trends of appliance efficiency and saturations for electricity and natural gas will be presented. These projections are based on PGandE's Residential End-Use Model which relies on net present value cost calculations and consumer discount rates ranging between 15 and 65 percent to model consumer appliance choice (see Appendix I). The applicability of the projections to other regions in the United States will then be discussed.

## Electricity

The percent of consumption attributable to each of the eight major electricity end-uses in 1981 is shown in Table I. The miscellaneous category and refrigerators account for the largest percentages of electricity consumption, 25.8 and 21.1 percent, in the PGandE service area. Approximately 95 percent of the electricity consumption in the miscellaneous category is used in lighting. All of the other end-uses account for between 5 and 11 percent of electricity consumption. The current projection for electricity consumption in 2004 shows electricity use increasing for cooking, clothes dryers, dishwashers, and air conditioning. Total electricity use for all of the other end-uses is projected to decrease, along with the average total electricity use per household.<sup>1</sup>

Implicit in these projections are trends in appliance ownership and the average efficiency of newly purchased appliances. These trends are shown explicitly in Tables II and III. In Table II, the average unit energy consumption (UEC) and the percent saturation of the appliance type are displayed along with average kilowatt-hours of use per household for the years 1981 and

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<sup>1</sup>It should be noted that the projected decline in household electricity use is highly dependent on the forecast of miscellaneous consumption which is inherently difficult to determine.

TABLE I  
DISTRIBUTION OF ELECTRICITY CONSUMPTION  
IN THE RESIDENTIAL SECTOR BY MAJOR END-USES  
IN 1981 AND 2004

	Percent Distribution	
	1981	2004
Miscellaneous	25.8	29.8
Refrigerators	21.1	19.2
Water Heating	7.3	5.1
TV's	10.6	6.6
Cooking	6.7	9.0
Clothes Dryers	6.6	8.5
Freezers	6.2	4.8
Space Heating	4.4	3.6
Dishwashers	3.6	4.4
Central Air Conditioning	3.6	4.7
Pool Pumps	2.6	2.7
Clothes Washers	.8	.9
Room Air Conditioners	.7	.6

TABLE II  
END-USE ELECTRICITY CONSUMPTION TRENDS

	Average kWh Use Per Household		UEC (kWh)		Percent Saturation	
	1981	2004	1981	2004	1981	2004
Miscellaneous	1645.7	1650 <sup>1</sup>	-	-	-	-
Refrigerators	1345	1070	1140	920	118	116
Water Heating	466	285	3900	2020	11.7	14.4
TV's	684	365	450	240	152	152
Cooking	427	497	750	720	57	69
Clothes Dryers	419	470	910	890	46	53
Freezers	393	266	1190	830	33	32
Space Heaters	278	197	2870	1430	9.7	13.7
Dishwashers	230	243	460	369	50	66
Central Air Conditioning	232	260	1450	940	16	28
Pool Pumps	164	150	2740	2500	6	6
Clothes Washers	49	49	72	69	68	71
Room Air Conditioners	42	33	470	360	9	9
Total	6374.7	5535	-	-	-	-

<sup>1</sup>This estimate is based on a forecast of miscellaneous energy consumption by the California Energy Commission.

TABLE III  
 END-USE ELECTRICITY CONSUMPTION TRENDS - CONTINUED

	<u>Average KWh Use Per Household</u>	<u>UEC</u>	<u>Percent Saturation</u>
Miscellaneous	0	-	-
Refrigerators	-20.4	-19.3	-1.7
Water Heating	-38.8	-48.2	+23.1
TV's	-46.6	-46.7	0
Cooking	+16.4	-4.0	+21.1
Clothes Dryers	+12.2	-2.2	+15.2
Freezers	-32.3	-30.3	-3.0
Space Heating	-29.1	-50.2	+41.2
Dishwashers	+5.7	-19.8	+32.0
Central Air Conditioning	+12.1	-35.2	+75.0
Pool Pumps	-8.5	-8.8	0
Clothes Washers	0	-4.2	+4.4
Room Air Conditioners	-21.4	-23.4	0
Total	-12.8 <sup>1</sup>	-	-

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<sup>1</sup>This estimate is based on a forecast of miscellaneous energy consumption by the California Energy Commission.

2004. The use per household figure is defined as the product of the associated UEC and saturation. The percent change in the use per household, UEC, and the percent saturation projected to occur between 1981 and 2004 are shown in Table III. The saturations of electric water heaters, cooking, clothes dryers, space heating, dishwashers, central air conditioners, and clothes washers are projected to increase. The unit energy consumption is expected to decline for all of the appliance types due to efficiency improvements in the appliances. The percentage changes in the average use per household figures reveal that the efficiency gains outweigh the appliance saturation increases in the refrigerator, water heating, TV, freezer, space heating, pool pump, and room air conditioning end-uses. Increases in the saturations of electric cooking, clothes dryers, dishwashers and central air conditioning outweigh the efficiency gains in this time period.

Some appliance-specific information should be noted. The large decrease in the electric space heating UEC is due primarily to the increasing use of heat pumps due partially to the legislated ban on electric resistance heating in California. Heat pumps will also be used in water heating, resulting in large efficiency gains. The saturation of room air conditioners is held constant as central air conditioning becomes more popular among many income classes. The increase in the saturation of dishwashers is highly likely since many new housing units are installing them and the appliances are becoming more and more thought of as necessities rather than luxury items.

Increases in the use of electric space and water heating, cooking, and clothes dryers may be experienced throughout the nation. The preference for electric appliances is due partly to the desire for a clean fuel, the cost-effectiveness of heat pumps and the increasing price of other fuels.

It should be noted that the forecast of miscellaneous electricity use is highly uncertain. Some penetration of florescent lighting is expected which would yield efficiency gains. However, increases in the use of new appliances, such as personal computers, may more than offset any efficiency gains in lighting.

### Natural Gas

Natural gas consumption is attributable largely to space heating and water heating. As shown on Table IV these end-uses account for 66.6 and 26.7 percent of natural gas consumption respectively. Cooking, pool heating and clothes dryers account for 3.1 percent or less of residential natural gas consumption.

The average use per household, UEC, and percent saturation of these natural gas end-uses are shown in Table V for the years 1981 and 2004. Table VI displays the percentage changes in these figures between these years. The drastic decrease in the space heating UEC is due to both more efficient space heating units and the large improvements in insulation levels which are attributable to retrofits and building standards for new buildings. Intermittent ignition devices contribute to declines in the space heating, water heating, cooking, and clothes dryer UEC's. The pool heating UEC declines due to the use of pool covers and solar heating devices. The saturations of natural gas cooking and clothes dryer appliances will decline due to the increased use of comparable electric appliances.

TABLE IV  
 DISTRIBUTION OF NATURAL GAS CONSUMPTION IN THE RESIDENTIAL  
 SECTOR BY MAJOR END USES IN 1981 AND 2004  
 PERCENT DISTRIBUTION

	<u>1981</u>	<u>2004</u>
Space Heating	66.6	54.9
Water Heating	26.7	38.4
Miscellaneous	1.9	3.1
Cooking	3.1	2.8
Pool Heating	1.0	.3
Clothes Dryer	.7	.5

TABLE V  
 END-USE NATURAL GAS CONSUMPTION TRENDS

	Average Use Per Household		UEC (Therms)		Percent Saturation	
	<u>1981</u>	<u>2004</u>	<u>1981</u>	<u>2004</u>	<u>1981</u>	<u>2004</u>
Space Heating	377	188	469	242	80.5	77.6
Water Heating	151.5	131.6	212.2	178.6	71.4	73.7
Miscellaneous	10.7	10.7	-	-	-	-
Cooking	17.8	9.7	46.6	37.5	38.3	25.8
Pool Heating	5.6	1.2	559.4	123	1	1
Clothes Dryer	3.8	1.8	26.6	16.2	14.2	11.4
Total	566.4	343.0	-	-	-	-

TABLE VI  
 END-USE NATURAL GAS CONSUMPTION TRENDS - CONTINUED  
 PERCENT CHANGE FROM 1981 TO 2004

	<u>Average Use Per Household</u>	<u>UEC</u>	<u>Percent Saturation</u>
Space Heating	-50.1	-48.4	-3.6
Water Heating	-13.1	-15.8	3.2
Miscellaneous	0	-	-
Cooking	-45.5	-19.5	-32.6
Pool Heating	-78.6	-78.0	0
Clothes Dryer	-52.6	-39.1	-19.7
Total	-33.6	-	-

Given these trends, the drastic decreases in the average use per household for all gas appliance is not unexpected. Consumption for miscellaneous natural gas uses may increase if Californians increase their purchases of natural gas-heated hot tubs but this will not make up for the other decreases in natural gas consumption.

### National Trends

In other regions, the percentage shares attributable to different end-uses may vary due to the variation in fuels used for space heating, water heating, cooking, and clothes drying. Concerning efficiency gains, the stringent building and appliance standards adopted by the state of California may make some of the efficiency gains projected for some end-uses overly optimistic for other regions. In addition, some of the economic assumptions (notably consumer discount rates) and the rate of retrofit and retirement used to calculate these projections may not portray the future exactly. However, the efficiency gains projected in this analysis are based on the use of appliances which are both technically and economically feasible for the time period specified (see Appendix I). Given the large gains in energy efficiency expected for most appliances, energy use in the residential sector is likely to decline or remain constant over the next twenty years. Slight increases in total energy consumption will occur only if new appliances are both bought and fully utilized by a large number of households.

### Conclusion

The extent of the substitution of capital for energy in the residential sector only becomes apparent when appliances within each major end-use are examined. The trend does not appear when price and income variables are used to predict residential energy consumption. By the year 2000, it is highly likely that large gains in energy efficiency will be realized.

## APPENDIX I THE RESIDENTIAL END-USE MODEL

The PGandE Residential End-Use Model<sup>1</sup> presently forecasts energy use for seventeen end-uses. These end-uses are listed in Table 1. Because the characteristics and trends of energy-use differ among different types of dwellings, separate forecasts are made for single family dwellings, two to four unit multifamily dwellings, five or more unit multifamily dwellings and mobile homes. In addition, space heating and central air conditioning are forecast for five different climate zones in the PGandE service area.

Residential end-use models are characterized by the following equation:

$$\text{Energy Consumed}_i = \text{Appliance Stock}_i * \text{Average Energy Use/Appliance}_i,$$

with  $i$  referring to a particular end-use.

Extremely simple residential end-use models consist of only this equation. Such simplicity, however, limits the accuracy and usefulness of these models. For instance, the effect of an increase in the price of energy cannot be determined by such a model. More complex models account for the effects of economic and other trends by using various methods to forecast appliance ownership and average energy-use per household.

A number of forecasting methods are used to calculate appliance ownership and average energy-use per household in the PGandE model. These methods will be described for both of those energy consumption determinants in turn.

### Appliance Ownership

Data on the percentage of PGandE customers who own a particular appliance is provided by the biennial Residential Appliance Saturation Survey (RASS). The RASS is sent to a representative sample of PGandE's customers. To calculate the total stock of a given appliance, the percentage of ownership is multiplied by the total number of households in the service area. The latter variable is forecast by the Economic Review and Forecasting section of PGandE.

For 1981, the results of the entire sample of the 1981 RASS were used. For the years 1982-2004, changes in appliance ownership are assumed to follow the patterns found in new dwellings built between 1979-1981. These recently built dwellings are more likely to show current preferences, such as the ownership of frost-free refrigerators and freezers, and microwave ovens. In future years, as the share of homes built since 1981 become an increasing share of the total homes, the appliance ownership patterns of the entire service area will become more and more like those of the dwellings built between 1979-1981.

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<sup>1</sup>This model was originally developed by Arthur D. Little, Inc. and has been adapted for PGandE use.

## Average Energy Consumption Per Household

For a given appliance, the average energy consumption per household is determined by two factors: the energy efficiency of the type or model in use and the degree to which the appliance is utilized. The rate of utilization of an appliance is estimated explicitly by the PGandE model. This rate is calculated as a function of the average price of a unit of energy used relative to the average efficiency of the appliance stock. The equation is highly responsive for space heating and air conditioning and relatively unresponsive for other end-uses. A full description of this equation is given in Appendix C.4 of the Integrated Load Forecasting System Technical Users Guide.

## Efficiency and Appliance Choice

The energy efficiency of an appliance can be defined as the amount of energy needed to provide a given level of service. More efficient appliances utilize less energy, but are often more expensive than less efficient models. The trade-off between capital and energy costs must be assessed by the consumer at the time of purchase. The consumer's choice will be determined by his preference for income at the present time versus income (or energy savings) in the future. In other words, the consumer's preferences reflect the rate at which he discounts future income relative to present income. Research with appliance choice has indicated that a consumer's discount rate varies inversely with his total income.<sup>1</sup> Thus, consumers with relatively low income will have high discount rates and will be influenced more by the high capital cost of new appliances than those with higher incomes and lower discount rates.

For each end-use, the model specifies different appliance models as well as their associated capital costs and energy efficiencies. Table 2 displays the models of dishwashers that are used in the model along with the data that characterize them. The share of each appliance model currently in use (shown as "Overall Splits" in Table 2) was determined by the RASS and research by Arthur D. Little, Inc. For future years, the model simulates the consumer's decision-making process. Given an estimate of the distribution of income in the PGandE service area and the discount rates associated with certain income ranges, the model calculates the present value cost of each appliance model choice for the various discount rates. The discount rates and the income distribution used in the model are shown in Tables 3-4. The present value calculation is shown below. When a new appliance is purchased, the technology

$$\begin{array}{rcl} \text{Present Value} & = & \text{Down Payment} & - & \text{Capital Cost Subsidy} \\ \text{Cost} & & & & \\ & & - & \text{Tax Credit} & + & \text{Discounted Annual Financing Cost} \\ & + & \text{Discounted Annual} & - & \text{Discounted Annual Tax Reduction Due to} \\ & & \text{Operating Cost} & & \text{Interest Tax Deduction} \end{array}$$

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<sup>1</sup>Hausman, J. A. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables." Bell Journal of Economics, Vol. 10, No. 1 (Spring 1979), pp. 33-54.

TABLE 1  
 END-USES IN THE PGandE RESIDENTIAL END-USE MODEL

Space Heater  
 Central Air Conditioner  
 Range  
 Clothes Washer  
 Clothes Dryer  
 Dishwasher  
 Room Air Conditioner  
 Pool Pump  
 Pool Heater  
 Black and White TV  
 Color TV  
 Standard Refrigerator  
 Frost-free Refrigerator  
 Standard Freezer  
 Frost-free Freezer  
 Water Heater  
 Miscellaneous

TABLE 2  
 RESIDENTIAL SECTOR TECHNOLOGY OPTIONS

End-Use: Dishwasher

Building Type: Single Family

<u>Technology Option</u>	<u>Years Available</u>	<u>Capital Cost (1979 \$)</u>	<u>UEC<sup>1</sup> (kWh/yr. or therm/yr.)</u>	<u>Overall<sup>2</sup> (%)</u>
<u>Electric Options:</u>				
1. Base dishwasher	1979-200	240	284	95.00
2. Base dishwasher with air dry/"power miser" drying cycle feature	1979-2002	250	195	5.00

<sup>1</sup>UEC = Unit Energy Consumption = Average household energy consumption per appliance.

<sup>2</sup>The Overall Splits are the percent of each model in use among those who own a dishwasher.

TABLE 3  
CONSUMER DISCOUNT RATES BY MEAN INCOME LEVEL

Market Segment Defined by Mean Income Level (1979 \$)	Discount Rate (%)
6,000	64
8,750	57
11,250	52
13,750	46
17,500	40
22,500	32
27,500	26
40,000	15

TABLE 4  
MARKET SEGMENTS DEFINED BY MEAN INCOME LEVEL

Market Segment Defined by Mean Income Level (1979 \$)	Share of Dwelling Type for Each Market Segment			
	Single Family (%)	Multifamily 2-4 Units (%)	Multifamily 5+ Units (%)	Mobile Home (%)
6,000	15	26	28	33
8,750	8	13	12	12
11,250	9	15	11	14
13,750	7	7	10	8
17,500	14	13	16	16
22,500	15	10	12	9
27,500	9	5	4	3
40,000	23	11	7	5
	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>

with the lowest present value cost is chosen for each population segment associated with a given income range.

The decision to purchase a new appliance can occur for a number of reasons. The situation a consumer faces when purchasing a new appliance determines the range of appliances available to him as well as the way in which the costs of different appliance models are compared. Three types of purchasing decisions are evaluated in the PGandE model; early replacement or retrofit decisions, normal replacement, and new purchases. The number of each of the former three decisions taking place during a given year depends upon the number of dwellings and appliances of various vintages that exist in a given year. The model determines the vintage of dwellings and appliances and uses different methods to simulate the various kinds of decisions made when new appliances are purchased.